Dynamic Modeling of a Teaching/Learning System To Aid System Re-engineering

Nassereddin Eftekhar

A thesis
submitted to the Faculty of Graduate Studies
in fulfillment of the requirements
for the degree of

Doctor of Philosophy

Department of Mechanical and Industrial Engineering
University of Manitoba
Winnipeg, Manitoba, Canada

0-612-31974-1

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

*****

COPYRIGHT PERMISSION PAGE

DYNAMIC MODELING OF A TEACHING/LEARNING SYSTEM TO AID SYSTEM RE-ENGINEERING

BY

NASSEREDDIN EFTEKHAR

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements of the degree

of

DOCTOR OF PHILOSOPHY

I hereby declare that I am the sole author of this thesis.

I authorize the University of Manitoba to lend this thesis to other institutions or individuals for the purpose of scholarly research.

I further authorize the University of Manitoba to reproduce this thesis by photocopying or by other means, in total or in part, at the request of other institutions or individuals for the purpose of scholarly research.

The University of Manitoba requires the signatures of all persons using or photocopying this thesis. Please sign below, and give address and date.

Abstract

This study investigates how to model a teaching/learning system for subject matter taught to engineering students, and how to use the model to predict and improve the consequences of changes to the inputs, the process, and the outputs of the system. The model is based on a system dynamics approach supported by Systems Thinking and soft Operation Research techniques. It takes into consideration the interaction between three major sets of components in the system: (1) the learner's learning abilities and motivation, (2) the teaching system's characteristics, and (3) the nature and types of the subject matter.

Through investigation for a dynamic model of a teaching/learning system, the research discovers a dimension that takes into account all of the other dimensions that are involved in a teaching/learning system. This dimension is a new concept, related to the thinking process, that has not been discussed before and is particularly important in technical learning. It is the *form-function* dimension. Based on this concept, the research identifies two distinctive types of learners: *form* oriented and *function* oriented. The *form* learner is mainly interested in the information as it is presented. The *function* learner is interested in the new information in terms of cause-effect relationships. The other parts of the endeavor show the consequences of this concept.

The results from the simulations of a teaching/learning system based on the form-function approach, provide considerable insight into the operation of educational systems. The research can help educational decision-makers and educators select performance parameters that will optimize a given strategy. The effect of system configuration on the performance of a teaching/learning system may be used to influence the design of the system before the planning stage is implemented. This information can be critical in developing an efficient and effective system for engineering students as well as engineering educators.

Acknowledgement

This thesis represents a long adventure in my academic career. In retrospect, it has been an enriching and worthwhile experience. Perhaps the greatest benefit was that of personal development.

I have had the good fortune of working with Dr. Doug Strong, my advisor; a knowledgeable, well-experienced, adventurous, yet humble researcher. Dr. Strong has provided insight, expertise, and support throughout this study. More importantly, he has been a good friend and I believe it has been an enjoyable adventure for him as it has been to me.

I would like to thank my co-advisor, Professor Ostap Hawaleshka, for his academic guidance, useful remarks and continuing encouragement. Special thanks are extended to my dissertation committee, Dr. Beverly Cameron, director of University Teaching Services for her valuable support, assistance in selection of suitable reference information, and wonderful scrutiny of the manuscript and Dr. Ron Britton, of the Department of Bio-Systems Engineering for his encouragement and academic remarks during the course of this work. Also, I would like to extend my appreciation to the external examiner, Dr. Dale Watts, Dean of Industrial Technology, Red River College for his scrutiny of the manuscript.

I appreciate the financial support offered to me by Red River Community College, and by the Program Development Fund and the Faculty of Engineering of the University of Manitoba. Finally, I thank the National Iranian Oil Company for their valuable financial support and extended leave of absence during the program.

This thesis is dedicated to the soul of my deceased father and to my loving mother whose love and desire for my academic success have been the major source of inspiration in pursuing my higher education after so many years. And, it is dedicated to my closest friend in my life; my beloved wife, Nahid, and my three children whose love, patience, and encouragement made it all possible.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Background

The work for Dynamic Modeling of a Teaching/Learning System began some three years ago when I prepared the first draft of my Ph.D. research proposal on the computer modeling of an educational system. This draft was seen quite appropriately as too ambitious by my advisory committee, which was chaired by Dr. Doug Strong. I was asked to carve out a tractable slice of the problem to work on for my thesis if I did not wish to spend some fifteen years on my Ph.D. Following this advice, I defined the boundary of my doctoral thesis work around issues of modeling of a learning process for a typical engineering student in an introductory course in industrial engineering. Later on, when I was investigating the subject more thoroughly, I found myself even more confined to a more limited approach because of the diversity and complexity of the nature of the issues I was dealing with.

However, in my own assessment, the most significant point I have discovered over the course of my work on the development of such model is the way that a diverse soft information base from the field of educational psychology containing quantitative (statistical) data, experiential information and theoretical concepts, can be engineered into a unified theory sensible on an engineering scale. How do students get each piece of the teaching materials, how do they process it and how do they keep it, how is the arrangement of knowledge in their mind in the beginning and at the end of the learning process, and how can the findings of this research improve the teaching/learning situation? In fact, in an engineering worldview, what is the mechanism of a learning system and what do we mean when we say something has been *learned*? These issues are more easily stated than answered, since the engineering approach used to seek and analyze answers to these types of questions is complicated and complex, yet informal, and has many assumptions and simplifications in it [1].

1.2 Motivation

For the last few years, budgets for post secondary institutions have held constant, then decreased, with no hope of increasing over the next several years. As a present necessary response to this, institutions have cut less popular programs, cut both full and part-time staff, reduced the amount of equipment available for labs, reduced the number of students allowed to enter post-secondary education, and charged higher tuition fees to the students that entered [2]. The general public, the students, and the commercial world are increasingly asking about the relevance, quality and cost of post-secondary education. Meanwhile, in the background, technology, especially related to computers, software and information flow is changing and improving at a very rapid rate. Two fundamental questions arise from the interaction of the above forces: *what* should be taught to *whom*; and *how* should it be taught. This research attempts to help answer the question of *how what* should be taught by teaching systems and similarly *how what* should be learned by different types of learner.

Answers to the above two questions require identifying the mechanism of a teaching/learning system. When this is achieved, analysis and an examination of how such system could be improved follows. This is a journey that motivates an adventurous researcher. In fact, when a system requires improvement, the mission of an industrial engineer begins.

The motivation for this research is a challenge to apply industrial engineering techniques to the analysis of a non-physical system. The challenge is to seek information about cause-and-effect relationships in such systems. The results of this analysis would allow educators and educational administrators to make necessary changes to the system, with greater knowledge of the ramifications than is presently available. This work is in an essentially uncharted area, and will use information that is not as reliable as that usually used by engineers. However, it seems that research into simulation modeling of teaching/learning systems is a worthwhile direction for three reasons:

- Simulation modeling is increasingly used by industries to help guide their change process.
- Simulation modeling will be useful in helping define the direction of change for the teaching/learning systems that are about to go through a massive change, driven by the continuing decrease of funds and the continuing improvement of technology.
- Industrial engineering simulation modeling and education metrics combined is an ambitious undertaking and a unique effort that expands the techniques typically used for physical variables to cover non-physical ones as well. In fact, dealing with non-physical variables is an ambitious undertaking.

1.3 Purpose

The purpose of this research is to determine how to usefully model a teaching-learning system for an engineering course taught to an engineering student, and use the model to help predict consequences of changes to the process. Engineering students were chosen because the question of what should be taught and learned, both in subject matter and knowledge structure, are reasonably well-defined and well-established. An introductory course, Introduction to Industrial Engineering, was chosen because it contains both theoretical and practical modes of teaching/learning.

It is believed that results of this research can be the basis for future research on a broader front in engineering education and on a more specific front in analysis and re-engineering of dynamic systems of soft and non-measurable variables. In point form, the purpose of this research is fourfold:

- Modeling the mind of a learner from an engineering perspective
- Developing a dynamic model of a teaching/learning system to gain a better insight into its dynamic behavior

- Applying industrial engineering simulation techniques to the analysis of teaching/learning systems
- Understanding the interrelationships of the decision areas and investigating policies that lead to an improved structure for the system (re-engineering)

In dealing with the above objectives, the research will consider the following six parameters:

1. Types of Learning

Different types of learning are accepted and required in any educational process. They generally include: rote learning, closed problem solving, open problem solving, and skill development. Other types and sub-types of learning have also been defined. Each type of learning will be studied in a new light, and techniques for dealing with each type will be created.

2. Teaching System

Different types of teaching are considered. They include: traditional teaching (professors, instructors, graduate students as teaching assistants and lecturers, lectures, textbooks, lecture notes, overhead and slide projectors, labs, etc.), computer-driven overhead projector, instructive software, testing and marking software, interactive distance video, all students with computers, and improvements to Internet to remove paper requirements.

3. Subject Matter

Engineering students undertake introductory courses in engineering before embarking on courses in their major. The theoretical trial in this research is performed on an example lecture related to the Introduction to Industrial Engineering course. Mastering "Introduction to Industrial Engineering" requires mathematics, analytic, memorization, dexterity and other abilities. This research, on purpose, has chosen part of a lecture on "productivity issue" from a beginning lecture in the course. The students find it to be a section of moderate difficulty of the mixed use of mathematics and common-sense materials.

4. Information Types

The textbook material used by engineering students in the "Introduction to Industrial Engineering" course has been analyzed according to the relevant instructor's manual and solution techniques [3 & 4]. Typically, a subject area or a learning objective text chapter includes some basic definitions, rules and principles that give rise to the concept that must be learned. The chapter material is normally organized into lecture notes for presentation. Information from the lecture notes could be divided into three general learning groups called "rote-type," "relationship-type," and "procedure-type." A rote-type is subjective oriented and is the kind of information that is memory-intensive with no link to one's real life experience. The relationship-type information is objective-oriented and is the kind of information that recalls past pieces of knowledge, ideas, concepts, or experience, and can be directly or indirectly connected to it. The procedure-type information has a classification or stepwise scheme, and involves relationships.

5. Student Type

A student description requires at least three groups of parameters. They are: (1) ability to learn relative to subject type and learning type, (2) prior knowledge about the subject (general background knowledge), and (3) desire to learn (motivation to learn).

An individual's ability to learn is essentially fixed, although certain learning skills may be learned. The prior knowledge (background knowledge) of the students can typically be adjusted by remedial programs if they have the basic ability to learn in the subject. Some types of motivation, e.g., basic interest in the subject, tend to be intrinsic while other types, (e.g., seeing a relation between the subject and a future profession), can be adjusted to some extent by the structure and style of the teaching process.

This research is interested in two types of students; relators and memorizers. Relators or the *function* type students, see the *function* of things, want to understand *why* and *how* things work, rapidly analyze complex problems into components or subgoals, plan a solution strategy, and then evaluate the components based on experience. In this analysis they use a high degree of intuition. By contrast, the memorizers or the *form* type students, see the *form* of things, look for *what* and *how many* of things, and tend to refer to memorized steps from previous examples which is an unsuccessful strategy for solution of unique problems. A secondary purpose of the research is to show that the performance of each type of student may be improved by teaching which clearly matches their learning style.

6. The Measures

The most significant problems will relate to measures of a student's abilities, learning level, and motivation. Although some measures, such as measures of the memory of data, are accurate and easy to apply, measures in some areas are very subjective and in other areas do not exist. Also, many of the subjective measures are very time consuming to apply. For this reason, much research has centered around how to define and to show equivalencies between different teaching and learning techniques, and on student and teacher traits using information containing many educated guesses (cognitive algebra).

A secondary purpose of this modeling research is to help determine the most suitable measurement technique for learning outcomes, to increase understanding of the education process. For instance, student performance is measured in terms of ability to solve quantitative problems on small tests. This research shall not debate whether this is desirable or effective but take it as the normal procedure. "Teaching" students involves presenting the structured set of learning material and requiring them to solve example problems. The research intends to show that problem-solving skill is the key to successful performance in engineering.

Measures of effectiveness of proposed teaching/learning systems, relative to the present system and relative to each other, include different components. Some of the main components may be recognized as:

- the type, quantity and the complexity level of the information presented by the teaching system;
- the time required by the student to proceed through the learning process;
- the learning rate of the student (taking in, processing, storing);
- the level of student motivation under the effect of internal and external reinforcement factors;
- the learning style compatibility of the teaching system and the learner; and
- the amount learned by the student (the level of the acquired knowledge).

1.4 The Methodology

This research uses system dynamics as a suitable methodology to analyze the *process of student learning*. System dynamics is a system analysis approach that is concerned with creating models or representations of real world systems and studying their dynamics. Interest in system dynamics is spreading as researchers and system analysts appreciate its unique ability to represent the real world. System dynamics can accept the complexity, non-linearity, and feedback loop structures that are inherent in physical and non-physical systems [5].

On the other hand, according to the learning literature, several difficult steps in moving from problems to solution hamper system dynamics. First, and probably the most elusive, is the little guidance that exists for converting a real-life situation into a simulation model. At later stages, many system dynamics projects have fallen short of their potential because of failure to gain the understanding and support necessary for implementation. To be on the safe side, this research employs systems thinking and soft operation research (soft OR) to help organize and guide system dynamics for better understanding of a teaching/learning system.

Systems thinking and soft OR are soft methodologies that operate without a rigorous quantitative foundation. As will be discussed in the following chapters, the conceptualization phase of system dynamics has much in common with these two soft methodologies, but system dynamics is disciplined by an organizing framework that leads to model formulation and simulation.

Some researchers use systems thinking to mean, more or less, the same as system dynamics. Others look at it as a process that has gathered momentum on the periphery of system dynamics [6]. This research uses the form of systems thinking that is the same as system dynamics. Systems thinking, in this research, serves a crucial role as a door opener to system dynamics and to the work towards understanding a complicated system like teaching/learning. In so doing, it acts from the beginning (the stage of the literature survey) and usefully reveals the important aspects of a teaching/learning system.

How Systems Thinking Works.

Systems thinking is defined as consisting of a vantage point and a set of three thinking skills that are complementary to each other [5]. The "vantage point" is the position that an analyst places himself or herself in for viewing purposes. The vantage point advocates maintaining a *bi-focal perspective*. This means keeping one eye on the biggest relevant picture while the other eye descends into the detail. The vantage point from which one operates serves as a first filter for what one experiences. A second filter is provided by the set of assumptions or perspectives that one carries about how the world works. No doubt, "how one looks," as well as "where one stands," exerts a large influence on both what one sees and how one makes models out of what one sees. Systems thinking carries with it three principal approaches in terms of the skills that a person would need to "do" systems dynamics [5].

The first perspective is that the system or process is the cause of its performance (i.e., as opposed to its performance being determined by outside forces). It is a kind of *system-as-cause* approach to construct a boundary around a system in such a way that the cause of the dynamics being exhibited resides within the relationships that are contained within the boundary. In particular, this means that it is unnecessary to invoke any forces from outside the boundary in order to "drive" the system's dynamics. This perspective enables a researcher to decide what to include, and what not to include, within the model. The quest does not deny that there are many other relationships at work in the real system. But the technical question always is: What *is the simplest possible set of relationships that can explain the phenomenon?*

The second perspective is called *operational approach*. It means looking at a system in terms of how it is actually structured, and within that structure, how the associated activities really work. Therefore, the first perspective (system-as-cause) urges the researcher to look within the system boundary for the causes of the dynamics being exhibited while the second one tells him or her that the causes of dynamics lie in the "mechanism" of the system. By thinking in terms of how a process or system really works, one has a much better chance of understanding how to make it work better!

The third perspective is *closed-loop approach*. This perspective uses as one of its integral part, a "factors" method. To understand the "factors" method, let assume that one is investigating an answer to the question of "what causes student achievement?" To answer such a question, one can form a list of factors. Listing "factors" is the first step in building a model. The distinctive structure of such a model is shown in Fig. 1.1(a). As the diagram suggests, the structure of the model produced by a factor approach is "these factors (in this case, seven factors as demonstrated) influence that (in this case, student achievement)." A link runs from each seven factors (motivation, ability to learn, teaching quality, learning style, prior knowledge, mark of desire, effort put into the task) to "student achievement."

Looking more closely at the list of factors, one can discover the priority of each one, and hence, assign a weight to them. This factor exerts the most important influence on "student achievement;" this factor is second in importance; and so on. The large number of weighted list-of-factors models is testimony to the popularity of this way of thinking. Indeed, list of factors and prioritizing them can be useful. It causes one to focus on what s/he feels is most important – omitting that which is less important, and in so doing, a simpler explanation is achieved.

Unfortunately, weighted list-of-factors models also have a major pitfall. They are linear, and hence, static in nature. Causality runs only one-way (from factor to thing being influenced), and the relative strengths of the factors tend to be fixed, rather than varying over time. In reality, however, causality is often circular and the relative importance of a particular relationship tends to shift over time. To reflect these important characteristics of the reality in many systems, these systems need to embrace the closed-loop concept.

From a closed-loop thinking perspective, causal relationships are seen as reciprocal. No absolute distinction is maintained between cause and effect. Each "factor" is at once both cause and effect. Indeed, "factors" cease to be the relevant unit of causality, being supplanted by "relationships." Furthermore, fixed weightings are not assigned to the various relationships. The importance of each relationship is allowed to shift over time. One relationship might dominate early on. As the system evolves, two others may come into prominence. Later, a fourth relationship might "take control."

To illustrate the above idea, only two of the "factors" from the previous model in Fig. 1.1(a) are represented in the closed-loop diagram of Fig. 1.1(b). The fundamental difference in structure between the factor thinking method (left diagram) and closed-loop thinking model (right diagram) is clear.

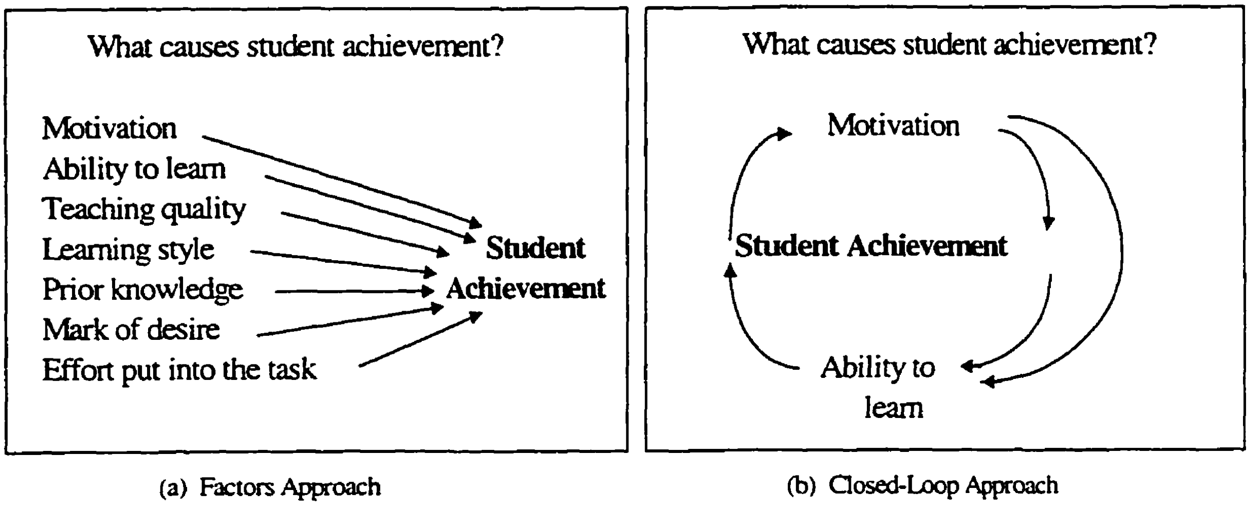


Fig. 1.1: Comparing Two Approaches
Adopted and Modified from Richmond [5]

As shown in Fig. 1.1(b), motivation does not just cause achievement, achievement also feeds back to cause motivation; an ongoing, in this case, *reinforcing*, process. Similarly, ability to learn does not just influence achievement; achievement also influences ability to learn; the causality is *reciprocal*. In this case, one has closed-loops rather than straight lines. One has dynamic, ongoing processes, rather than one-time "this causes that." This is the way the closed-loop approach works.

It is important to note that the circular relationships include connections between the "factors" themselves. For example, in Fig 1.1(b) motivation is assumed to influence ability to learn and vice versa. What one ends up with is a web of circular relationships. Achievement, like all other variables, is just as much a cause as it is an effect.

Summing up, the methodology that is used consists of a vantage point and an associated set of three perspectives. The vantage point causes one to see with bi-focal vision, always maintaining a view of the forest while pursuing the trees. The three perspectives determine how one may go about making meaning out of what one sees. The skills include the system-as-cause, the operational and the closed-loop concepts. Taken together, they form a methodology for mental model construction. System-as-cause says draw the boundary around the system in such a way as to cause what's inside the boundary to be the cause of the dynamics of interest. Operational approach picks up inside the boundary to say it is the mechanism that is the cause of the dynamics. A closed-loop concept adds the final piece. It says that the structural arrangements that bring the mechanism to life are called feedback loops. Causality is reciprocal, not a straight line [5].

1.5 Tools

Although a large volume of this research deals inevitably with the study of a learner's mind, the primary purpose is to investigate how a teaching/learning system looks and how it behaves over time. This goal is achieved by using an appropriate simulation tool like STELLA software [5, 116, 128]. Needless to say, it is not necessary to embrace system dynamics or systems thinking in order to make use of the STELLA software. However, as the conceptual underpinnings of the software are rooted in this framework, the software is particularly well-suited for representing mental models that have been developed using these methodologies.

In a structural standpoint, a STELLA model starts with stocks and flows – the principal building blocks of structure [5, 116]. Next, come infrastructures – higher order assemblies of stocks and flows. Finally it adds feedback loops – the relationships which bring infrastructures to life, and which give STELLA models their life-like behaviors.

STELLA software has a multi-level, hierarchical environment for constructing and interacting with complex models. Since it is built around a progression of structures it is particularly compatible with the nature of a teaching/learning system.

Several other simulation modeling languages are available but presently the most promising are STELLA, POWERSIM and WITNESS, which are all flexible enough to model a variety of time-related, complex interactions. POWERSIM runs similar to STELLA and both are convertible to each other.

WITNESS [7], though manufacturing-oriented, is more appropriate when simulation is discrete-based, since the focus can be on the very detailed picture or miniature of the process. The tracing and chasing of each piece of information is easy. For instance, the program can demonstrate the type of incoming information, show how it gets into the mind of the learner, how it gets processed, how it sits in the memory, how it becomes a trace of knowledge in the mind, how it behaves when it is recalled later, and so on. The disadvantage of using WITNESS is the way it treats each piece of knowledge. Probably one of the big differences between physical production process (e.g., manufacturing) and non-physical production process (e.g., knowledge construction) is that the former has a sequential movement while the latter has not. WITNESS would have great difficulty handling non-sequential movements.

1.6 The Major Discovery

Through investigation for a dynamic model of a teaching/learning system, this research discovers a new dimension that fits within all the major theories of learning. This discovery is shaped by the conceptualization, solidification, and validation of a new theory for the types of learners.

The theory which is called "Form-Function Theory of Types" defines two distinctive type of minds that learners possess. It suggests that individuals, in general, possess either a form-oriented mind or a function-oriented mind. A form-oriented mind grasps the information as it is presented while a function-oriented mind grasps the new information in terms of cause-effect relationships.

In fact, by conceptualizing how form-oriented and function-oriented learners and teachers really work and interact with each other, the theory provides a better likelihood for understanding how to make a teaching/learning system work better.

1.7 Contribution

The following are the contributions of this research:

- Identifying and categorizing different types of incoming information in the mind of a learner;
- Identifying and categorizing different types of the student's perception of the learning
- task value;
- Identifying and categorizing different types of external reinforcement factors on the student's perception of the learning task value;
- Identifying and categorizing different types of student's learning ability for two dominant types of student; a typical rote-type (form-oriented) learner and a typical relationship-type (function-oriented) learner;
- Conceptualizing, and developing a new theory: "Form-Function Theory of Types;"
- Introducing two types of mind; "form-oriented mind" and "function-oriented mind" and identifying the way these minds treat and process information;
- Constructing models for comparing the arrangement of knowledge in the mind of the two types of learners in the beginning and at the end of each lecturing period (for the same lecture);
- Examining the performance of each learner by trying different types of problems;
- Constructing a model for a teaching-learning system from a big picture perspective by using the logic and graphics of a continuous simulation program;
- Simulating the model to analyze the dynamic behavior of the system, and
- Applying different policies to improve the behavior of the system.

1.8 Organization

The next two chapters; Chapter 2 and Chapter 3, contain a review of the related topics in the literature by a systems thinking approach. The primary focus is on the aspects of teaching and learning in general and student learning in higher education in particular. Reviewing different teaching and learning approaches will establish a solid foundation for the later analysis. The search is mainly in the areas of education, educational psychology, and engineering education and psychology.

In Chapter 4, this study first discusses the system dynamics methodology in detail. Then, in line with the first step of this method, the literature review is started with the aim of defining a teaching/learning process. This step includes integration of the noticeable approaches and models for the purpose of building a unified theory [9]. Through this synthesis, a preliminary model for teaching/learning is defined and mapped on the basis of a number of renowned models in the literature. The proposed model, generally includes four major sets of variables: (1) student learning abilities, (2) student values and motivation, (3) teaching system characteristics, and (4) subject matter difficulty. This model will also give rise to the recognition of ten different types of student's perception of the learning task value and seven types of external reinforcement factors. However, the result of the study at this stage points out that, an important element is missing. The mapping of the model is not complete without identifying the types of the students. Hence, a separate investigation of the types of learner and the types of the mind they possess is the next challenge.

A detailed analysis of the minds of learners is done in Chapter 5. "The way students learn" (chapter 5.2) discusses how this research views "learning" and student approaches to learning. The research, by using systems thinking and soft OR technique (to support the system dynamics method), performs this endeavor. Chapter 5 is the core of this research. The main efforts are to identify how elements of information get into the minds of learners and how the elements of information are processed. The outcome of the investigation is compared with those from four important studies in the literature. Two types of learners with two distinctive approaches to learning are identified. This leads the research to a new edge in the field of engineering education. A new theory on the types of learner and the types of mind that they possess is shaped, conceptualized and introduced (Form-Function Theory of Types). "Form" and "function" oriented brains are the products of this theory. They are defined, discussed and validated with respect to the available knowledge in the research.

A simple theoretical experiment for analyzing the learning process (in the mind of form type and function type learners respectively) will be worked out in detail. This example will demonstrate four crucial items:

- The original knowledge as it is arranged in the mind of each type of learner,
- The type of information that is sent by the teaching system to the mind of each type of learner,
- The way that each learner will treat (process) each incoming piece of information, and
- The final knowledge as it is arranged in the mind of each type of learner.

The findings in Chapter 5, also include introducing eight types of information and seven types of learning abilities for each form and function learner. These findings give rise to a more acceptable experimentation on the mechanism of a learning process. Having all of this information at the disposal of the study, the mapping of the teaching/learning is complete. The stage is now ready to translate the findings into a computer simulation model by converting it to a stock and flow diagram and constructing the STELLA model.

In Chapter 6, the STELLA simulation software is briefly introduced. Then, during a step-by-step analysis, different features of the program are used for modeling non-physical entities within a teaching/learning system. STELLA base models for two different types of learners (form-oriented and function-oriented) are created, outlined and then run. Each base model demonstrates how a teaching/learning system looks for each type of learner and how it works in general, and how each type of student receives information, processes it, and adds it to his or her stock of knowledge. The graph of the base run for a form learner are closely analyzed. A number of experiments (comparative trials) are carried out with the simulation model. Comparative trials are run in line with the sensitivity analysis of each main variable in the model. Different policies are examined and the effect of each on the behavior of the overall system are evaluated.

The study concludes in Chapter 7. First, a synopsis of findings of the research is described. Then, the implications and the results of the study are presented. Finally, a number of potential grounds for any future work are discussed.

Chapter 2

Literature Review:
1. Teaching and Learning

The major purpose of a literature search is to increase the researcher's awareness and understanding of the most important issues, practices and research associated with his or her area of study. Taking into consideration the depth and diversity of materials in the field of educational psychology and in keeping with the above purpose, the search is divided into two major areas. The first area is a general search in the field of teaching/learning and is composed of two main parts: "teaching" and "learning." The first part is an investigation of the historical perspective, and the nature and practices of "teaching," and the historical implication of the subject. Part two focuses on the review of "learning" and examines the literature on learning in general, learning theory, student motivation and related research on important aspects associated with these issues. The literature survey on this area is presented in this chapter.

The second area that will be discussed later (in Chapter 3), is a more focused search in the field of learning psychology and engineering education. The intent is threefold: (1) to discuss different approaches on human memory and information processing, (2) to review some noticeable developmental models of student learning in university classrooms, and (3) to locate a number of effective models of student learning styles and their specific themes and perspectives concerning engineering students. The latter models are those that have been used frequently in the field of engineering education. In the mean time, the studies about teachers' behaviors and practices, and student-teacher interactions, student achievement and its relation to the effective teaching and learning styles will be reviewed.

2.1 Teaching

2.1.1 Overview

During the history of mankind and up to the seventeenth century, the role of a teacher was a paternalistic one in which listening to lessons and supervising student conduct were equally important. Education up to the seventeenth century, and later, higher education in the seventeenth and eighteenth centuries, were designed for the sons of elite, to promote religion and train young men for the ministerial positions. The curriculum prescribed was very rigid and basically comprised languages, mathematics, and so-called moral truths (natural and moral philosophy). All the men who entered in universities in any one year became a *class*; a group that took all their instruction together, usually from a single teacher who had the total responsibility for delivering the curriculum. Books were not abundant, and the classical lecture method gave students access to information they otherwise could not obtain [10].

Teaching methods up to seventeenth century consisted of recitation, lecture, and disputations with the greatest amount of time and energy being given to *recitation*. The emphasis was on the lowest order of learning skill, or pure memory, and students were rarely challenged for discussion or analysis. Until the nineteenth century, the recitation method remained at the heart of the teaching/learning process.

Testing, in its current meaning, appeared about four hundred years ago. Testing was usually done in public through a process of oral questioning by one or more examiners. Marks were not given, but judgements were passed on both the student and his teacher. It was therefore to the teacher's advantage that his students performed well.

By the end of the eighteenth century, and concurrent with the era of the Industrial Revolution, the impracticality of such education in North America and European countries became an issue, and a new emphasis was born. The Watt's steam engine had already begun the liberation of mankind from physical effort while the Declaration of Independence had begun the liberation of mankind from totalitarianism. Watt's steam engine and other inventions permitted implementation of the "factory system," cheap and fast transportation, and urbanization.

In the beginning of the nineteenth century, new universities were founded, with a wider appeal, and education began to be recognized as a means of getting ahead. Both the curriculum and the teaching methodology began to broaden. Natural science and increased use of lectures, demonstration, and laboratory methods were added to the curriculum, though these were resisted by traditionalists [11]. Specialization began to appear in the curriculum. The old "natural philosophy" evolved into geology, biology, physics, and chemistry, the old "moral philosophy" into economics, anthropology, sociology, and political science, and finally the old "classics" into language and literary specialties. Also during these times, the universities in their current meaning were born [10]. By the end of the nineteenth century, concern over standards and excellence was raised. Higher education broadened, deepened, and became popular. Testing moved from public examination to written exams with marks and grades, but student motivation often remained low.

The twentieth century began with the prospect of an ever-increasing student population, many with social needs that outweighed their academic needs. In general, three viewpoints developed for higher education: the vocational view - which emphasized job and career training, the scientific view - which emphasized research and the development of new knowledge, and the general educational view - which emphasized social development as well as vocational development. Most experts in the field of education, believe these three viewpoints have remained prominent on university campuses even today [10].

The twentieth century is also characterized by systematic attempts to develop teaching/learning methods based on theories of learning. Three dominated theories were *behaviorist*, *humanistic*, and *cognitive* views of learning [12]. The *behaviorist* view suggests that humans' behaviors are controlled by stimuli in their environments. The pioneers in this view believed that anyone could be taught to become anything by the proper manipulation of environmental stimuli. Skinner introduced a modified version of this view in the 1930s. He developed what is called a technology of operant conditioning [13]. This technology stresses the need to shape behaviors in small steps and to reward each small success a learner has. It also emphasizes that organisms learn at different rates and that some custom designing of learning environments is necessary to accommodate such variations. In the late 1940s and 1950s, educational applications began to appear. Teaching machines, personalized systems of instruction such as the

Keller Plan (that will be addressed later), and computer-assisted instruction have evolved based on behavioral principles [10].

The *humanistic* view, on the other hand, recognizes that learning is something that students must do for themselves. Teachers must not merely transmit, but must involve and engage students in the activities of discovery and meaning-making. Teachers are encouraged to guide and direct less and to facilitate or act as a catalyst for students to initiate and take responsibility for their own learning. It is an attempt to personalize education. It represents a reaction against the excesses of the technological emphasis in education during the late 1950s [12].

The *cognitive* view provides a conceptual base for understanding the results of the earlier studies in the area and provides guidance for teaching/learning. From a cognitive view, students actively process material rather than passively listen and read. It says that effective teaching/learning is demonstrated when teachers (a) use classroom procedures that are compatible with a student's cognitive characteristics, (b) can organize and present information to promote problem solving and original thinking on issues, and (c) demonstrate that students are able to become more productive thinkers and problem solvers [14].

In later sections, the assumptions, methods, and status of behaviorist and cognitive views will be analyzed in more detail. The humanistic view will not be discussed in more detail, as it is less important in learning theory and research.

Table 2.1 is an effort to compare the past and present status of the different aspects of teaching in a pictorial format. The Industrial Revolution - the change from an agricultural to a manufacturing-based society by using machine as the prime mover - (starting about 1750 in England, about 1800 in North America, and about 1825 in Europe) has been taken as a reference point. Prior to Industrial Revolution, the overall standard of living (including education) was no better in 1700 than it had been in 1000 or Roman times. The emergence of industrial society brought a fast pace of progress rather than the slow and steady pace of the past. Separate from the larger social context, industrial societies with their key features of a rapid increase in knowledge, diffusion of knowledge, job specialization, mass production from machines, standardization of parts, and other new aspects led humankind to enter in the technological societies of the twentieth century [15]. The twentieth century is characterized by the invention of the computer, magnification of mental efforts and explosion of information technology.

Table 2.1: A Comparison Table of the Past and Present in University Teaching
Based on Schneider Fuhrmann & Grasha [10]

Aspects of Teaching	Before Industrial Revolution	Up to the End of 19th Century	20th Century
Purpose of University Teaching	- Discipline rather than meaningful learning - Training selected people (sons of elite) for ministerial and clergy positions	- A means for getting ahead - A university education is for more than just a highly selected student population - A university education should prepare people to assume a job	- Development of new knowledge - Production of a well-educated person trained in a liberal arts tradition - Vocational and career training as an important mission
Role of Teacher	- Paternalistic - Teacher knows what students need to learn - Students should learn what the teacher thinks is important	- Democratic - Teacher took a less directive role in prescribing what students should learn	- Revolutionary - Teachers are less directive and act more as facilitators in student's learning
Curriculum	- Rigid - A single prescribed curriculum composed of ancient languages (Latin and Greek), mathematics, and philosophy (moral truth)	- Specialization appeared in the curriculum which gave a potential free choice of electives - Evolution of the various scientific disciplines: geology, biology, physics, chemistry, and social specialties	FIRST HALF: - Development of divisions, such as physical sciences, social sciences and humanities, led to the development of curriculum based on major and non-major courses - Students have to master the basics (with a combination of prescribed electives) in each division before selecting an area of specialization SECOND HALF: - Curriculum reforms (especially sciences and technology)
Teaching Methods	- Recitation - Lecturing - Disputation (Greatest amount of time and energy was given to recitation and the emphasis was on the lowest order of cognitive skill - pure memory)	- Increased use of lectures - Increased use of demonstrations and seminars - Laboratory methods - Research papers become a popular teaching method	- Development of teaching methods and practices based on learning theories
Student-Teacher Interaction	- Teacher should have the last word in resolving debates on content and should prescribe in detail the course content, assignments, etc.	- Teacher can learn from their students - Teachers helping students to develop the capacity to become independent learners	- Teachers help students develop problem-solving and decision-making skills - Teachers personalize their instructions to meet the unique needs of their students
Type of Delivery	- Single instructor who was usually a recent graduate of the institution and was filling time until he received his call to the ministry	- Different teachers for different disciplines, some supporters of the recitation method and some of the lecture method	- Different teachers for different courses, some supporters of traditional, some supporters of non-traditional, and the rest supporters of a combination of both
Access to Information	- Teacher's notes - Books were not abundant	- Instructor's notes as well as hands-on experiences in laboratories, emerging research papers, books and other settings	- Textbooks, reference books, research papers, conference proceedings and journal publications - Data-bases and computerized information bank (1980s on)
Method of Testing	- Oral questioning of each student in public by examiners whom were university personnel and other learned citizens from the local community - No marks but judgements were passed on both the student and his tutor	- Introduction of written exams with marks (0-100) and grades (A-E)	- Introduction of normal distribution curves in marking and grading - Allocation of different weight percents to assess the learning activities - Written short tests and long exams (mid-term and final) - Individual or group projects - Individual or group assignment works - Seminars and oral presentations

2.1.2 The Evolution of Research on Teaching

Are small classes more effective than large classes? According to Wilbert McKeachie a prominent researcher in educational psychology, this was probably the first major question that research on teaching/learning in higher education tried to answer [16]. He mentions that the first investigation in class size was performed in the 1920s to compare the performance of students enrolled in a large class with that of students enrolled in a small class of the same course. The achievement of the two groups was approximately equal. Students reported a preference for small classes. McKeachie believes that, the larger the class, the less the sense of personal responsibility and activity, and the less the likelihood that the teacher can know each student personally and adapt teaching to the individual student. However, it seems likely that in larger classes, teachers typically require less written work and spend more time lecturing and less time on discussion. It is not surprising that shortly after the first research on class size, experiments comparing lecture and discussion began to appear [16]. McKeachie mentions the name of Bane as the pioneer researcher in the field of comparison of lecture and discussion methods [16]. Bane introduced an important methodological advance by using a measure of delayed recall after the course examination as well as the conventional final examination score. There was little difference between his groups taught by lectures and discussion on the immediate test, but there was significant superiority for discussion on the measure of delayed recall. Bane's studies, and later research by other experts showed that the lecture is equal to, and often more effective than, discussion for immediate recall of factual knowledge on a course examination. However, discussion is superior for long-term retention [16].

In the 1940s, the discussion method was divided into two categories, "student-centered" and "instructor-centered." The studies of student-centered classes resulted in recognition of a broader range of student outcomes like attitudes toward the learning tasks, motivation, and personality variables. Later studies in 1950s found that student-centered classes showed greater insight into problems. As in the studies of class size and lecture discussion, it was found that the favorable effects of student-centered teaching methods emerge in the "higher level" outcomes (e.g., analysis and synthesis – see Section 2.2.3 for more detail) rather than in factual knowledge [17].

McKeachie believes that the decade of 1960s was a period that resulted in substantial progress in the understanding of teaching and learning [16]. For the first time, data was collected from observations and questionnaires and combined with quantitative and qualitative approaches. This progress was reflected in Mann's book "*The College Classroom*" published in 1970 [18]. Mann provides insight into student characteristics, teacher roles, and the development of the class as a working group over the course of a semester. The book focuses on running classes in three different phases over a semester based on two different roles for the teachers and the students. Mann began with a phase in which the teachers have the roles of "facilitators" who where trying to facilitate independent, autonomous work, while the students tested the teachers' tolerance for student autonomy. In a second phase, the teachers became dissatisfied with the students' lack of work and were likely to become more punitive and authoritarian. Nevertheless, during this second period, the students and teachers began to gain a better understanding of the kind of work and involvement that was needed. In the third phase, classes became more cooperative, and effective work occurred. Although the phases over the course of a semester, could not be precisely replicated in other classes, the book helps both teachers and students understand and think about the unique development of their own classes and the sort of interaction that can facilitate productive development.

The forces of the cognitive revolution in psychology and education in the 1970s and 1980s produced effective methods for helping students to achieve cognitive goals. One of the best-developed systems for helping students learn more effectively was the development of "cooperative learning" [19]. Cooperative learning refers to "learning cells," in which pairs of students alternatively asking and answering questions on materials they have read. "Pay to be a tutor, not to be tutored" is the message from these systems. McKeachie, for example, gives reference to the comparison made by Annis [20] for learning under five conditions:

- Students read a textbook passage.
- Students read the passage and were taught by a peer.
- Students did not read the passage but were taught by a peer.
- Students read the passage and prepared to teach it to other students.

- Students read the passage and taught it to another student.

The results demonstrated that better learning occurred when students taught than when they were being taught. These results fit well with contemporary theories of learning and memory. Preparing to teach, teaching, questioning, and explaining involve active thought, analysis, selection of main ideas, and processing concepts into one's own thoughts and words. Motivational effects of peer learning and independent study also fit well with motivation theorists' emphasis on the importance of personal control of one's environment [16].

2.1.3 Effective Teaching

Any research on effective teaching quickly is ended up with the problem of evaluating the outcomes of the teaching and learning processes [16]. One first looks at student learning and measures of student achievement. But to be more realistic, it is hard to come up with better measures than the students' own perception of effective teaching. Student evaluations of teaching have commonly been used as a source of data, not only for research, but also to improve teaching and learning systems. Despite some teachers' doubt about the ability of students to rate their teaching and its effect on their students' learning, basic questions about validity and reliability have been confronted and answered by the research. As Marsh [21] emphasizes; these types of questions have been handled and answered with clarity as follows:

- Do students' evaluations agree with those of peers or administrators? Yes.
- Do students change their minds after they have been out of college long enough to appreciate the qualities of teachers whom they failed to appreciate while enrolled? No.
- Can the poorer students' evaluations be disregarded? No. When a teacher is particularly effective with the poorer students, these students rate the teacher higher than do other students.
- When several teachers are teaching sections of the same course, do the teachers whose students score highest on the achievement tests get the highest ratings? Yes.

Interestingly, the research shows that variables, such as time of day, class size, or required versus elective classes, make a difference, but not a large enough difference to cause researchers to misclassify a good teacher as a poor teacher. McKeachie believes that although one should collect evidence from other sources of teaching evaluation, student ratings are the best validated of all the practical sources of relevant data on teaching quality [16].

Another line of research investigates the relationship between teacher personality, teacher behavior, and teaching effectiveness. Two personality factors, "achievement orientation" and "interpersonal orientation" that relate to classroom behavior factors were found. According to findings in recent research, personality characteristics related to effective teaching vary, depending on the type of course [17].

2.1.4 Use of Technology in Teaching

Use of technology in teaching started with the use of instructional films. Later, it resulted in institutions using television for college-level instruction. Then the research studies started to measure the effectiveness of television on learning, particularly as an alternative to large lectures. The results of these studies, essentially, indicated that although students learn almost as much information in courses taught by television as in courses taught conventionally, live classes tend to produce superior learning [22]. Courses adapted for television by the addition of supplementary visual aids proved to be no more effective than televised lecture-blackboard presentations.

The outcome of the teaching machines and programmed learning that came later were not as good as expected. Programs for teaching were written in accordance with carefully specified behavioral objectives, but no dramatic change in learning was observed. Research showed that programmed instructions are very slightly superior to traditional instruction [17]. The only programmed learning related method that seemed to be successful was the Keller Plan [23]. The Keller Plan or Personalized System of Instruction (PSI), was a self-paced, mastery-oriented, modular system of instruction that produced not only superior end-of-course achievement but also superior retention. In fact, Keller took good advantage of behavioral psychology principles in building a teaching system with such assumptions as:

- Self-pacing, according to the time that the learner has
- Breaking the learning task into manageable units
- Using classroom lectures primarily for motivational purposes
- Detailed assignments that actively involved learners
- Frequent testing and immediate feedback

In viewing the individualization of education as an alternative to classroom lectures and group discussions. Cross [24] points out that self-pacing, active participation, clear and explicit goals, small lesson units, and feedback are basic principles upon which all individualized education is based. In fact, the application of these principles can be found in programmed instruction, computer-assisted instruction, and individually-prescribed instruction (PSI). The major weakness of Keller's PSI and all other later individualized education is the forms of self-management that many learners are lacking.

The development of the first business computer in 1951 heralded a wave of new applications for computers. Educators responded quickly to the perceived potential for using computers in education and the dream of the 50s was that university classrooms would be connected to computers which would serve as patient tutors, scrupulous examiners and tireless schedulers of instruction. Further, it was expected that the benefits to students would include the freedom to follow their own paths of learning, at their own pace at a time convenient to them, with richer materials to work with and automatic measurement of their progress [25].

Early evaluation studies of Computer-Based Instruction (CBI) began to appear by the late 1960s and early 1970s, which in general supported the effectiveness of computer-based teaching as a supplement to conventional teaching. CBI was reported to reduce time required to learn and to be effective for teaching mathematics and a number of other disciplines [26]. In the late 70s, however, a major evaluation of two systems, PLATO (an educational network providing access to a central library of lessons) and TICCIT (a system supporting lessons displayed on a color television screen connected to the student's keyboard and a local computer), found that neither had reached the potential so long claimed. Clark [27], in a review of a number of similar studies questioned the methods of teaching used in the "experiments" and suggested that CBI authors had simply computerized methods of programmed instruction rather than capitalizing on the possible "added value" of using computers.

However, by the introduction of microcomputers in the 1970s and later, wide spread use of computers into education in the 1980s, a revival of optimism has been seen again. In just 50 years, driven by engineering advances such as the integrated circuit

(IC), high density memory (HDM), and powerful display technology, computer technology advanced from the 30-ton ENIAC to battery-powered laptops that are 1,000 times faster and store 10,000 times more data. Encouraged by the growth of computer technology, the last few years have seen the promises of multimedia draw yet more optimistic predictions [28].

The review of the literature on the use of technology in teaching indicates that the latest in this long line of learning technologies is the World Wide Web (WWW). A major feature of the WWW is the potential for developers to create links between text and other media, not only within an individual document, but also between documents residing on any computers in the world which have access to the Web. One approach to using these features for teaching/learning is to create documents which contain hypertext/hypermedia links in which the learner follows a sequence that is often unique to the individual learner. Some researchers claim this kind of facility matches human cognition, in particular the organization of memory as a semantic network in which concepts are linked together by associations [29].

Today, the effect of computer technology on the enhancement of teaching and learning processes is still a matter of investigation. The greatest successes, however, are achieved with drill and practice programs, and are not yet the stuff of human's dreams [29].

2.1.5 The Move from Teaching to Learning

The move from a focus on teaching and teaching material to a focus on students is concurrent with the impact of cognitive psychology on educational research during the 1960s and 1970s. One of the most striking studies was carried out at the University of Gothenburg by Ference Marton [30] and his associates Saljo [31] and Svenson [32]. These Swedish researchers used a phenomenological-like approach and described the two different ways that students approach their textbook assignments. Surface processors read the assignment straight and use little attempt to think about the purpose and relationship between the assigned reading and their own previous knowledge. They tend to memorize the parts of the information they consider to be important. Deep processors, on the other hand, look for the purpose of the reading and more likely try to relate it to their previous and other learning. They start with the intention of understanding the meaning of the assignment, interact actively with the arguments and try to see to what extent the conclusions are justified by the evidence presented.

The distinction between surface and deep approaches to learning appears to be a powerful form of categorization for differences in learning strategies. Svenson [32] in a study of student learning over the course of a semester, has a similar categorization. His categories are "holistic" and "atomistic" which represent different ways in which students organize or structure their responses in describing what they remember. The "holistic" approach involves integrating the main parts into a structured whole. The "atomistic" approach concentrates on aggregating the parts without interrelating or integrating them.

The Gothenburg studies stimulated other researchers to devise questionnaires and develop remedial programs for students whose approaches to learning were rigid and ineffective. Thus, the focus in research on teaching shifted from the teacher to the students. Courses designed to teach students how to be more effective learners have been designed by researchers like McKeachie, Pintrich, and Lin [33], and Weinstein and Mayer [34].

Recent research based on cognitive theory indicates a better understanding of student's learning. Motivation theory, too, is beginning to help researchers understand why some students fail to achieve their potential. Research on the relationships between active deep processing and intrinsic motivation also is in the beginning stages [17].

2.2 Learning

2.2.1 Definition

There are at least two approaches to finding an appropriate definition for "learning." One approach is to check the way psychologists define it. The best reference may be the fifth edition of Ernest Hilgard's classic, *Theories of Learning*, a book whose contents have been taught to several generations of psychology students [35]:

Learning refers to the change in a subject's behavior or behavior potential to a given situation brought about by the subject's repeated experiences in that situation, provided that the behavior change cannot be explained on the basis of the subject's native response tendencies, maturation, or temporary states (such as fatigue, drunkenness, drives, and so on).

The most significant weakness in the above definition, as has been pointed out by the critics, is the failure to link learning directly to teaching. Apparently, students learn best when they are well taught. This is obviously in contradiction with the notion that "learning" may result from "native response tendencies" and "maturation" [17].

The other approach is to find how the experts in the field of education and educational psychology define "learning." One effort to define learning in educational terms is as follows [36]:

Learning is a process of acquiring and integrating through a systemized process of instruction or organized experience varying forms of knowledge, skill, and understanding that the learner may use or apply in later situations and under conditions different from those of instruction.

One of the global definitions of learning can be found from the most widely reported studies carried out in the University of Gothenburg in Sweden. Saljo [31] carried out an interview study of what individuals understood by learning and from this interview he developed five categories:

- Learning as a quantitative increase in knowledge: Learning is acquiring information or "knowing a lot."
- Learning as memorizing: Learning is storing information that can be reproduced.
- Learning as acquiring facts, skills and methods that can be retained and used as necessary.
- Learning as making sense or abstracting meaning: Learning involves relating parts of the subject matter to each other and to the real world.
- Learning as interpreting and understanding reality in a different way: Learning involves comprehending the world by reinterpreting knowledge.

According to Ramsden [37] conceptions four and five are qualitatively different from the first three which imply a less complex view of what learning is (i.e., learning is something external to the learner). Conceptions four and five emphasize the internal or personal aspect of learning: learning is something that one does in order to understand the real world, rather than something done by someone or something to the learner.

Moreover, Fincher, a prominent education psychologist, believes that in any effort to define "learning" one should take the following items into consideration [38]:

- Some learning can result from teaching but it can result from other forms of organized experience.

- The process of learning include cognitive, behavioral, and experimental dimensions or components.
- Learning should be seen in relation to its future uses or applications and its transfer to situations and conditions.
- Learning and teaching are dual processes that must be treated systematically if they are to make educational sense.

As a definition, it is quite compatible with Robert Gagne's more concise definition [39]:

Learning is a change in human disposition or capability, which persists over time, and which is not simply ascribable to processes of growth.

However, it seems that learning is something more than a change in performance. In its broadest sense, another definition is as follows [38]:

Learning is as a process of progressive change from ignorance to knowledge, from inability to competence, and from indifference to understanding.

Since learning and teaching are complementary processes, teaching, in the same manner can be defined as the means by which the situations, conditions, tasks, and materials are systemized to give the learners the opportunity to acquire new or different ways of thinking, feeling, and doing [38].

2.2.2 *Learning Situations*

Learning situations or the conditions under which learning occurs are many and varied. The major factors within the learning situation that have been identified are as follows [38]:

- The individual differences in the students themselves (i.e., their academic ability, their previous preparation at the secondary level, and the various motives or incentives that bring them to the classroom);
- The nature of the learning materials, tasks, equipment, and facilities that will be involved in academic course work including the structure and content of the academic programs themselves, the type of teaching aids, and the other educational facilities;
- The nature and quality of instruction the student receives, the conditions of practice, guidance, mode of presentation, feedback, and other teaching dimensions; and

- Environmental variables that may be either simple or complex in their influence on learning outcomes; i.e., conditions, and situations affecting learning process including those as simple as class size and those as complex as the various forms of external reinforcement, and interaction.

Many educational researchers believe that individual difference between learners will always account for the larger proportion of variance in learning outcomes, and that institutional characteristics do not have immediate influence on what students learn and how well they learn [40]. The influence of course organization and content, instructional methods, and the means by which student performance is evaluated can sometimes be major determining factors in learning. More or less, this is the case for the influence of environmental variables, which have their own appreciable credence.

Gagne, more than any educational psychologist, has tried to specify the situations under which human learning occurs [39]. In Gagne's view, learning takes place when external events, in the form of stimuli, and internal events in the form of memories, affect the learner in such a way as to produce a change in performance. Teaching is defined as a collection of external events that are deliberately planned and arranged. Information-processing models of learning and memory account for the internal events that affect changes in performance. Thus, the *outcomes of learning* are varied, but Gagne believes that most of them can be classified under five major capabilities as intellectual skills, cognitive strategies, verbal information, motor skills, and attitudes.

Gagne believes, the events of learning can be identified as follows:

- Sensory attending and selective perception
- Storage in short-term memory
- Encoding
- Storage in long-term memory
- Retrieval and response generation
- Feedback or reinforcement.

Perhaps, as Fincher suggests, the most pertinent view may be the emphasis that Gagne gives to the structure or organization of education (learning) and the advantages of breaking down learning tasks into their less complex components [38]. The main message in all of Gagne's works is that if teaching is to enhance student learning, it must be designed for that specific purpose.

However, as Fincher argues, research in learning situations indicates that the unanswered questions are many. Much to a researcher's regret, general theories of behavior based on learning provide diverse, yet no precise answers to some fundamental questions. In Fincher's view, some of the crucial questions may be identified as follows [38]:

- What is *it* that is learned?
- Does learning proceed through sequential and incremental stages or by integration and multi-directional characteristics or what?
- Do learners learn specific responses or do they learn to connect or associate responses to differential situations or what?
- Do learners acquire skills or cognitive structures (in the form of expectancies, schemata, or images) or what?
- How do learners respond to questions? Is it a kind of trial-and-error or a kind of insight into the relations of a problem?
- Can any learning occur without "practice?" If yes, what is the nature of the reinforcement to fixate it?
- How are the influences of variables like memory, consciousness, active attention, and other situations of human nervous system on learning?

2.2.3 Learning Theory and Research

As was discussed in the previous section, two views have dominated learning theory and research. They are behaviorist and cognitive views of learning. In general, the behaviorist approach to learning suggests that good learning is demonstrated when the instructor can write objectives relevant to the course content, specify classroom procedures and student behaviors needed to teach and learn such objectives, and demonstrate that students have achieved the objective afterward. Cognitive theory, on the other hand, sees a learner at the center stage [41]. The teacher becomes a facilitator of learning, rather than one who delivers information. This perspective on learning contrasts sharply with views that learners get the point as long as the teacher provides appropriate stimuli.

Judged by the research, none of the learning theories has been successful, as theories in engineering or other disciplines usually do, in defining the boundary and significant features of a learning system [38]. The irony is that when one needs systematic, verifiable knowledge about learning processes and their implications for higher education, s/he finds that learning theory and research is quite limited.

As Fincher argues [38], the greatest weakness of learning theories is their inability to agree on an acceptable typology for learning. None offer a taxonomy that makes sense in modeling a learning process. The only taxonomy with some promise is from the 1950s. It is called Bloom's Taxonomy [42]. It divides the learning skills and intellectual abilities into six major levels identified as: (1) acquisition of knowledge or information (memorizing), (2) comprehension or understanding the message, (3) application of the material comprehended, (4) analysis of the meaning of a comprehension, (5) synthesis of parts for a whole to constitute a new pattern/structure, and (6) evaluation or judgment about the value of an idea, solution, material, procedure or method.

As shown in Fig. 2.1, the first two levels are known as lower-order abilities and the others as higher-orders. Higher-order learning skills are more difficult to master than lower-orders. Higher-order learning skills are required to ever-greater extents as students

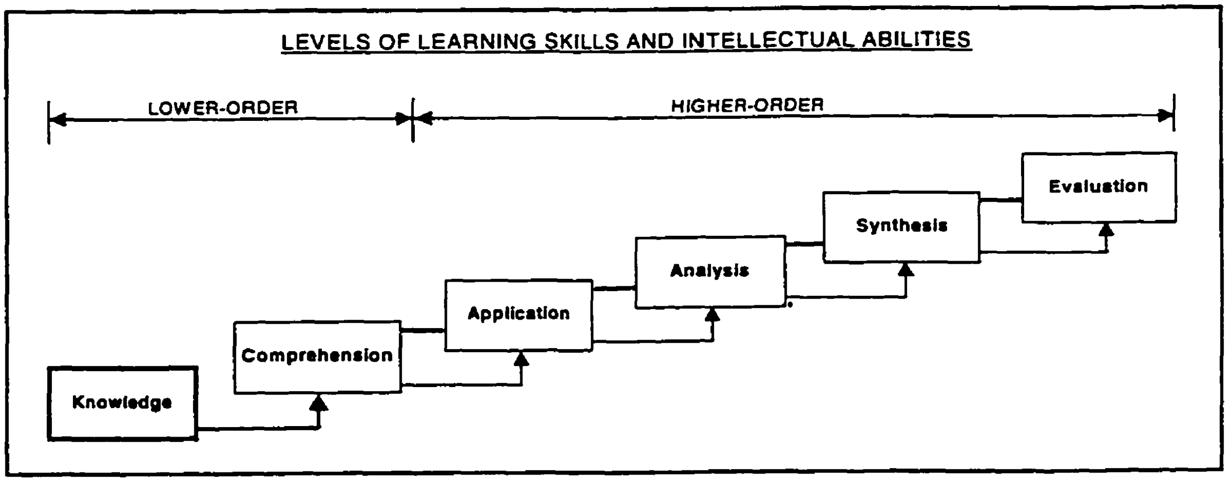


Fig. 2.1: Bloom's Taxonomy
Created Based on Anderson and Sosniak [42]

progress to upper level courses. Although it is possible to conceive of these major levels in several different arrangements, this Bloom's classification represents something of the hierarchical order of the different levels of abilities. The skills or abilities in one level are likely to make use of and be built on the behaviors found in the preceding levels.

A more direct application of learning theories may be seen in the efforts of some psychologists for translating theories of learning into a workable theory of teaching. For instance, Bruner [43] initiated such an effort by emphasizing the structure of knowledge as the content of what is taught and the teaching methods as the means by which students should learn. He saw a theory of teaching as a perspective that could set forth rules for achieving knowledge.

Research in the 70s gave better insight into the structure and processes of memory. Studies of Marton and others in Gothenburg University opened new avenues to understand the process of teaching/learning. Learning, in general, was viewed as the structural networks of concepts and actions that link network components in an integrated form. According to Bower and Hilgard [12], several thousand researchers in related fields were at work on the problem of learning during those years. Unfortunately, for those researchers who were expecting some unity in learning theories, behavioral research was increasingly diversified in subjects that could be categorized as sub-problems. In the meantime cognitive psychologists were more or less concerned with model building and the networking of sub-routines in cognition. Much of their research has resulted in better understanding of short-term memory, the function of organization in long-term memory, and the different kinds of memory that may be used in information processing but with no lead to any realistic suggestion for the educational implications.

However, based on different working hypotheses found in the research literature, Fincher [38] believes that one can reach some general principles of learning that are most visible and agreeable as follows:

- Learning is dependent on the capacities of learner.
- Learning is a function of the conditions of practices and or instruction imposed on the learner.
- Learning materials and tasks are more easily mastered when they are meaningful, i.e., when they are suitably organized, have a logically related part or components, and specify the conditions or circumstances under which they will be used or applied.
- Learning is facilitated by knowledge of results – especially if that knowledge is immediate and specific.
- The transfer of learning is dependent on the similarities of the learning tasks and/or the similarities of principles and work methods that can be applied in the transfer situation.
- Learning is related to the degree and quality of learner motivation, i.e., learners apparently perform better when motivation is intrinsic instead of extrinsic and reward is to be preferred over punishment.
- Learning is also related to the learner's level of aspiration, and the learner's experiences with success or failure in striving to reach certain levels of aspiration.

Fincher then argues that the following hypotheses can be derived from the above with the consideration of later findings:

- Learning is an active process and not the passive reception of stimuli or information.
- Motivation is a necessary condition of learning, but excessive motivation may not be conductive to learning effectiveness.
- Intrinsic motivation may be preferable to extrinsic motivation but is seldom possible with human subjects, thus researchers must be satisfied to control incentives and not motive *per se*.
- Some experience with success is necessary to develop a tolerance for failure.
- Guidance in training can be effective if given early and in relatively small doses.
- An understanding of relationships, facilitates transfer of training but there is no substitute for repetitive practice in the acquisition and development of a skill.
- Training methods must take into consideration not only the product of learning methods but the process as well, i.e., consideration must be given not only to "what to do" but "how to do it."

McKeachie, on the other hand, believes that only two principles of learning hold consistently [45]: (1) active learning is still better than passive learning, and (2) meaningful learning is still more effective than rote memory. Other principles apparently do not hold because education is an interactive situation in which the conditions, materials, and tasks of learning are different and much more complex. The learning of students in school and university is an interaction of numberless complex variables over an extended period of time.

2.2.4 Acquisition of Knowledge

According to the work of many theorists and researchers, to understand student acquisition of knowledge, one has to investigate both the content structure (structure of subject matter) and the student's internal representation of content structure. In a cognitive view, the content structure is defined as "the web of concepts and their interrelationships in a body of teaching material". Content structure consists of two parts: meaning of concepts and operations, and sets of rules and step-by-step procedures for solving a problem or attaining a goal. The content structure of a course may be derived from the teaching material, consisting of lectures, textbooks, syllabi, handouts, exams, and so on.

Donald has studied the content structures in sixteen university courses representing different disciplines [45]. She asked professors to rate the key concepts in terms of certain characteristics. The professors then used these key concepts to construct a "tree" and described the relationships of each link in the tree structure. The tree structure illustrated the dominant relationships of key concepts in the course. Donald found that the relationship among the key concepts was frequently the superordinate-subordinates (big picture-small picture) relationship. She also found that natural science courses showed greater use of dependency or causal relationships between key concepts, whereas social science and humanities courses showed greater use of similarity relationships.

On the other hand, the student's internal representation of content structure, called cognitive structure, may be considered as a mental structure of organized knowledge stored in his or her memory. Some cognitive theorists believe that these structures are cumulative and assimilative blends of information [17]. They argue that these are categories of mental structures that store and organize past experience and guide each individual's subsequent perception and experience. Cognitive structure, as prior knowledge, is viewed as one of the most important variables in determining meaningful learning and retention. Different theories of memory have postulated different kinds of components and different representations of cognitive structures. One theory, for instance, includes images and episodes as components of cognitive structure and the other one, proposes spatial images as a kind of knowledge representation that preserves the configuration or pattern of elements [17].

The importance of organization and structure in the acquisition of knowledge and learning is revealed in the top-down approach of teaching. As McKeachie believes [45], teachers could influence the development of students' knowledge structures by presenting the structure and organization of teaching material in a meaningful way, requiring students to actively organize the learning material, and activating the learner's cognitive structure and linking (bridging) the teaching material to students' knowledge structures.

Separate from the above view, some educators give an interesting interpretation of learning theories involving the acquisition of knowledge. For instance, Baroody, based on a similar interpretation, tries to show how each of these theoretical approaches deals with the acquisition of knowledge [44]. He suggests that:

Generally, there are two basic theories of learning: absorption theory and cognitive theory. Each reflects a different belief about the nature of knowledge and how knowledge is acquired. Absorption theory suggests that knowledge is impressed upon the mind from without. Basically, knowledge is viewed as a collection of facts. Facts are learned by means of memorization. In effect, learning is a process of internalizing or copying information.

Table 2.2 is an effort by this research to highlight and demonstrate the ways that the absorption approach defines the process of knowledge acquisition as argued by Baroody [44].

Table 2.2: Absorption Approach to Knowledge Acquisition
Based on Baroody [44]

Learning By Association	- Knowledge is viewed as a collection of facts and skills made up of basic elements (associations). - At the most basic level, learning facts and skills involves forming associations. For instance, mastering a basic addition combination requires learning that a number pair is associated with a particular sum (e.g., 7 and 3 are associated with 10). - Automatic and accurate production of a basic number combination is simply a well-ingrained habit of associating a particular response with a particular stimulus. Example: Upon seeing or hearing the stimulus 7 + 3, student looks up the associated sum in long-term memory and responds, "= 10."
Learning By Repetition	- Learning is fundamentally a process of memorization. - Understanding is not deemed necessary for the formation of associations. - A learner merely needs to be receptive and willing to practice. - Facts are learned by means of memorization. - Learning is a process of internalizing or copying information, and essentially passive process. - Associations are impressed upon the mind largely through repetition. - Motto: Practice makes perfect. Example: Student cements the bond between 7 + 3 and 10 through repeated practice with sufficient exposure. The fact 7 + 3 = 10 is firmly printed on the mind.
Learning By Accumulation	- Knowledge expansion is basically an accumulative process: an increase in the number of associations stored. - Knowledge expands by the memorization of new associations (e.g., mastering the basic addition combinations, involves accumulating 100's associations or facts). - Basic facts/habits can be linked together to form more complex facts or habits. Example: Mastering an addition algorithm (a step-by-step procedure) for two-digit addition without carrying (e.g., 46 + 23 = ---). This skill entails stringing together six simple habits into a habit sequences: (a) Start with the right-hand column (b) Retrieve the sum for the two terms in this column (6 + 3 = 9) (c) Record the sum beneath these terms (d) Move to the left-hand column (e) Recall the sum of these two terms (4 + 2 = 6) (f) Record the sum beneath these left-hand digits

Moreover, Baroody suggests that [44]:

Cognitive theory, on the other hand, argues that meaningful knowledge cannot be imposed from without but must be worked out from within. Genuine knowledge entails insight or understanding. Meaningful learning is a different process from learning by rote memorization. Learning by insight or understanding is effectively a problem-solving process: noting and then puzzling over clues, rearranging the available evidence, and finally seeing a problem in a new light. Cognitive theory claims that knowledge is structure: elements of information connected by relationships to form an organized and meaningful whole. Thus, the essence of knowledge acquisition is learning general relationships. Once one discovers a relationship, s/he has a powerful tool for remembering a body of knowledge despite its extent. Cognitive theory points out that, typically, memory is not photographic. One usually does not make an exact copy of the external world and store every detail or fact. Instead, one tends to store relationships that summarize information about many particular cases. In this way, memory can store vast amounts of information efficiently and economically.

Table 2.3 is a similar effort by this research study to highlight and demonstrate the ways that the cognitive approach defines the knowledge acquisition as argued by Baroody [44].

Table 2.3: Cognitive Approach to Knowledge Acquisition
Based on Baroody [44]

Learning By Relationships	- Relationships are a key basis of learning. - The essence of knowledge acquisition is learning structure and general relationships. - Structures are elements of information connected by relationships to form an organized and meaningful whole. - Once a relationship is discovered between elements of information, it acts as a powerful tool for remembering a body of knowledge despite of its extent. Example: Combinations that include zero as an addend (e.g., 1 + 0 = 1, 2 + 0 = 2, ...), all are bodies of knowledge of the same general relationships. Whenever zero is an addend, the other addend remains unchanged (N + 0 = N or N + 0 = N rule).
Learning By Active Construction (Growth of Meaningful Knowledge)	(1) LEARNING BY ASSIMILATION - Understanding occurs by relating new information to what is already known (or understanding new information in terms of extant knowledge). Example: If the new incoming information is that: 0 is the number name for adding "nothing", the student reflects that 6 + 0 must be 6. By relating the unfamiliar zero symbol to his previous knowledge that adding nothing to a set leaves the set unchanged, s/he quickly assimilates the new symbolic information. (As a result of his or her insight, s/he can then understand and respond appropriately to similar but new expression such as 3 + 0 = -- .
	(2) LEARNING BY INTEGRATION - Understanding occurs by noticing a relationship between previously known but isolated bits of information (integration). Example: Take a student who knows s/he has 5 fingers on each hand and 10 fingers altogether, yet persists in calculating the sum when given the symbolic problem 5 + 5 = --. (His or her practical knowledge concerning his fingers is not connected to his or her formal knowledge of addition. If these two bits of isolated knowledge can be brought together, s/he will be able to respond automatically with "10" whenever s/he sees or hears the symbolic problem 5 + 5 = --.)
Learning By Changes In Thinking Pattern	- Knowledge acquisition involves more than just accumulating information. It changes thought patterns. Making a connection can change the way knowledge is organized, thus changing how a student thinks about something. Example: Take a student who does not know the basic subtraction combinations and must use finger counting to calculate differences. Given the series of problems 2 – 1 = --, 4 – 2 = --, 6 – 3 = --, 8 – 4 = --, 10 – 5 = --. The student laboriously calculates each answer. Suddenly he has an insight: the subtraction combinations are a mirror image of the well-known addition doubles (1 + 1 = 2, 2 + 2 = 4, 3 + 3 = 6, 4 + 4 = 8, 5 + 5 = 10). There is a relationship between subtraction combinations and the familiar addition facts! Afterward s/he views subtraction in a different light. Given problem like 5 – 3 = --, s/he thinks to her/him: "three plus what makes five? Oh, yeah, two."

Laurillard discusses a number of key aspects of learning that are useful in concluding this section [46]. These aspects are:

Apprehending Structure: Students construct meaning as they read, listen, act and reflect on the subject content. "Meaning" is given through structure and it is therefore essential that students are able to interpret the structure of any discourse before they can construct the meaning that is crucial to understanding. Students adopting the surface approach, as they focus on memorizing a number of phrases and points for later reproduction, would fail to do this.

Integrating Parts: Students need to be able to integrate the signs of knowledge such as language, symbols, diagrams with what is signified by them.

Acting on the Word: There are few teachers who attempt to teach without asking students to do something, whether it be laboratory sessions or essay writing. Students are asked to engage in some form of activity which, when integrated with other activities mentioned here, assist in understanding of content.

Using Feedback: Actions such as those mentioned above are futile for student learning, unless feedback on individual actions is available.

Reflecting on Goals – Action – Feedback: Learners interpret and understand reality as they make links between each of the above aspects by reflecting on the goals of learning, actions taken, and the results of those actions.

Worth mentioning is the accommodation of the above aspects by Alexander [29] in her proposed notion on the use of hypertext/hypermedia in learning. She believes that because hypertext is a node-link system based upon semantic structures, as opposed to a sequential access system, hypermedia can map fairly directly the structure of knowledge representing it. (See 2.1.4)

However Laurillard's ideas [46] about apprehending structure, integrating parts, action, feedback and reflection has been well-taken by Alexander [29], but the extent to which it is possible for students to acquire the teacher's structure and map it on to their own existing structures is questionable. Learners develop individual interpretations of information and hence construct their own meaning. Alexander [29] notifies this fact when she says that since it is rare for two people to construct the same "semantic structure," it is therefore unreasonable to expect that a learner could easily adopt the teacher's structure and meaning.

2.2.5 Rate of Learning

The research indicates that students differ in the rate at which they learn a given subject or learning task and their learning rate may vary from subject or task to task. Studies of programs in which student learning is self-paced suggest that the slower students may require five to six times as long as the faster to master a set of learning materials [47].

Basically, rate of learning should be measured in terms of amount of skill or knowledge gained per unit of time. However, the nature of the learning task will partly determine the shape of the learning curve – which is, after all, a reflection of learning rate. Some learning tasks are of the nature that the amount of gain is approximately linear per unit of time. This is true when the learning task itself consists of a large number of subtasks, each learnable in approximately the same amount of time. Carroll [48], a prominent expert in this field, believes that if the amount learned is a linear function of time, the degree of learning (in terms of a proportion) is a direct, linear function of the ratio of time actually spent (time taken to learn) over time needed to learn:

$$\text{Degree of Learning} = f\left[\frac{\text{Time Actually Spent}}{\text{Time Needed}}\right]$$

He argued that if the amount learned is not a linear function of time, which is usually the case in engineering courses, degree of learning is also not a linear function of the above ratio. Sjogren, [49] studied a case in which he confirmed the above ratio, but as Carroll noted, only by study of a variety of situations would it be possible to make any generalization about the constancy of rate of learning over time.

In the above ratio, the true amount of time that a student needs to learn something is a variable that cannot be observed directly since it assumes that the student is well-motivated (that is, he is willing to spend all necessary time to learn), and that instruction is optimal. Nevertheless, one way to estimate the time needed to learn is by projecting from early stages of learning. For example, if one had a program of teaching that contained 1,000 pieces of information and a student took 10 hours to master the first 100, it is reasonable guess that s/he would take 100 hours to do the whole lot.

The best way of estimating time needed is to use tests of relevant aptitudes and prior knowledge. Carroll originally developed the above ratio in the context of his main work on the prediction of success in foreign languages. He found that a battery of tests that he developed, now called the *Modern Language Aptitude Test,* was an excellent predictor of rate of learning foreign languages, particularly when the student had no prior training in the language.

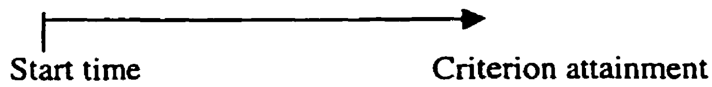
Aptitudes, as measured by either standardized aptitude tests or simple pretests of students' prior knowledge of a subject, are not only good predictions of the level to which students will learn in a *given time*, but also can show the amount of time they will require to learn to a *given level*. Carroll looked at aptitudes as measuring gauges rather than as indices for the level to which students could learn. The model stated that if students were allowed the time they needed to learn to some level, and they spent the required learning time, then they could be expected to attain the level. However, if students were not allowed enough time, then the degree to which they could be expected to learn was a function of the ratio of the time actually spent in learning to the time needed. The full Carroll model can be summarized as follows [48]:

$$\text{Degree of Learning} = f\left[\frac{\text{1. Time Allowed \ 2. Perserverance}}{\text{3. Aptitude \ 4. Quality of Teaching \ 5. Ability to Understand}}\right]$$

The time spent was determined by the amount of time students were willing to spend actively involved in the learning (i.e., their perseverance) and the total learning time they were allowed. The learning time each student required was determined by his or her aptitude for the task, the quality of teaching, and his or her ability to understand the instruction. Quality of teaching was defined in terms of the degree to which the presentation, explanation, and ordering of the learning task's elements approached the optimum for each learner. The ability to understand instruction represented the student's ability to generally profit from the instruction and was closely identified with general intelligence.

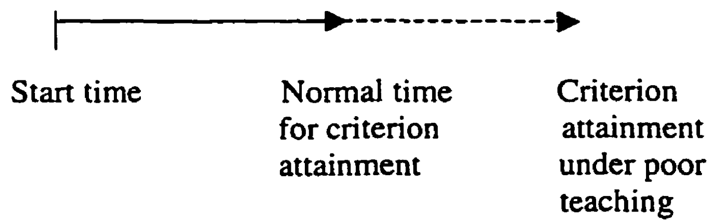
Actually, it was Bloom who later transformed this conceptual model into an effective working model for learning [50]. Bloom argued that if students were normally distributed with respect to aptitude for a subject, and if they were provided uniform instruction in terms of quantity and learning time, then achievement at the subject's completion would be normally distributed. Further, the relationship between aptitude and achievement would be high. However, if students were normally distributed on aptitude but each learner received optimal quality of teaching and the required learning time, then a majority of students could be expected to attain mastery. There would be little or no relationship between aptitude and achievement (e.g., aptitude is normally distributed and achievement may be a skewed distribution to the right side).

The model offered by Bloom inspired Carroll for further work. Carroll later argued that the time a given student will take to attain a criterion (master a learning task) may be thought of as a time-line: [51]



The line for the faster student will, of course, be short, while it may be very long for the slower student. In fact, it is necessary to allow for the possibility that some students will never reach criterion; for such students, one may think of the length of the line as infinite. When the task is very difficult, or when it depends upon very special aptitudes, there may be quite a number of students who will never "make" it.

With reference to the student's aptitude time-line, the effect of poor quality of teaching interacting with poor ability to understand instruction is to increase the required learning time beyond what would be required under optimal conditions:



Carroll assumed that the two variables, quality of teaching and student's ability to understand, interact with each other. He mentioned that there are more interactions among the components of his model. For example, good quality of teaching tends to enhance students' interest and willingness to spend the required amount of time on learning. Carroll also assumed that the students are "starting from scratch" in whatever learning task they are undertaking. But new learning tasks are often started without regard for the fact that some students already have some knowledge about it (prior knowledge) or have even previously learned whatever is being taught.

2.2.6 Learning Strategies

There are different definitions of learning strategies. Weinstein and Mayer [34] define learning strategies as thoughts and behaviors that a learner engages in during learning and that are intended to influence the encoding process. They have proposed four main components of information processing, all of which can be influenced by the use of learning strategies. The four components are: selection, acquisition, construction, and integration.

The selection component is defined as the attention to certain information in the environment and the transfer of it to working memory. Acquisition involves the transfer of information from working memory to long-term memory for permanent storage. The construction component is the involvement of the student in building connections between ideas in working memory. This process is also called schema development. The integration phase is connecting prior knowledge with incoming information. McKeachie and others prefer to refer to these different phases of information processing as attraction, encoding, organization, and retrieval [45].

In contrast, some researchers divide learning strategies in *macro-level* and *micro-level* [17]. They believe reviewing, note taking, and comprehension are macro-level learning strategies that complement micro-level cognitive processes such as attention and encoding. These macro-processes concern the students' processing of instructional input, whether this input is from a teacher, a textbook, or another medium.

McKeachie and others believes in three cognitive strategies: basic rehearsal strategies, elaboration strategies, and organizational strategies [45]. Basic rehearsal strategies involve reciting or naming items from a list to be learned. They believe this strategy is related to the attention and encoding components as the learner brings information into working memory. Rehearsal strategies for complex tasks such as learning material from a text include saying the material aloud as one reads, copying the material over into a notebook, taking notes as one reads, and underlining or highlighting sections of the text.

Elaboration strategies help students store information in their long-term memory by building internal connections between items to be learned. One of the basic learning tasks that can be performed with elaboration strategies is learning foreign language vocabulary. Research has shown that a technique known as "keyword method" is the best method for learning vocabulary [17]. The "keyword method" involves the building of two types of links between the foreign word and its English counterpart. One link is formed between the words by choosing an English word that sounds similar to the foreign word. Then, this new word that sounds like the foreign word is paired with the English definition of the foreign word in a mental image that helps the reader to remember the links between all three words. Some researchers suggest that the students will have better performance if the teacher or the textbook provides the links.

Organizational strategies help the learner to select appropriate information and also construct connections among the information by clustering. Clustering is the grouping of the words to be learned into categories that reflect some shared characteristics or attributes. Based on these strategies, a variety of techniques have been developed to help learners to identify the main ideas in a text. Weinstein and Mayer [34] believe that these techniques help students to analyze the text structure and understand the material better.

Some researchers believe that learning strategies can be taught to the students. They suggest that there are four important principles to follow in teaching the learning strategies. They are [45]:

- "Different tools should be used for different jobs." The instructor should teach different learning strategies for different learning tasks. However, there is no one best learning strategy.
- Strategies should be able to be decomposed into identifiable components. This approach has the advantage that students can learn the components and then combine them in different ways depending on the task.
- Learning strategies must be considered in relation to students' knowledge and skills. That is; there must be a "match" between the student and the strategy. For example, if students cannot decode words, then it is useless to teach them sophisticated reading comprehension strategies.
- Learning strategies that are assumed to be effective must be empirically validated. For instance, techniques that are effective in laboratory may not be effective in classroom.

However, research indicates that there are many other principles that should be considered as well. For instance, training for learning strategies may be more effective if it identifies students' existing strategies and strengthens them. Moreover, research suggests that short-term training strategies may not be very effective for college students as they may prefer and continue to use their own strategies.

2.3 Motivation

2.3.1 Overview

Motivation is defined in a general way by educators and psychologists as the processes that initiate and sustain behavior. Motivation is defined more specifically for learning in university courses as purposeful engagement in classroom tasks and study to master concepts or skills [52].

Weiner believes that perhaps the most salient controversy in the field of motivation is whether behavior should be conceptualized as *mechanistic* or *cognitive* [53]. For example, in the presence of hunger stimuli the response most likely is the attainment of food. Behavior directed toward the food then persists until the removal of the sustaining stimuli.

Cognitive theories of motivation, on the other hand, conceive of an action sequence as instigated not by stimulation, but by some source of information. External or internal events are encoded, categorized, and transformed into a belief, such as "I am hungry." The direction and persistence of behavior as the organism pursues its goal is a function of the intervening thought processes. This approach may be broadly characterized as stimulus-cognition-response (S-C-R). That is, higher mental processes intervene between inputs or stimuli and behavioral outputs or consequences, the structure of thought determines action [53].

2.3.2. Types of Mechanistic and Cognitive Theories

There are types of mechanistic theories, types of cognitive theories, and all shades of gray in between. For the research purpose, two types of mechanistic theories and two types of cognitive concepts are reviewed. Among the mechanists, some investigators attempt to explain behavior without using hypothetical constructs or intervening variables. They believe that stimuli and responses are sufficient terms in their scientific schema. The approach of Skinner and his followers is included within this category [54].

On the other hand, neobehaviorists such as Hull [55] and Spence [56] include many intervening constructs in their theories of behavior. Although they are still mechanistic theorists, nevertheless they recognize that the complexity of behavior demands the postulation of complex construct systems. This point of view assumes that stimuli are the instigators of behavior and learning or habits are rigid S-R connections. In contrast to the Hull-Spence approach, the cognitive theories of Atkinson [57], Lewin [58], and Tolman [59] state that stimuli are not conceived as the causes of action, and learning is not conceived as rigid S-R couplings. These conceptions are classified as Expectancy * Value theories. That is, the direction and intensity of behavior in these conceptions is a function of the expectation that certain actions will lead to the goal. The four types of theories are shown in the Table 2.4. A closer, yet concise, look at the broad spectrum of proposed theories of motivation is given in the next section.

Table 2.4: Types of Motivation Theories
Based on Weiner [53]

Theory Classification	Theory Structure	Summary	Proponents
Mechanistic	S-R	Behavior explained in terms of stimulus-response connections. Intervening hypothetical constructs are not employed in the analysis of actions.	Skinner, Watson, other associationists and behavioirists.
Mechanistic	S-Construct-R	Behavior explained in terms of stimulus-response connections. Intervening constructs also are employed in the analysis of action, such as drive, habit, incentive, and so forth.	Spence, Hull, Miller, Brown, and other neobehaviorists.
Cognitive	S-Cognition-R	Thoughts intervene between incoming information and the final behavioral response. The main cognitive determinant of action is an "expectancy."	Atkinson, Lewin, Rotter, Vroom, and Tolman
Cognitive	S-Cognition-R	Thoughts intervene between incoming information and the final behavioral response. Many cognitive processes determine action, such as information seeking, causal attributions, etc.	Heider, Festinger, Kelley, and Lazarus

2.3.3. A Closer Look at Human Motivation

Weiner, in his latest book on human motivation, defines motivation as the study of the determinants of thought and action. [60]. He believes that motivation addresses why behavior is initiated, persists, and stops, as well as what choices are made. Weiner argues that in attempting to develop a scientific explanation that examines the above questions,

questions, researchers have formulated general theories that are guided by metaphors of what a person "is." The roots of the motivational theories that have been developed can be traced back to the seminal contributions of Descartes and Darwin. Descartes suggested that subhumans are machines, and Darwin documented that, therefore, humans are machines. Furthermore, both fostered the notion that humans are Godlike, that is, they have minds and engage in rational thinking and judging of others. These two metaphors spawned two types of motivational theories; those accepting some aspect of the machine comparison (drive and field theories) and those guided by the Godlike comparison (expectancy-value and attribution theories).

The *drive* theoretical approach to motivation states that behavior is determined by drive * habit [55 & 56]. With later elaboration, learned drives and incentives came to be included among the determinants of performance. The main contribution of drive theory has been the systematic and precise exploration of motivated behavior from a mechanistic position.

The *field* theory proposed by Heider [53] states that the perception of an object is influenced by the field of forces surrounding that object and the interrelationships among the forces in the field. Furthermore, there is a tendency for the force field to reach equilibrium. Guided by these presumptions, the theories of Lewin and Heider presumed that behavior occurs within a psychological field and that many interaction forces determine behavior at any one moment [53].

On the other hand, the three *expectancy-value* conceptions of motivation are: Lewin's resultant valence theory [58], Atkinson's theory of *achievement* [57], and Rotter's *social learning* approach [61]. All are based on the principle that individuals maximize their hedonic pursuits by selecting those activities with the highest likelihood of reaching the most valued goal. These approaches are based on a Godlike metaphor; that is, humans, like God, are given complete rational powers. They are assumed to possess knowledge of all alternatives, the likelihood of attaining these potential choices, complete capability of assigning each goal a value, and the capacity not only to merge expectancy and value into a single numerical figure, but also to compare this figure with all others. These theories concentrate on achievement strivings, with goal attainment captured by *success* and non-attainment of a goal synonymous with *failure*. Furthermore, level of aspiration, or the difficulty of the goal for which one is striving, is a key research issue for all. Also, expectancy shifts play a dominant role in their empirical investigations. Finally, individual differences assume a much more dominant role than was the case in the machine-based conceptions. This is because, as the metaphors for the study of human motivation changed, the research shifted from the study of sub-humans to the testing of humans, where these individual differences are so prominent.

The founder of the *attributional* approach of motivation is Fritz Heider, and the underlying assumption of this conceptual approach is that humans are motivated to attain a causal understanding of the world [60]. That is, they want to know "why" an event has occurred. Causes have been classified within three dimensions, or as having basic properties, labeled locus of causality (internal or external), stability (stable or unstable over time), and controllability (controllable or not controllable). The causal dimension of stability relates to expectancy changes after success and failure. Relatively enduring causes indicate that the past outcomes will be repeated again in the future, whereas variable causes signify that the future may differ from the past. The causal dimension of locus relates to self-esteem and pride in accomplishment following success and failure, with internal causes magnifying positive and negative self-regard, respectively, following success and failure. The locus-esteem relation also is seen in research on excuse giving, and may account for the maintenance of self-esteem among the stigmatized, who may tend to attribute bad outcomes to the prejudice of others rather than to their handicaps. Finally, the dimension of controllability relates to self-directed affects of guilt and shame, with guilt requiring a controllable attribution for a transgression, whereas shame follows given and uncontrollable ascription for a failure or negative event [53].

Expectancy and affect, both of which are mediated by causal attributions, influence the choice, intensity, and persistence of behavior. Attributions of failure to a lack of ability are particularly debilitating because ability is a stable cause that also generates low self-esteem and shame given failure. On the other hand, causal attributions of failure to a lack of effort tend to enhance performance [53].

Weiner emphasizes that there is a growing belief in psychology that individuals are inefficient users of information, attempting to reduce cognitive strain by taking shortcuts in mental processing. Further, they are not rational decision-makers. What is emerging, then, is a belief that the capacities and capabilities of humans, their information-processing and decision-making capacities are more limited than the Godlike metaphor. Thus, the order of the Godlike metaphor has become strange such that its validity is becoming increasingly questioned. As happened with the mechanistic metaphor, psychologists are beginning to accept that the metaphor is "untrue;" individuals are not Godlike in their cognitive abilities. A new associated implication of the Godlike metaphor appears to be emerging, one that relies more on emotionality and less on rationality, more on evaluation and less on decision-making and choice, and is more focused on the external social world and less on the self. Weiner has called this the "person as a judge" metaphor [60].

2.3.4. Student Motivation

In this section, the focus is on addressing the recent theories of motivation that have particular relevance for university teaching and learning. As was stated earlier, motivation can be defined more specifically for learning in university courses as purposeful engagement in classroom tasks and study, to master concepts or skills. As suggested by Ames [62] and Brophy [63], it is a process in which students value learning and involve themselves in classroom assignments and activities.

Although there are many models of motivation that may be relevant to university student learning, this research has chosen to focus on two typical models for review. These two models are a *need-expectancy* model and an *expectancy-value* model. These models are basically cognitive models of motivation, in contrast to psychodynamic models (e.g., models based on Freudian theory), ego-psychology models (e.g., models based on Erikson's theory), drive models (models based on Spence's or Hull's theories), or humanistic models (models based on Maslow's theory) [17, 64]. Since this research is primarily concerned with student learning, rather than other aspects in teaching/learning, these two models of motivation fit nicely with this focus.

1. A Need-Expectancy Model of Student Motivation

McMillan and Forsyth have successfully developed a model of student motivation in a collective perspective [52]. On the basis of motivation theories by Rotter, Atkinson, and Vroom, and earlier work by McMillan himself, they have developed a model to organize what they believe are, theoretically, the most important influences of motivation for learning [52, 53, 60] (Fig. 2.2).

In developing the model, they have made the following assumptions [52]:

- Students can be motivated to greater involvement and higher achievement. Research indicates that appropriate instructional behaviors and course structures will enhance students' motivation.
- Motivation concerns three fundamental questions: (1) what originates or initiates students' activity? (2) what causes a student to move toward a goal? and (3) what causes a student to persist in striving toward a goal?
- Motivational theories tend to emphasize factors within individuals or factors in the environment. Factors within individuals are traits such as fear of failure, need to achieve high grades, or get into graduate school. Factors in the environment are such as the manner in which lectures are given, the competitiveness of grading system, or the relation the teacher establishes with students.
- While questions concerning motivation are simple, the answers are complex, involving a multitude of factors in both the students and the environment. Thus, no one theory can be applied to every situation. Each one is insufficient by itself, and thus many theories must be considered simultaneously.
- Most of theories of classroom motivation focus on needs or cognition of students. Needs are deficiencies within students but can be influenced significantly from external sources. Cognitive theories, which maintain that thoughts and mental processes are crucial in determining motivation, currently dominate the motivational literature.

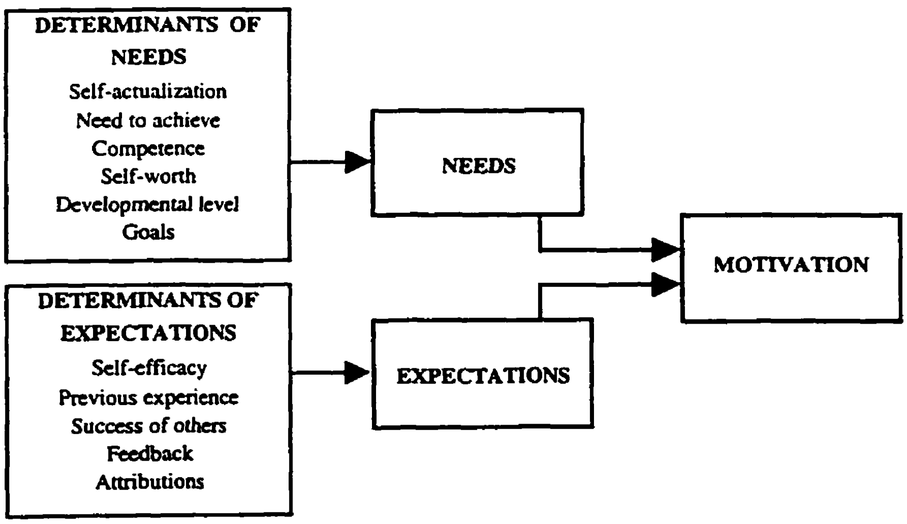


Fig. 2.2: A Cognitive Behavioral Model for Student Motivation
Adopted from McMillan & Forsyth [52]

McMillan and Forsyth's model is based on the approach that academic learning is basically a cognitive activity and that students' motivation is heavily influenced by their thinking about what they perceive as important, and what they believe they can accomplish. Simply stated, according to their model, two crucial categories of factors that determine motivation are *needs* and *expectations*. Needs, which have dominated much of the humanistic and behaviorist theories on motivation, initiate action and tend to motivate students to attain satisfaction and rewards. The term *expectations*, on the other hand, refers to the notion that the student's evaluations of their ability to achieve will influence their level of effort in learning. Students need to believe that with reasonable effort, they can perform a task successfully.

The determinants of *needs* and *expectations* emphasize different theories of motivation. Conversely, several well-established theories emphasize different kinds of *needs*. In the mean time, determinants of *expectations* emphasize cognitive theories of motivation. By searching the literature, one finds that these determinants have been described in different theories of motivation. The definition of each of these determinants have been paraphrased from different sources as follows:

Self-Actualization: It is the need of personal fulfillment and full realization of potential. Self-actualization is at the top of Maslow's well-known hierarchy of needs [64] (Fig. 2.3). At the bottom of the hierarchy are physiological and safety needs, which must be met before a person will be motivated to satisfy belonging, love, and esteem needs. These in turn must be satisfied before self-actualization. A higher need generally emerges only after lower needs have been met, thus students may be ideally motivated

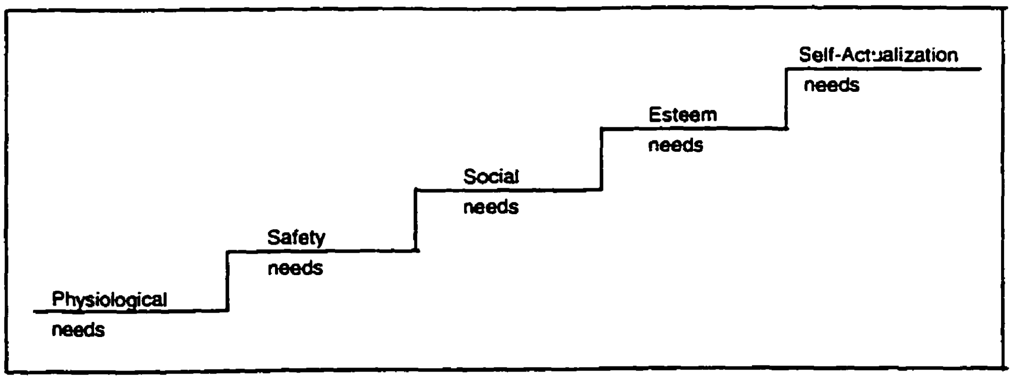


Fig. 2.3: Maslow's Hierarchy of Needs
Created Based on [64]

for achievement when love and belonging needs (such as friendship and acceptance of others) have been met. Maslow's hierarchy suggests that classes in which students have positive regards for one another and feel a sense of caring from the professor will be more motivated to achieve.

Need to Achieve: One of the most fully developed and relevant need models for teaching and learning is achievement motivation theory developed by Atkinson [65]. This theory is based on the assumption that a stable personality characteristics, termed the *need to achieve,* is an important determinant of achievement-related behaviors in any learning situation. Based on the research, students with a high need for achievement will be attracted to challenging learning tasks and students with a need to avoid failure may exhibit anxiety and fear, and thus, will need more positive feedback.

Competence: A primary need motive for university students is to become competent or to affect one's environment. This need involves achieving mastery and accomplishment and feeling a sense of control. Chikering [66] points out that students are in need of experiences that build their confidence in their ability to handle university-level courses.

Self-Worth: It is maintaining a positive view of oneself. Covington [67] theorizes that much of students' behavior is designed to enhance their self-worth. In competitive situations, two conditions affect behavior to enhance self-worth - scarcity of rewards, and the tendency to equate the ability to achieve with self-worth. The emphasis on ability coupled with grading on the curve and other competitive practices, indicates that grades are evidence of ability; that is, when one student out of a class of thirty receives an A, that achievement suggests strong ability. Conversely, students who fail may interpret their achievement as an indication of low ability, particularly if high effort was exerted. When students believe that an upcoming situation holds little hope for obtaining scarce rewards, behaviors are adopted to avoid the feelings of negative self-worth that would accompany low achievement.

Developmental Level: Students are motivated by what interests them, what challenges them, and what competencies or abilities they feel a need to improve. During the past three decades, a number of developmental theories of university students have been articulated that help to understand where students are, and how students change during university [68]. Two well-known theories are Chickering's model of student development and Perry's theory of intellectual and ethical development. Chickering [66] has postulated that students have seven developmental needs or concerns: developing competence, managing emotions, developing autonomy, establishing identity, freeing interpersonal relationships, developing purpose, and developing integrity. The more students can be engaged in these issues, the more likely they are to be motivated. On the other hand, Perry's theory of intellectual and ethical development [69] provides a basis for understanding how students think about and take responsibility for what they know and value. From the motivational view, students are most likely to be engaged and interested when they are challenged by thinking that is beyond their current viewpoints.

Goals: Students' needs are also determined by the goals they set for themselves. Goals can be short-term, such as a goal to achieve a certain grade on a test, or long-term, involving career decisions. According to Atkinson's achievement theory [65], need for achievement can affect goals. That is those with a high need for success select goals demonstrating excellence and tend to be most motivated when there is feedback of results and some risk of failing. Moreover according to this theory, students in easy classes are unlikely to be motivated. It is also important to select goals and objectives that are worth learning. Often, to increase students' perception of task value, teachers need to explicitly indicate why learning is worthwhile. When one sets goals and makes a commitment to reaching them, motivation is increased.

Self-Efficacy: Perceived self-efficacy involves beliefs about abilities to perform behaviors to attain designed outcomes. Students with high self-efficacy have high expectations and are more likely to engage in learning and vice versa. High self-efficacy is important in difficult learning tasks, since students who believe they are capable of performing well, tend to persist longer than students who doubt their abilities [70].

Previous Experience: Students who have previously performed well in particular content areas or on particular learning tasks are likely to have high expectations of being able to perform well in similar areas or tasks. Likewise, a history of difficulty or failure will produce negative expectations.

Success of Others: Self-evaluations and expectations are influenced by social comparisons, especially where objective standards of performance are lacking. Even in classrooms that utilize criterion-referenced goals, students, by observing the success of others, tend to come to certain conclusions to explain their performance.

Feedback: Expectations can be influenced greatly by feedback from professors. If a source is credible and trustworthy, positive feedback about abilities is likely to lead to increase expectations and motivation. Research indicates that teachers' expectations can influence students' expectations, and feedback is a primary means of communicating teachers' expectations. Feedback about performance is generally more motivating than simple rewards or reinforcements, because the information is meaningful to the student. According to Deci [71], if a teacher rewards students extrinsically with grades, to bribe them into performance, it is possible to decrease their motivation for continuing the behavior in the future. Students' attention should be on learning and on their competence, not on achieving rewards.

Attribution: Attributional theory is a theory of how individuals reason about causes of events. Attribution theorists believe that students explain their successes and failures in many ways. For example, some students attribute what they perceive to be success to their high ability and effort; others attribute failure to bad luck, unfair tests, or lack of sleep the night before. As stated earlier, these attributional factors have been characterized through three dimensions [72]: (1) locus; (2) constancy; and (3) responsibility. Locus refers to whether the cause is an internal factor, such as ability or effort, or an external factor, such as test difficulty or the grading procedure. Constancy refers to the duration of the attribution, whether stable or unstable. Responsibility refers to whether the cause is controlled and/or intentional. Fig. 2.4. demonstrate the attributional theory of motivation in a pictorial form. As the diagram shows after success or failure (*achievement behavior*), students incorporate information that can be thought of as *antecedents* in order to make *attributions*, which in turn determine *expectancies*. The

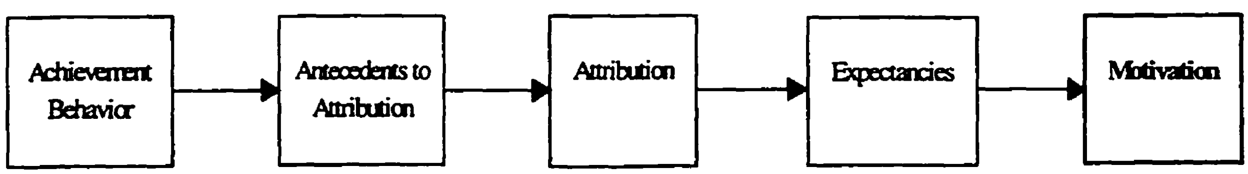


Fig. 2.4: Atributional Theory of Motivation
Created Based on Weiner [72]

most important antecedent is the student's initial expectations for how well s/he will do. Students who expect success and who are successful tend to attribute their performance to ability. Effort is also an important antecedent. If students exert a great deal of effort and fail, the tendency is to find external causes or attribute failure to lack of ability. Brophy [63] points out that motivation is higher when students succeed with reasonable rather than with high effort, so that they see themselves as capable.

2. A Value-Expectancy Model of Student Motivation

This model has been proposed by McKeachie and his colleagues [45] in an attempt to examine the joint cognitive and motivational construct in the context of the university classroom. Although this model is based on Atkinson's model of achievement motivation [65], it also relates nicely to attributional theory [72]. In fact, recent cognitive reformulation of Atkinson's model have made the role of students' perceptions or cognitions central to achievement dynamics. In Atkinson's model, the students' probability of success was defined in terms of task difficulty. Several researchers, e.g., Weiner [73] and Eccles [74], have pointed out that it is not the actual task difficulty that determines the students' expectancy of success but the students' perceived probability of success given their perceptions of the task difficulty and their perceived ability. Accordingly, in these newer cognitive models of motivation, students' perceptions about themselves and the task are the most important components of motivation.

Fig. 2.5 displays the general relationships between the expectancy and task value components and their relationship to achievement. The model is interestingly similar to

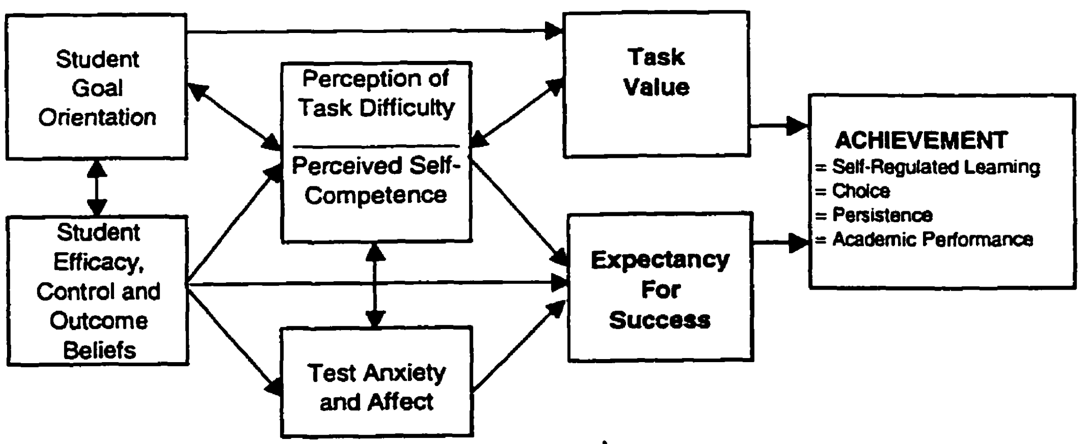


Fig. 2.5: A Value-Expectancy Model
Adopted from McKeachie, et al. [45]

the Eccles' expectancy-value model with some additions and refinements [74]. The developers of this model stress that these additions and refinements have been added to integrate the various motivational constructs of other researchers.

The model is composed of two paths. The task value path is at the top of the figure and flows from students' goal orientation to their perceptions of the task, and from their perceived self-competence to the task value. The expectancy path, on the other hand, is at the bottom of the figure and flows from students' efficacy, control, and outcome beliefs to both their perceptions of the task and test anxiety, and from their perceived competence and test anxiety to the expectancy. Expectancy in combination with task value is assumed to lead to task involvement and subsequent achievement. The six general constructs that lead to "achievement;" i.e., student goal orientation, student efficacy, control and outcome belief, perception of task difficulty, task-specific perceived competence, test anxiety and affect, task value and expectancy for success, are all student perception constructs assumed to mediate the relationship between the college classroom environment and student involvement and achievement.

Needless to say, the missing part in this model is the influence of the environmental factors on student achievement. The impact of environmental variables at the course level, such as instructor characteristics, structure of the class, grading practice, and types of exams, although indirect factors, could not be ignored in any model for student motivation. However, the relationships among the value and expectancy components in this model, as defined by McKeachie and his colleagues [45], are paraphrased as follows:

Expectancy: The expectancy component, as stated earlier, is the student's belief about his or her probability of success or failure on a particular task. Expectancies can be specific or general. For example, students can believe they will fail a mid-term exam in chemistry because they did not study. A more generalized expectancy would be students' beliefs about their potential for receiving a good grade in chemistry, while an even more generalized expectancy would be the perception that they will do well or poorly in all future science courses.

Perceived Self-Competence: In this model, it is assumed that the interaction of the student's perception of task difficulty and perceived self-competence produces the student's expectancy. Perceived self-competence is not the same as expectancy for success or actual ability. It is defined as students' perceptions of their ability to accomplish a particular task. In addition, perceived self-competence may vary along the specific to general dimension, as does expectancy. However, it is generally assumed that perceived self-competence is more stable than expectancy.

Perception of Task Difficulty: According to the research the exact relationship of perceived task difficulty to expectancy is not clear. Eccles [74] and some other researchers believe that perceptions of task difficulty is inversely related to expectancy. However, Students' achievement, if measured by GPA, is somehow related to difficulty of the types of courses they elect. This model assumes that student perceptions of task difficulty may change the relationship of task difficulty to students' expectancy for success and their subsequent achievement behavior. For example, and introductory psychology course may not be as difficult as a general chemistry course in terms of complexity of the materials covered, yet it may be perceived by some students to be more difficult due to different requirements.

Test Anxiety: This model assumes that student beliefs influence test anxiety and that test anxiety is negatively related to expectancy for success. Generally, test anxiety is assumed to have two components, a cognitive component and an emotionality component. Research suggest that test anxiety is a cluster of interrelated factors whose relationships to cognition, motivation, and ultimately to test performance, change as a student progresses through the achievement cycle. The research also suggests that the test anxiety is the result of poor study strategies than of anxiety itself.

Student Efficacy, Control, and Outcome Beliefs: This construct has been described very well in the attributional theory of motivation. According to attributional theory, many attributions can be provided for most achievement situations, e.g., ability, skill, effort, luck, task difficulty, mood, illness, fatigue. As stated earlier, the three main dimensions on which attributions can be placed include *locus*, *stability*, and *controllability*. The *locus* dimension refers to the internal or external nature of the cause in relation to the individual. For example, ability and effort are internal causes, while task difficulty and luck are external causes. The *stability* of an attribution refers to the manner in which the cause may fluctuate over time. For example, ability is an internal cause that is assumed to be stable over time, while effort is assumed to be changeable over time. Luck and task difficulty are both external causes that are assumed to be unstable. The *controllability* dimension refers to the individual's ability to control the cause. For example, mood, fatigue, and effort are all internal and unstable causes, yet effort is under the individual's control while mood and fatigue are not. Similarly, aptitude (an internal and stable cause) is not considered to be under the individual's control, while skill (an internal and unstable cause) can be brought under the individual's control.

Student Goal Orientation: Students goals influence the degree to which they value certain learning tasks. As stated earlier, student goals can be long-term or short-term goals. Generally, their goals can be conceptualized along a continuum from the career goals and life goals to the more specific level, to a particular task, exam, or course. Research shows that there are three general perspectives on student goals, an intrinsic motivation approach, a self-worth approach, and a cognitive goal formation approach as described below respectively:

a. *Intrinsic Motivation:* Intrinsic motivation is the expectation that engaging in or completing a task will be enjoyable. It, therefore, includes both attainment value and interest. Intrinsic motivation to learn has been conceptualized as the students' desire to learn, to discover and to develop. Intrinsic motivation for learning contrasts with extrinsic motivation in which the motivation is determined by values not inherent in the task such as grades, vocational utility, or praise.

b. *Self-Worth:* This component was discussed earlier. A self-worth approach of motivation assumes that one of the driving forces of students' motivational dynamics is the maintaining of self-worth. In this approach, students are not necessarily intrinsically motivated for challenge of learning, but rather are motivated to increase their feelings of self-worth and self-esteem.

c. *Cognitive Goal Formation:* This approach encompasses aspects of the intrinsic motivation view as well as the self-worth view. It is a very recent approach to motivation and yet has not been formulated fully. This approach synthesizes the other two views but is more process-oriented and predicts that students will have different goal orientation for different tasks. For some tasks, students may be driven by a performance goal in other cases, they may adopt a learning goal to strive to master the task.

<u>Task Value:</u> The task value component includes the characteristics of the task as well as the needs and goals of the student. Three components of the task value are: the attainment value, the intrinsic value or the intrinsic interest value of the task, and the utility value of the task for future goals. There has been very little research on these components of the task value.

a. *Attainment Value*: Attainment value refers to the students' perception of the task's ability to provide a challenge, fulfill certain achievement needs, and to confirm the self-competence. For example, students who think of themselves as "smart" and perceive a certain course as both a challenge and a confirmation of "smartness" would have a high attainment value for this course.

b. *Intrinsic or Interest Value*: This value refers to the individual's inherent enjoyment of the task. Intrinsic interest is assumed to influence students' involvement in the task and their future achievement.

c. *Utility Value*: Utility value refers to the "ends" or instrumental motivation of the student. It is determined by the importance of the task in facilitating the student's goals. For example, general chemistry may not be an inherently interesting task or have high attainment value for a student, but because the student has a goal of becoming an engineer, the course has a high utility value for the student.

2.3 Summary

The analysis of teaching and learning systems is a complex matter. The systematic literature review employed in this research tried to capture as much of this complexity as possible. Snapshots of different aspects of teaching and learning and their interaction were presented. The literature review might be seen as eclectic, but it was organized around certain clearly focused goals and purposes. The major goals and purposes were achieved by recognizing the most important issues, practices and research associated with teaching and learning in higher education in particular, and student motivation in general. Section 1 of this chapter, established historical perspective on the nature and practice of teaching as well as the historical background of research conducted in this field. Section 2, in reporting the issue of student learning and learning theories and research, showed the important implications associated with student learning diversity. Section 3, introduced the issue of motivation in general and then focused on two general models of student motivation to illustrate the main factors involved within typical motivational models.

Lastly, the ideas on teaching/learning for impatient and hasty readers of this chapter, can be summarized as follows:

- Teaching and learning are dual and complementary processes.
- In any effort for modeling a teaching-learning system, more weight should go to the "learning side." Student "learning" should be the main focus.
- Teaching/learning is a system comprising three main components interacting directly with each other, and being influenced indirectly by environmental factors. The three main components of the system are: students' characteristics, teaching characteristics, and subject matter characteristics. Motivational variables are involved with all of the three components and exchanged between them.
- The process of teaching/learning includes cognitive, behavioral, and experimental dimensions. These dimensions take their weights from the following views on learning:
  = The Behaviorist View: Learning behaviors are controlled by stimuli.
  = The Humanistic View: The emphasis is on student needs.
  = The Cognitive View: The focus is on students' cognition, their opinions and beliefs about the situation around them and their evaluation of their abilities form the learning behavior.

Fig. 2.6 is an effort by this study to demonstrate these ideas in a pictorial form. "Learning" could be placed at the center-stage. It may be expressed basically in terms of the degree of student abilities and motivation. "Student" and "teacher," where the latter is shown in general term as "teaching system," are the pivotal axes of the teaching/learning system. "Subject matter," is the other axis of the system. Learning environment and teaching environment represent the impact of teaching and learning dimensions that are in the background and impart their indirect influences on the system. Teaching and learning environment, in general, refer to those aspects in the teaching/learning system that affect the teacher and the student respectively, e.g., the administrative policies, curriculum, facilities and so forth. The last component, "other factors," covers all the side issues such as learning strategies, effective teaching methods, and those issues not discussed such as student gender, culture, and so on.

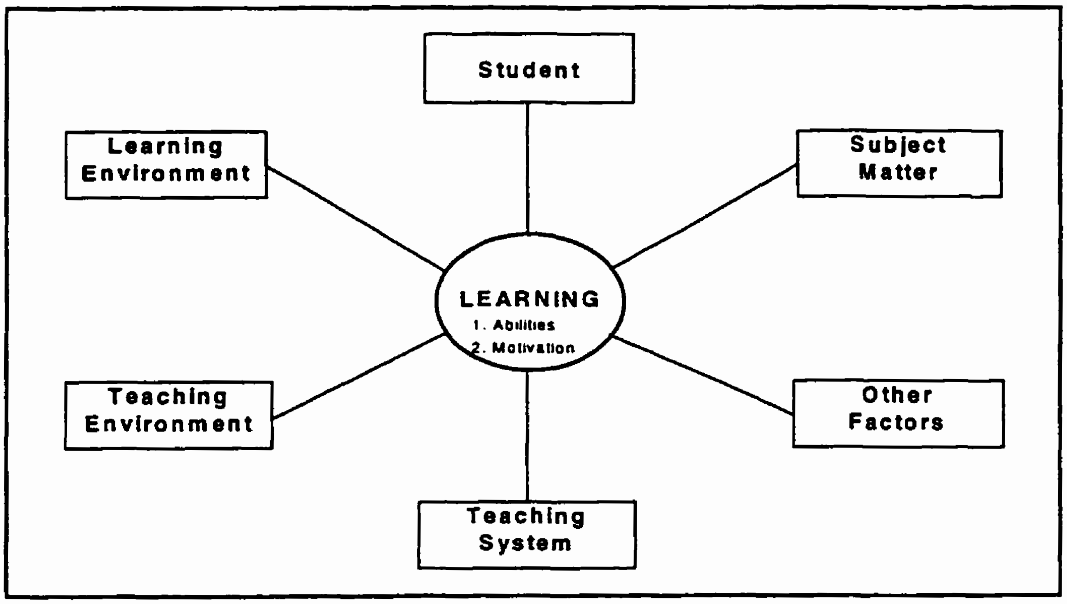


Fig. 2.6: Components Affecting Teaching/Learning Systems

Chapter 3

Literature Review: 2. More on Learning

In the previous chapter, this study described a number of general aspects in the literature on teaching and learning that were mainly related to student learning. But to be more specific, a survey should be conducted to find how educators have dealt with the links that exist between students' learning characteristics and the ways that learners approach a learning task. This, inevitably, demands a search into countless theories, views, and models that are available in the literature. To be more efficient and to not get overwhelmed by the large quantity, this research will select and focus on a few significant theories and models for this purpose. First, this chapter contains literature review of the main approaches about human memory and information processing. Second, some well known developmental models of student learning will be discussed. These models describe how students change and develop as their learning progresses. Finally, the focus will be switched to four popular models of learning styles in engineering education. These models will present a more acceptable picture of stable and distinctive characteristics of learners. This, in return, will complete the literature review and lead the study to the stage of the analysis and synthesis of the different viewpoints.

3.1 How the Mind Works

3.1.1 The Traditional Approach

The traditional psychological model of the human information system is sequential. That is, input is sensed, then processed, and output follows. While this model has been criticized by all types of researchers, nearly all the currently available information is based on it [75].

In the traditional system concept of engineering psychology, the human is considered a receptor and processor of information or energy, who outputs information or energy. Input, processing, and output follow each other in a sequence. The output can be used to solve a problem, tackle an issue in case of information, or run a machine in case of energy. The actual performance of this system is monitored, compared with the desired performance (reference) and then adjusted. Hence, one feedback loop connects or several feedback loops connect, the output side, or one of its elements, with the input side [75].

The difference between output and input is registered in a comparator where both output and input are compared with each other, and corrective actions are taken to minimize any output/input difference. The human in this system compares, makes decisions, and corrects. This basic model is depicted in Fig. 3.1.

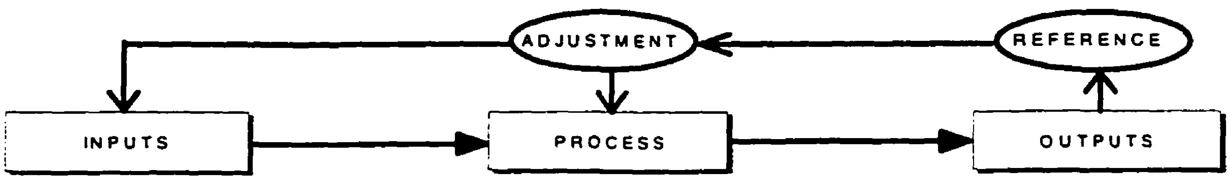


Fig. 3.1: Structure of a General Engineering Control Process

This "human processor," which is known as "human mind" is the object of research, either to understand learning functions or to observe the mind's actions and reactions within the system. In the 1970s and 80s, information theory, including signal channeling and processing, were major research topics. These theories and concepts are beyond the scope of this research, but there are many related publications in the field of cognitive psychology [75]. "Input" and "output" are the sites of application of human-factors engineering as well [76].

"Traditional" psychologists believe that human memory functions can be described as a linear sequence of stages, from perception to encoding to decision to response (Fig. 3.2).

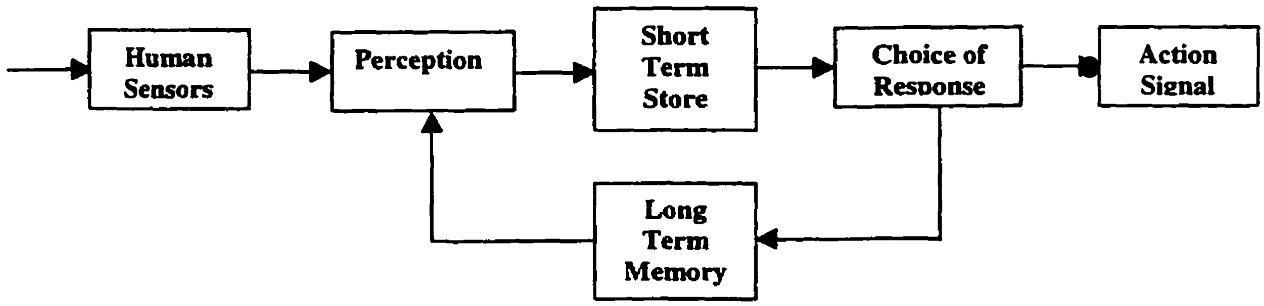


Fig. 3.2: The Traditional Psychological Model of Human Mind
Adopted from Karl [74]

Research is done separately on each of these stages, on their substages, and on their connections. Such independent, stage-related information is then combined in a linear model to provide information for the engineering psychologist [76].

3.1.2 Other Approaches

The traditional model is thought invalid by "ecological" psychologists. Ecological psychologists suggest that human perception is basically oriented toward the environment. Based on the thoughts of many of them, human perception assumes simultaneous rather than sequential interactions [76]. Two major concepts in the ecological approach are *affordance* and its *perception.* Affordance is the property of an environment that has certain values to the human. For instance, in an example of teaching/learning, a university affords opportunity to higher education for students who have the necessary qualifications, but not for students who do not have. Thus, opportunity for higher education is the property of the university, but its affordance value is specific to the user. The second concept is that information about affordance can be perceived directly and simultaneously by various human senses. That is, encoding does not precede decision, which does not precede response, but instead information is distributed throughout the system. This approach requires fundamentally new models and research on information processing in a different way than that associated with traditional psychology.

Cognitive psychologists, on the other hand, are the advocates of a concept known as the theory of information integration [77]. This theory treats memory (knowledge or thought) and judgement (action) as interdependent at every level. It aims to incorporate thought and action within a general theory of cognition. Integration theory has a functional approach to the memory structure. It suggests that functional memory is multiform and distributed and can be accessed in arbitrary serial-parallel complexity.

A challenging point of the cognitive integration theory is its capability for measurement of psychological values. To illustrate, suppose that information is given about a student's ability and past performance, together with two pieces of information about motivation. The prediction for future performance, then may be given by:

$$\text{Future Performance} = \text{Past Performance} + (\text{Motivation1} + \text{Motivation2}) \times \text{Ability}$$

As one may notify, the theory of information integration employs cognitive algebra for measurement of psychological values. In fact, this approach provides a powerful ground for defining and measuring similar psychological values. (See Chapter 6.2)

However, as mentioned in the previous section, the literature still states that, current knowledge is almost completely based on the "traditional" sequential-system concept. Despite suffering critics by all types of researchers, nearly all the currently available information is based on traditional approach [75].

3.1.3. Levels of Processing in the Memory

The idea of different levels of processing is well established in the psychological literature on human memory and information processing. Models of human memory have described generally three distinct types of memory: a sensory register, a short–term memory and a long–term memory.

Sensory Memory

Sensory memories are known to exist for vision, audition, and, possibly touch. They are characterized by being very brief, and at least in the case of vision, as being a literal representation, i.e., a more or less photographic image of the stimulus. Items in sensory memory quickly fade or are erased by new inputs. In the case of vision an image usually persists for about a quarter of a second or slightly longer. The auditory sensory memory appears to last for at least a quarter of a second and may last as long as one to five seconds [76].

In addition to vision and audition, there is some evidence for a sensory memory for touch that lasts for about 0.8 second. Similar memories may exist for other senses as well. Literature shows it is still not altogether clear what role sensory memory plays in cognition [76].

Short-term Memory (STM)

A second memory store is short–term memory (STM). People use STM to hold information temporarily, usually for a few seconds and up to about 20 seconds. Information stored in STM appears to come from both external and internal sources. External information comes into the short–term memory through the senses and the perceptual process. Internal sources include the results of reasoning or the outcome of a problem-solving task. The exact visual, auditory, or kinesthetic image or message is not directly stored in STM. Rather, the information stored must first be encoded. Information is converted into a form that is consistent with human physiology and that aids further processing of the information [75].

Research indicates that the two best known characteristics of STM are capacity and duration. The short–term memory store is small and can hold about six or seven units of information. A unit is any organization of information that has previously become familiar, such as familiar words or a familiar configuration. For example, if someone looked up a seven-character telephone number and stored this information in STM for a few seconds while dialing, he or she would usually store and correctly recall the seven characters. To improve learner's performance in learning tasks that use STM, one must take into account the capacity limit of STM and ensure that it is never exceeded [75].

Long-term Memory (LTM)

The long-term memory (LTM) is a more or less permanent memory storage. The concepts of learning and memory are closely related. The results of learning must be remembered for experience to accumulate. Unlike STM, long-term memory essentially seems to be unlimited, and items stored in it appear to last forever. LTM can be divided into episodic (storing episodes of experience) and semantic (storing and relating concepts). Items tend to make it into LTM if the item can easily be "hooked-up" or "linked" with something that is already there. Thus, long–term memory relies heavily on organization to build and maintain content [75].

Information can be held in storage for longer periods by internal repetition (rehearsal), and if repeated sufficiently often, it will become permanent memory trace, presumably in episodic LTM. This process is what would normally be called rote memorization or surface level processing. However, much incoming information is reassessed and categorized in STM before being passed to semantic LTM. This process is what is involved in deep level processing [78].

When an individual refers to learning, remembering, and forgetting, s/he is really thinking of her or his LTM. Although information may never actually be lost from LTM, some stored information may become less accessible, or less easy to retrieve.

A discussion of memory is also a discussion of forgetting since these two terms are complementary [75]. This relation can be shown as follows:

Amount Forgotten = Amount Learned - Amount Retained

Why then does one seem to forget material from his or her long–term memory? The answer may be found in the fact that at least three operations take place related to remembering and forgetting. These are encoding, storage, and retrieval [75]:

Encoding: In human memory, the process of deciding how to classify information is referred to as *encoding*. An encoding system is like a filing system organized, in part, according to the categories in their appropriate sections. It requires an individual to perceive the information and determine one or more essential characteristics of the information. Occasionally, what actually is stored is not the same as what was perceived originally. Maybe only the essence of what was sensed will be encoded. In fact, this is the basic difference between a human memory when it is compared to a filing system in real life.

Storage: The second necessary operation in long-term memory is storage. The LTM has been compared to a library. It contains a database of concepts and records of events tied together within inter-connecting systems. Each individual has a unique conceptual structure, although the linkages between concepts which constitute definitions have enough in common to allow effective communication of ideas. Concepts can be built up by repeated comparisons of incoming perceptions or information with pre-existing concepts or linkages between images (for example the sight of a professor and the sound of the word "professor").

Retrieval: The third long–term memory operation is called retrieval. Retrieval is the inverse of storing. Retrieval from memory depends on the accuracy of the encoding system which has already determined where the incoming information would be stored, and hence where it is expected subsequently to be found. If the encoding system is to be effective and recall easy, it is essential that the data base should contain a large number of clearly defined and well differentiated concepts which also carry a large number of connecting links with other concepts, ideas or events.
Forgetting: Forgetting may be due to a failure of any of the fore-mentioned three operations in LTM. Original encoding may be incorrect (information may be stored under another category), information may be in some way degraded during storage, or information may be difficult to retrieve because the search process takes place in the wrong part of the file. Some researchers believe that forgetting varies according to the nature of the activity that takes place after information is stored and before it is used. Others have suggested that forgetting takes place because there has not been ample opportunity for new information to be consolidated with previous knowledge (past learning).

Style of Thinking

Entwistle and Ramsden [78] attempt to define the terms "divergent thinking" and "convergent thinking" based on their broad literature research. They define divergent thinking as a search strategy that has a broad focus and allows connections between ideas to be made, even when the justifications for the associations are not obvious. They see it clearly as a component of problem solving, but logical thinking is also needed. On the other hand, Entwistle and Ramsden suggest, convergent thinking will tend to be narrowly focused, intense, fast and limited to specific locations. The difference between divergent thinking and convergent thinking is not just one of different processes. However, it seems that emotional and attitudinal components are also involved.

de Bono [79] has used the term "lateral thinking" to describe the alternative to traditional logical (vertical) thinking. He rejects the view that vertical thinking is the only possible form of effective thinking. He believes "thinking is a skill that can be developed and improved if one knows how." He attempts to show how lateral thinking is different from the vertical thinking by scrutinizing the nature of both. Some main differences, he suggests, are as follows:

Vertical thinking is selective, lateral thinking is generative. Rightness is what matters in vertical thinking. Richness is what matters in lateral thinking. Vertical thinking selects a pathway by excluding other pathways. Lateral thinking does not select but seeks to open up other pathways. With vertical thinking one selects the most promising approach to a problem, the best way of looking at a situation. With lateral thinking one generates as many alternative approaches as one can even after one has found a promising one.

Vertical thinking moves only if there is a direction in which to move, lateral thinking moves in order to generate a direction. With vertical thinking one moves in a clearly defined direction towards the solution of a problem if there is a direction in which to move. With lateral thinking one moves for the sake of moving and generating a direction.

Vertical thinking is sequential, lateral thinking can make jumps. With vertical thinking one moves forward one step at a time. Each step arises directly from the preceding step to which it is firmly connected. With lateral thinking the steps do not have to be sequential. One may jump ahead to a new point and then fill in the gap afterwards.

With vertical thinking one has to be correct at every step, with lateral thinking one does not have to be. The very essence of vertical thinking is that one must be right at each step. This is absolutely fundamental to the nature of vertical thinking. Logical thinking and mathematics would not function at all without this necessity. In lateral thinking however one does not have to be right at each step provided the conclusion is right.

With vertical thinking one concentrates and excludes what is irrelevant, with lateral thinking one welcomes chance intrusions. Vertical thinking is selection by exclusion. One works within a frame of reference and throws out what is not relevant. With lateral thinking one realizes that a pattern cannot be restructured from within itself but only as the result of some outside influence.

de Bono argues that the mind is a pattern-making system that creates patterns out of the environment, and then recognizes and uses such patterns [79]. Because the sequence of arrival of information determines how it is to be arranged into a pattern, such patterns are always less than the best possible arrangement of information. To bring such patterns up-to-date, and so make better use of the contained information, one needs a mechanism for insight restructuring. This can never be provided by logical thinking which works to relate accepted concepts, not to restructure them. Lateral thinking is required to restructure the perceptual pattern which is the way a situation is viewed. Vertical thinking then accepts that perceptual pattern and develops it.

de Bono believes that lateral thinking is directly concerned with insight and with creativity. Whereas both these processes are usually only recognized after they have happened, lateral thinking is a deliberate way of using information to bring processes about. In practice, lateral thinking and vertical thinking are so complementary that they are mixed together. de Bono also argues that lateral thinking is especially useful in problem solving and in generation of new ideas. He likens problem solving to digging holes. Logical (vertical) thinking may dig deeper and deeper holes in quite the wrong place. He suggests that lateral thinking is more likely to be effective, like a shallow, exploratory hole prior to "deep drilling". Lateral thinking seems to be closely allied with divergent thinking, and de Bono sees it as necessarily leisurely, often having a dream-like quality where the emotions, as well as the intellect, are given free rein [78].

3.2 Developmental Models of Student Learning

Wilson in his striking book on student learning in higher education [80] has reviewed most of the empirical findings on how students learn in higher education. The content of his book is centered on such main themes as the context of learning, the general pattern of student intellectual development, and the approach, strategies and styles of thinking that students adopt in learning material. He believes that such factors as general ability, level of anxiety, and level and type of motivation, play an important part in student performance. Wilson points out that the relationship between these variables and academic success is not necessarily direct or linear, and it is from the interactions and clustering of the variables that one can understand how students tackle particular tasks. He believes that given the current state of knowledge about students and their characteristics, model making is like trying to fashion bricks without straw. Surprisingly, about a decade later, McKeachie notes that not much has changed and the situation seems the same [45].

However, to serve the purpose of the research and in line with Wilson's book [80], five general models of the process of student learning, which reasonably represent the important ones in the area of learning psychology, are reviewed in this section. The first and second are by Biggs [81 & 82] and Entwistle [83] respectively, who present a snapshot of different types of learners interacting with conceptually difficult academic subject matters. The third one is by Laurillard [84], who, by contrast, is interactionist and sees students as decision-makers, capable of choosing their own orientations and strategies of approach and responsive to the context as they perceive it. The fourth one is by Wilson [80] who relates types of learners clearly to the level of academic performance and the development of the student's capacity to learn. Finally, the fifth model by Milton and his colleagues [85] sees both the students and their approaches to the learning process in a totally different scheme.

Biggs' Presage-Process-Product Model

Biggs [81] sees "study processes," which constitute a complex of tactics, strategies and approaches, as mediating between "presage" factors, such as personal characteristics and institutional variables, and "product" factors or academic performance. He has advanced a three-factor interactive model in which different combinations of values, motives, and strategies produce different "kinds" of learners, all of whom may be equally successful in higher education.

Biggs' general model is presented in Fig 3.3. The model maintains that the students' approaches to their academic works, and the strategies (e.g., rote learning) they adopt are determined by such factors as anxiety, induced possibly by "fear of failure" or attitudes toward university study, came from their expectations and values shaped in the home or earlier school. Study behavior, as Biggs believes, reflects values, assumptions, cognitive style and basic personality structure. With this view, the research problem is to

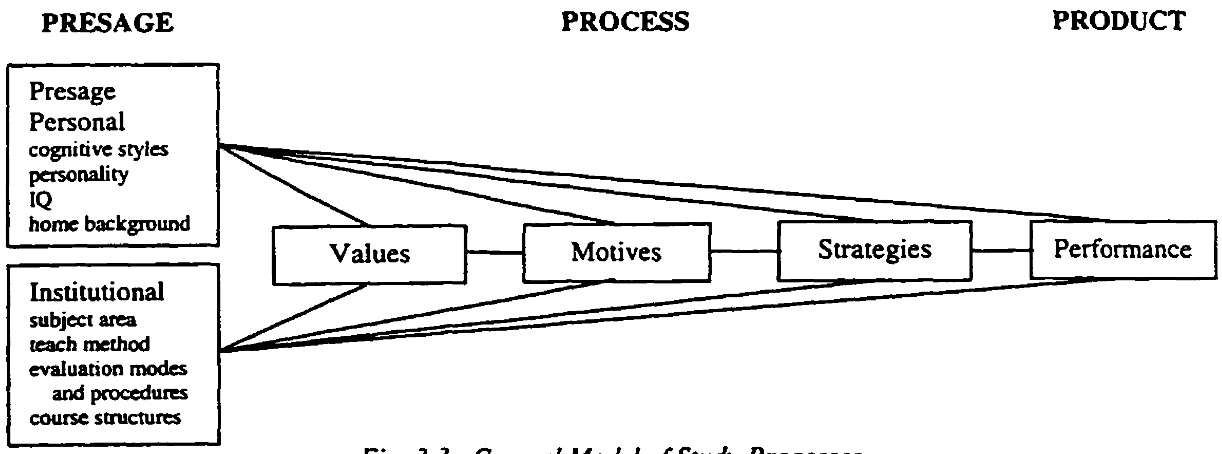


Fig. 3.3: General Model of Study Processes
Adopted from Biggs [81]

map out individual characteristics and to relate them to performance. With these objectives in mind, Biggs has devised a Study Process Questionnaire Scales (Table 3.1).

The scales employ different personality variables, academic values and study habits, which are seen as being relevant for predicting academic performance [81].

Table 3.1: Study Process Questionnaire Scales
Adopted from Biggs [81]

1. Pragmatism: grade-oriented; student sees university qualifications as a mean to some other ends.
2. Academic motivation: intrinsically motivated; sees university study as an end in itself.
3. Academic neuroticism: overwhelmed and confused by demands of course work.
4. Internalilty: uses internal, self-determined standards of truth, not external authority.
5. Study skills: works consistently , reviews regularly, schedules work.
6. Rote learning: centers on facts and details and rote-learns them.
7. Meaningful learning: reads widely and relates material to what is already known: oriented to understand all input material.
8. Test anxiety: worries about tests, exams, fear of failure.
9. Openness: student sees university as a place where values are questioned.
10. Class dependence: needs class structure; rarely questions lectures or texts.

Biggs obtained consistent results with three student samples in a higher order factor analysis of these scale scores in relation to academic performance, and identified three factors (which explained between 57 and 70 per cent of the total variance), which he labeled as "Reproducing," "Internalizing," and "Organizing." Correlation of the 80 scale items with each of these factors produced constellations of values, motives, and cognitive strategies, which made sense in terms of the interactive model proposed (Table 3.2).

Table 3.2: Three Orthogonal Value-Motive-Strategy Dimensions
Adopted from Biggs [81]

	Value	Motive	Strategy
Factor I (Reproducing)	pragmatism: instrumental values, university is means to another end.	test anxiety, neuroticism: motive to study is fear of failing	Class dependence: fact-rote. Minimax: goals are those defined in the course, no more: rote learned to a reproductive criterion.
Factor II (Internalizing)	openness, internality: self-growth or actualization seen as overall goal, university permits this.	Academic motivation: intrinsic, what contributes to growth is interesting, self-motivated.	Meaning: work unsatisfying unless understood and incorporated with existing knowledge. Class only basis for stimulation.
Factor III (Organizing)	Winning through competition: university a game to show excellence	Achievement motivation: need for success, low anxiety.	Structuring, organizing work, meets deadlines, plays the game.

Biggs describes each of these "types" as follows [81]:

The "reproducing" person sees the university as an instrument, a means to an end. His motives for studying are governed by the fear of not achieving that end, so he defines his goals minimally compatible with success, and uses the simplest strategy of learning, i.e., "reproducing what he is supposed to do and no more." The "internalizing" type sees the university as the place wherein the self actualization process can take place; the motive is intrinsic, studying is a process of growing and hence wide reading, interrelating and meaningful learning strategies. Growth only takes place if the material is internalized and related to existing knowledge. The "organizing" person is driven on by the need for achievement, and the value is competing and winning, whether the goals are self-set or not.

Fig. 3.4 outlines two possible "models" of study process dimensions: on the first (a) individuals may be located in terms of the three factors; on the second (b) the reproducing-internalizing dimension is seen to be one axis, with "organizing" a separate one. Worth mentioning is that Biggs links this latter two-factor theory with Marton's "depth" and "surface" approach [30].

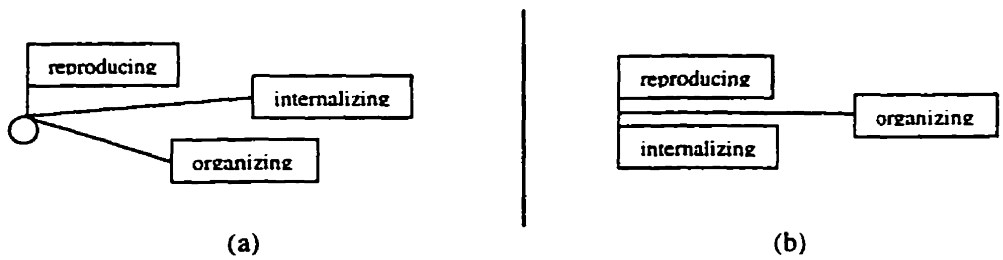


Fig 3.4: Alternative Models of Study Process Dimensions
Adopted and Modified from Biggs [81]

Entwistle's Distinctive Approaches Model

Entwistle and his colleagues [83] have tested several groups of university students on an inventory which comprises 15 sub-scales tapping intrinsic, extrinsic and achievement motivation as well as other variables, and related results to academic achievement. A factor analysis of the responses identified four dominant factors as shown below:

- Deep approach/comprehension learning
- Surface learning/operation learning
- Organized, achievement-oriented studying
- Stable extraversion

Entwistle's main focus was on the stylistic differences in the processes of study. He noted that adoption of a deep approach is not identical with orientation towards meaning as it clearly also involved tendencies towards superficiality, i.e., towards the pathology of globetrotting (failure to use supportive evidence). Within the reproducing orientation, he suggested that one could identify both the surface approach with its emphasis on memorization of facts and definitions, and the concentration on detailed procedures and factual evidence which is the hallmark of operation learning.

On the basis of these results, Entwistle advanced a tentative model (Table 3.3) of student learning which he explained it as follows:

Table 3.3: Categories Describing Distinctive Approaches to Learning
Adopted from Entwistle, et al. [83]

Factor	**Orientation and intention**	**Motivation (personality type)**	**Approach or style**	**Process**		**Outcome**
				Stage I	**Stage II**	
I	Understanding	Intrinsic (Autonomous and syllabus-free)	Deep approach/ versatile	All four processes below used appropriately to reach understanding		Deep level of understanding
			Comprehension learning	**Building overall description of content area**	**Reorganizing incoming information to relate to previous knowledge or experience and establishing personal meaning**	Incomplete understanding attributable to globetrotting
II	Reproducing	Extrinsic and fear of failure	Operation learning	**Detailed attention to evidence and steps in the argument**	**Relating evidence to conclusion and maintaining a critical, objective stance**	Incomplete understanding attributable to improvidence
		(Anxious and syllabus-bound)	Surface approach	Memorization	Overlearning	Surface level of understanding
III	Achieving high grades	Hope for success (Stable, self-confident, and ruthless)	Organized/ achievement orientated	Any combination of the six above processes considered appropriate to perceived task requirements and criteria of assessment.		High grades with or without understanding

The first three columns of the diagram describe the factor structure of the inventory, while the fourth column indicates the overlap that was found between approach and style of learning. The main advance provided by this figure is to isolate three distinct processes of learning, all of which are essential to a deep level of understanding.

These processes are shown as occurring in two stages. The first stage involves initial attention either to the overall description (comprehension learning) or to the evidence and to steps in the argument (operation learning). This initial focus of attention leads on to the second stage of considering relationships, which may involve either examining links between ideas or concepts and with personal experience (comprehension learning), or the way pieces of evidence fit together to build up a logical argument (operation learning). To reach a deep level of understanding all four processes would normally be required, but our factor analyses suggests a tendency for each factor identified to have a pathology, as well as a desirable attribute. The orientation towards understanding may be accompanied by a tendency towards the superficiality identified with globetrotting. The orientation towards reproducing may be partially compensated by the attention to detail found in operation learning. And finally the orientation towards success may sacrifice understanding for attainment unless a demand for full understanding is built into the criteria of assessment.

Laurillard's Interactionist Model

This model reflects how individual differences between students influence their perception of the learning task and how the nature of the task and teaching, affect the way that students carry out the task. Laurillard [84] assumed that the student's cognitive activity is conceived on three stages: "orientation," "strategy," and "execution." He suggested seven basic orientations that students take when they study (Fig. 3.5):

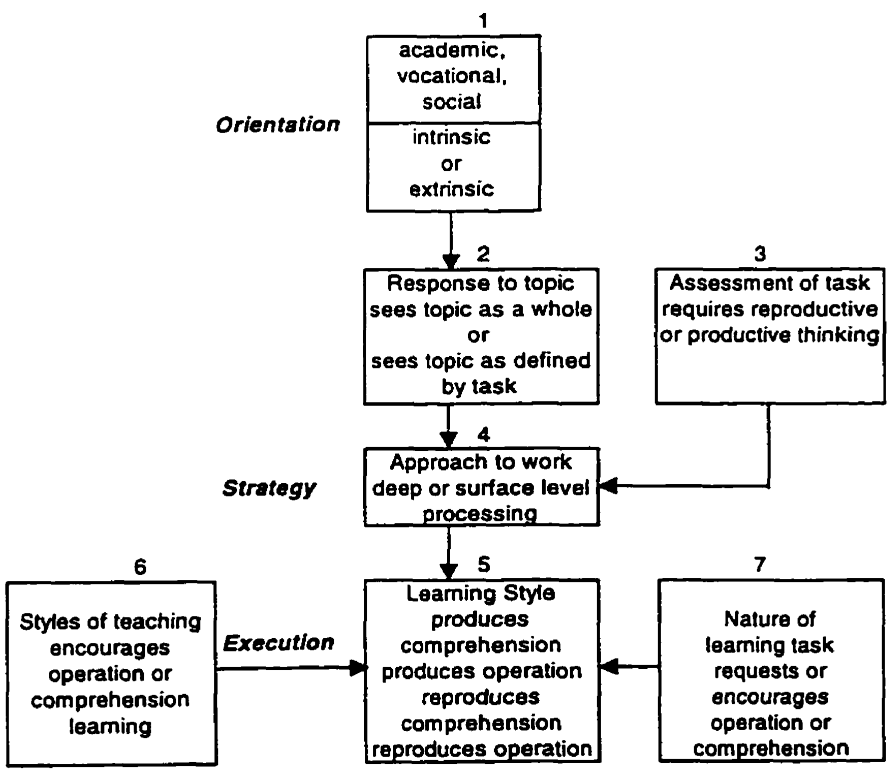


Fig. 3.5: Laurillard's Interactionist Model
Adopted from Laurillard [84]

Some students pursue higher education primarily for academic reasons and are genuinely interested in the subject matter; others have vocational or career motives; a number have social reasons for study, being interested, for example, in their general self-education (1). The balance between these reasons will differ for each student and the demands and appeal of the particular course being studied may also be important (even the most academically oriented student may lose interest in a poorly taught "service" course, for

	academically		work hard		intrinsic	
predominantly	vocationally	oriented students	work hard	for	extrinsic	reasons
	socially		work a little		intrinsic or extrinsic	

example), but it is likely that these differences will be reflected in the extent to which students apply themselves to their work in the following manner:
Intrinsically oriented students will tend to see the topic being studied as a whole (2); they will seek to understand it, irrespective of what the task itself requires. Extrinsically oriented students will see the topic in terms of the task they have to perform. The task itself (3) may be perceived to require "reproductive" (i.e. memorizing) or "productive" thinking, involving the ability to go "beyond the information given." Perception of the demands of the task influences the strategy the student adopts (4). It is maintained that intrinsically oriented students will take a "deep" approach, irrespective of the task requirements, while extrinsic students will conform to the demands of the task. Thus the latter will adopt a "surface" approach if the task requires reproduction, but they are capable of deeper processing if that is demanded. The important point is that extrinsic students respond to the situation rather than defining it. The strategy a student adopts, i.e., the approach he takes to the task, together with the style of teaching and the nature of the specific content being studied, all influence the execution or performance of that task. A student adopting a deep approach will reproduce whatever the teaching encourages (6), but he will also produce what it does not encourage, thus achieving a balanced understanding that includes both operation and comprehension learning. If a student takes a "surface" approach, however, he will reproduce only that part of the teaching that the learning task requires.

Wilson's Developmental Model

Wilson has developed a model to integrate all the available research findings in a developmental model of student learning [80]. This model clearly relates types of learners, to their academic performance as well as their developmental capacities to learn. The model outlined in Fig. 3.6, shows how students move from a relatively passive learning situation at entry (anxious, uncertain, lacking in skills, looking for "answers," and with no record of success to give them confidence) to an active, thoughtful, questioning and challenging, confident learning situation. Wilson's model takes Perry's findings [69] into account and assumes that a majority of students develop new conceptions of what studying in higher education involves over their years in college or university.

Referring to Fig. 3.6, the starting position of the students in the continuum depends on their "presage" factors. Wilson defines "presage" factors as factors that determine points of entry and influence the rate of progress. On the other hand, the ease and speed of progress along the continuum reflect presage factors and the nature of the teaching, learning and assessment. Wilson states [80]:

The model conceives of the various approaches to study displayed by students as correlates of dualistic and relativistic thinking. The dualistic conception defines knowing at the lowest level of Bloom's Taxonomy [42]: learning is passive, reproductive, surface and verbatim commitment to memory; such a conception implies being syllabus bound.

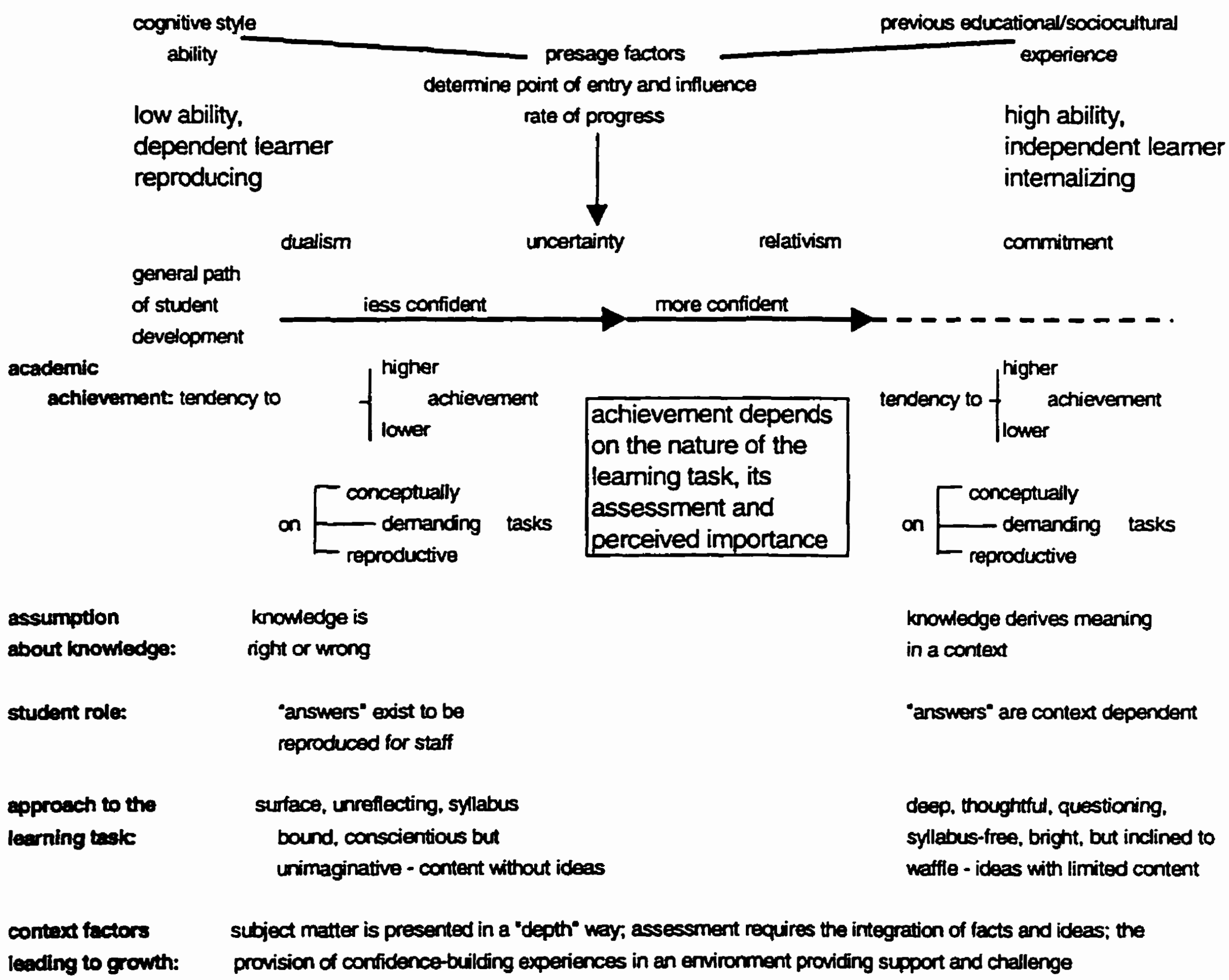


Fig. 3.6: A Developmental Model of Student Learning
Adopted from Wilson [80]

Relativistic conceptions define knowing as comprehending: learning is understanding the wider context in which ideas are located, and this implies a process of relating, questioning and making meaning. Such deep, thoughtful approaches are characteristics of students responsive to and alert for "cues" and of the syllabus free students. Relativistic thinkers implicitly have more control over their thinking process and have more flexible strategies.

Growth along the continuum depends partly on presage factors and partly on how students are processed in higher education. Therefore one can define different conditions under which intellectual and moral development will or will not occur. The model recognizes that context factors may lead to growth along the continuum: the role staff play, the structure of teaching and assessment, effective teach-back and counseling – all may help the student to grow in confidence as a learner. The learning environment must, as Perry argued, provide both support and challenge.

It is likely that students with tendencies towards comprehension learning, field independence and divergence even at entry reflect the more sophisticated, relativistic style of thinking about issues that higher education seeks to develop (particularly to the aim of promoting the general powers of the mind). Students with tendencies towards operation learning, field dependence and convergence are likely to have the greatest problems acquiring such styles of thinking and require most help in "learning how to learn."

A Different Scheme for Student Learning

Milton, Polio, and Eison, in their book, *Making Sense of College Grades*, introduce a totally different scheme to classify students attitude and perceptions toward their learning [85]. They argue that within any university class there are some students who are preoccupied with the pursuit of grades and other students who are genuinely committed to the process of learning. In fact, they believe that students could basically be classified as learning-oriented (LO) and grade-oriented (GO) as follows:

Learning-oriented (LO) students view the university classroom as a context in which they expect to encounter new information and ideas that will be both personally and professionally significant. Grade-oriented (GO) students view the college experience as a crucible in which they are tested and graded and which is endured as a necessary evil on the way to getting a degree or becoming certified in a profession.

Administration of the resulting scale to hundreds of university and college students resulted in the identification of four types of LO/GO student orientations, and psychological tests revealed important differences among the four student groups. For example. High LO/Low GO students employ the most effective study methods and impress instructors as emotionally able, willing and interested academically. Low LO/High GO students act in conventional ways, show the greatest respect for established ideas, and have poor study skills. Low LO/Low GO students are the most difficult to identify, their personal and educational patterns are less clear cut than those students in the other groups. High LO/High GO students attribute great importance to luck and fate as powerful influences in their lives.

Several implications for improving the quality of college learning flow from the differences between GO and LO students. Perhaps the most important implication is that faculty must examine the extent to which they contribute to the development of GO students. The course requirements of many of these grade givers may encourage grubbing for grades. Complicating matters is the fact that many faculty are derisive of GO students. Faculty who hold positions in graduate and professional schools are also grade users. An issue for that group is the extent to which admission requirements influence the development of grade-oriented undergraduates. Still other grade users are leaders in business and industry. They should ponder the question "How do our recruitment policies influence the development of GO students?"

GO and LO students differ not only in their educational and personal characteristics but also in the type of test they prefer to take and in what they pay attention to and do in the college or university classroom. Methods were developed to determine both what students did and what they were aware of during college lectures. Results for both procedures were coded into the categories of on- and off-target, and comparisons were made among the four different LO and GO groups. For both behavior and self-report, results indicated the low GO students were more often on-target than high GO student; specific differences in learning orientation were found to have no effect. High LO/High GO students are more calculating in their classroom behavior than is true for the other student groups.

Concerning the testing preferences, results revealed that while students in both groups chose multiple-choice tests, GO students chose such tests far more frequently than did LO students. An examination of test scores revealed that the highest scores on both types of tests were earned by students in the High LO/Low GO group while lowest scores were obtained by students in the High LO/High GO group. Put simply, students who are highly motivated by grades tend to be more concerned about what impression they create on their instructor than with learning the content of the lecture. A concern for grade, thus, does not translate directly into a concern for better learning; rather it translates into the student's attempt to appear concerned about learning. For those students the grade is more important than the learning supposedly symbolized by the grade.

Table 3.4 and 3.5 summarize some other important findings of the above studies as reported in the book by Milton and his colleagues [85]. Table 3.4 shows the general structure of the categories used to record classroom behavior and Table 3.5 lists the categories used to code self-report protocols.

Table 3.4: General Structure of Categories Used to Record Classroom Behavior
Based on Milton, et al. [85]

State categories:	
Attentive	Non-attentive
Event categories:	
On-Target	Off-Target
Note taking	Relaxing
Question (spontaneous)	Non-interpersonal behavior
Hand rising (spontaneous)	Watch checking

Table 3.5: Categories Used to Code Self-Report Protocols
Based on Milton, et al. [85]

Actively listening and absorbing
Relating material to other material or own life
Forming opinions, evaluations, ideas about materials
Taking notes and understanding
Participating in class discussion

3.3 Models of Learning Styles

Models of student learning styles are inevitably one of the corner stones in any study of the teaching/learning processes. Researchers and theorists have developed various models of learning styles to describe the different ways that students learn. The main focus of this research is on those learning style models that have been used effectively in engineering education. A good overview of different learning styles theories is given in articles by Felder and Silverman [86] and by Dunn and his colleagues [87].

The most important and popular models in the field of engineering education research are discussed in a chronological order of their development and in the following subsections:

3.3.1 The Myers-Briggs Type Indicator;
3.3.2 Kolb's Learning Style Model;
3.3.3 Felder-Silverman Learning Style Model; and
3.3.4 Herrmann Brain Dominance Instrument (HBDI).

Some ways that engineering educators have used the above learning style models to analyze and improve their students learning styles are discussed as well. However, many theorists and researchers agree that educators should try to reach all types of learners described in any one theory. Therefore, if one uses one of the above theories, then he or she should strive to meet the needs of all four styles. Moreover, the interested readers are referred to the comparative table of these models in Chapter 5.

3.3.1 The Myers-Briggs Type Indicator (MBTI)

The Myers-Briggs Type Indicator (MBTI), [88] is a self-report, forced-choice personality instrument well used in engineering education. This model classifies students according to their preferences on scales derived from psychologist Carl Jung's theory of psychological types. The model identifies basic individual preferences regarding perception and judgement, and expresses them on four separated bipolar scales. Students may be:

- Extraverts (E), try things out, focus on the outer world of people or Introverts (I), think things through, focus on the inner world of ideas;
- Sensors (S), are practical, detail-oriented, and focus on facts and procedures, or Intuitors (N), are imaginative, concept-oriented, and focus on meanings and possibilities;
- Thinkers (T), are skeptical and tend to make decisions based on logic and rules, or Feelers (F), are appreciative and tend to make decisions based on personal and humanistic considerations;
- Judgers (J), set and follow agendas and seek closure even with incomplete data, or Perceivers (P), adapt to changing circumstances, and resist closure to obtain more data.

The MBTI type preferences can be combined to form 16 different learning style types. However, each student uses all eight functions and attitudes, but usually favors four of them. These four preferences, the MBTI type, model an individual's consciousness and influence his or her attitudes and behaviors including learning styles and study habits. For example, one student may be an ESTP (extravert, sensor, thinker, and perceiver) and another may be an INFJ (introvert, intuitor, feeler, and judger).

Engineering professors usually orient their courses toward introverts (by presenting lectures and requiring individual assignments rather than emphasizing active class involvement and cooperative learning), intuitors (by focusing on engineering science rather than design and operations), thinkers (by stressing abstract analysis and neglecting interpersonal considerations), and judgers (by concentrating on following the syllabus and meeting assignment deadlines rather than on exploring ideas and solving problems creatively).

Applications of the Myers-Briggs Type Indicator

According to Felder, during the 1980s, thousands of engineering students and hundreds of engineering professors took the MBTI as part of a research study conducted by a consortium of eight engineering schools [89]. The study examined the effects of psychological type differences on the education and career development of engineering

For example, Yokomoto used the MBTI as a diagnostic tool for engineering students having academic difficulties [90]. He administered the instrument to them, gave them the results, described the characteristics of their type, and let them, as the ultimate judge of their behavior patterns, assess the accuracy of their descriptions. Working with an ISTJ (introvert, sensor, thinker, judger) student who was failing the introductory course in electrical circuits, Yokomoto speculated and confirmed that the student relied too heavily on memorization and drill (traits of ISTJs) as approaches to problem solving. Yokomoto persuaded his student to add strategies based more on a fundamental understanding of the concepts. The student's performance began to improve by his senior year he was earning A's. The student subsequently received a master's degree in electrical engineering.

Research shows that engineering students are uniformly represented on the sensing/intuition (S/N) scale of MBTI: about 50% S and 50%N. McCaulley [91] has suggested that S type students would benefit from step-by-step instruction containing practical examples and attention to detail, whereas N types would benefit from exposure first to theoretical principles followed by examples and applications.

A study by Rosati showed that mechanical engineering students read the book first for problems and examples, and only as a last resort read for theoretical textual explanations [92]. The S students read the topic more carefully for details and tried to pictured the problem, whereas N students tended to skim the material and were more concerned to hook the topic into the overall context of the subject.

3.3.2 Kolb's Learning Style Model

The Kolb learning theory has been used by a number of engineering educators to enhance the education of engineering students [93]. This model classifies students as having a preference for Concrete Experience or Abstract Conceptualization (how they take information in), and Active Experimentation or Reflective Observation (how they internalize information).

Kolb's four learning styles are based on the ways students perceive and process information. The vertical line in Fig. 3.7 represents how students perceive information, with one extreme being Concrete Experience and the other being Abstract

Conceptualization. Students each fall somewhere along that line between those two extremes. The horizontal line in Fig. 3.7 represents how students process information, with one extreme being Reflective Observation and the other being Active Experimentation. Superimposing these lines yield the four quadrants illustrating the learning style. Kolb calls these styles divergers, assimilators, convergers, and accommodators.

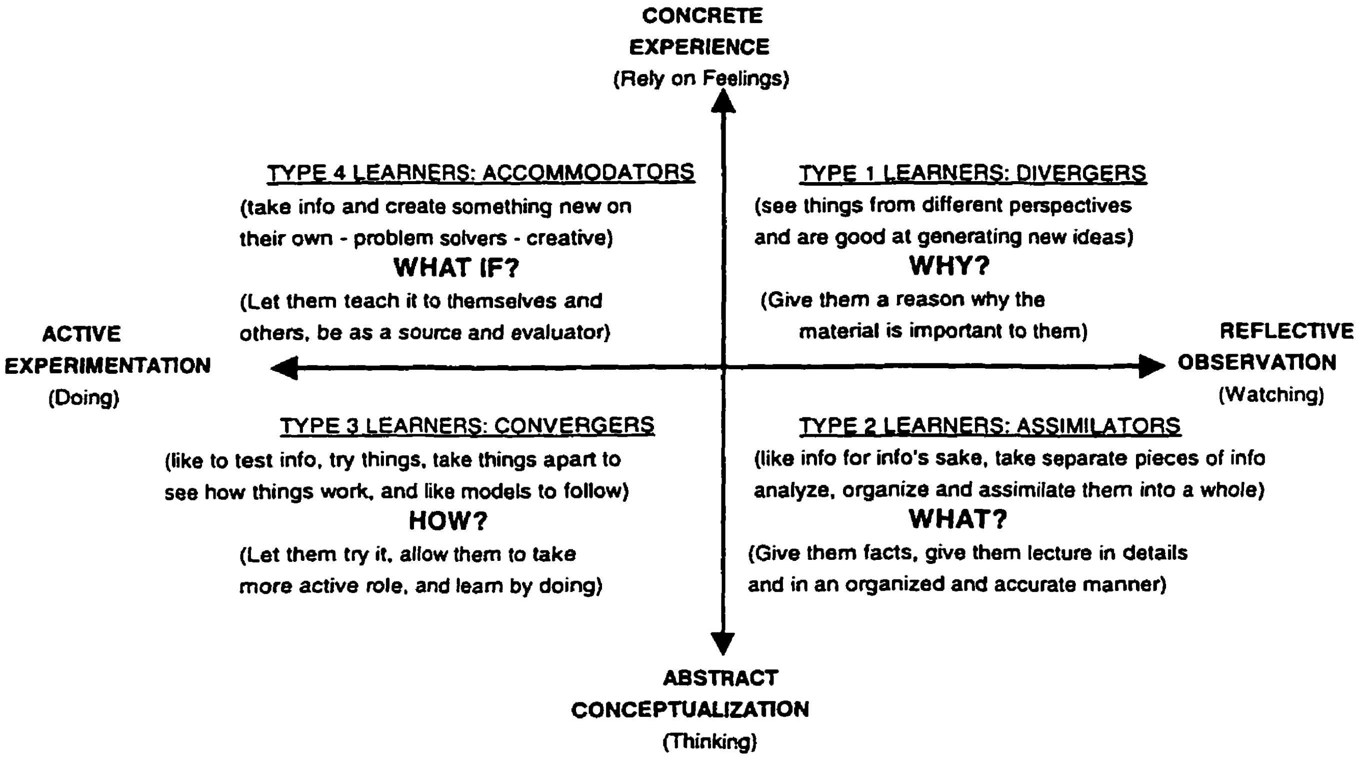


Fig. 3.7: Kolb's Learning Style Model
Adopted and Modified from Sharp, et al. [96]

In 1979 the educator McCarthy developed the 4MAT System, based on Kolb's experiential learning theory and research on split-brain learning [94]. McCarthy referred to the four learning styles as Type 1, Type 2, Type 3, and Type 4. She developed a framework for designing instruction that includes favorite questions for each learning style: Why? (Type 1), What? (Type 2), How? (Type 3), and What If? (Type 4) [95]. The questions and types match Kolb's terms in order respectively: divergers (Type 1), assimilators (Type 2), convergers (Type 3), and accommodators (Type 4). Fig. 3.7, in fact, shows Kolb's illustration to which McCarthy's types, corresponding questions to each learning style, and teacher's role has been added [96].

The Learning Cycle

Teaching the learning objectives in order creates what Kolb calls the "learning cycle," which is a pattern for learning new concepts [93]. The cycle begins in quadrant 1 (Fig. 3.7) with the question "Why?" and progresses clockwise to quadrant 2 (What?), quadrant 3 (How?), and then quadrant 4 (What If?). McCarthy believes that this progression forms a natural cycle of learning [94].

According to Kolb, and also McCarthy, following this cycle replicates the way people learn and thus increases learning. Kolb and McCarthy both advise teachers to begin with Type 1 activities (Why?) and progress sequentially to Type 2 activities (What?), Type 3 activities (How?), and then Type 4 activities (What If?). Progression through the learning cycle in clockwise order stretches students to move into non-preferred learning modes, thus promoting individual growth. This means that an individual's learning style is matched part of the time, but students are stretched also by using other styles not as comfortable for them. Sharp [96] points out that although an orderly progression seems helpful, using various activities from each learning style preference is beneficial to all learners (whether the activities are in sequential order or not).

In general, four types of learners in this classification scheme and the instructor's role for each type of student could be summarized as follows:

Type 1 (Concrete, Reflective): A characteristic question of this learning type is "Why?" Type 1 learners respond well to explanations of how course material relates to their experience, their interests, and their future careers. To be effective with Type 1 students, the instructor should function as a motivator.

Type 2 (Abstract, Reflective): A characteristic question of this learning type is "What?" Type 2 learners respond to information presented in an organized, logical fashion and benefit if they have time for reflection. To be effective, the instructor should function as an expert.

Type 3 (Abstract, Active): A characteristic question of this learning type is "How?" Type 3 learners respond to having opportunities to work actively on well-defined tasks and to learn by trial-and-error in an environment that allows them to fail safely. To be effective, the instructor should function as a coach, providing guided practice and feedback.

Type 4 (Concrete, Active): A characteristic question of this learning type is "What if?" Type 4 learners like applying course material in new situations to solve real problems. To be effective, the instructor should stay out of the way, maximizing opportunities for the students to discover things for themselves.

Felder [89] indicates that traditional engineering instruction focuses almost exclusively on formal presentation of material (lecturing), a style which is comfortable for only Type 2 learners. He suggests that to reach all types of learners, a professor should explain the relevance of each new topic (Type 1), present the basic information and methods associated with the topic (Type 2), provide opportunities for practice in the methods (Type 3), and encourage exploration of applications (Type 4).

Applications of the Kolb Model

Sharp has administered the Kolb Learning Style Inventory to her technical communication classes and senior chemical engineering laboratory course for the past six years [97]. She has found that teaching students about their learning styles help them learn the course material because they become aware of their thinking processes. More importantly, she believes, it helps them develop interpersonal skills that are critical to success in any professional career

In 1989 the College of Engineering and Technology at Brigham Young University initiated a faculty-training program based on Kolb learning styles. About one-third of the engineering faculty members, all volunteers, were trained in the concepts of the Kolb model and methods of teaching to each Kolb type. The volunteers implemented the approach in their courses, reviewed videotapes of their teaching, and discussed their successes and problems in focus groups. The benefits of the program were significant. Many faculty members redesigned their courses by using a variety of teaching methods such as group problem solving, brainstorming activities, design projects, and writing exercises in addition to formal lecturing [98].

3.3.3 Felder-Silverman Learning Style Model

The Felder-Silverman Learning Style Model was jointly developed by Felder and Silverman in the mid-eighties [86]. This model classifies students as:

- Sensing learners (concrete, practical, oriented toward facts and procedures) or Intuitive learners (conceptual, innovative, oriented toward theories and meanings)
- Visual learners (prefer visual representations of presented material--pictures, diagrams,

flow charts) or Verbal learners (prefer written and spoken explanations)
- Inductive learners (prefer presentations that proceed from the specific to the general) or Deductive learners (prefer presentations that go from the general to the specific)
- Active learners (learn by trying things out, working with others) or Reflective learners (learn by thinking things through, working alone)
- Sequential learners (linear, orderly, learn in small incremental steps) or Global learners (holistic, systems thinkers, learn in large leaps)

Felder [89] believes that for the past few decades, most engineering instruction has been heavily biased toward intuitive, verbal, deductive, reflective, and sequential learners. However, relatively few engineering students fall into all five of these categories. Therefore, according to his opinion, most engineering students receive an education that is mismatched to their learning styles. This apparently could hurt their performance and their attitudes toward their courses and toward engineering as a curriculum and career. He proposes the eight following strategies to the engineering educators to resolve such problems:

1. Teach theoretical material by first presenting phenomena and problems that relate to the theory (sensing, inductive, global). For example, don't jump directly into free-body diagrams and force balances on the first day of a statics course. First describe problems associated with the design of buildings, bridges, and artificial limbs, and perhaps give the students some of those problems and see how far they can go before they get all the tools for solving them.
2. In every course, balance conceptual information (intuitive) with concrete information (sensing). For example, when covering concepts of vapor-liquid equilibrium, explain Raoult's and Henry's Law calculations and non-ideal solution behavior, but also explain how these concepts relate to barometric pressure and the manufacture of carbonated beverages. Make extensive use of sketches, plots, schematics, computer graphics, and physical demonstrations (visual) in addition to oral and written explanations and derivations (verbal) in lectures and readings.
3. To illustrate an abstract concept or problem-solving algorithm, use at least one numerical example (sensing) to supplement the usual algebraic example (intuitive).
4. Use physical analogies and demonstrations to illustrate the magnitudes of calculated quantities (sensing, global). For example, tell your students to think of 100 microns as the thickness of a sheet of paper and to think of mole as a very large dozen molecules.
5. Occasionally give some experimental observations before presenting the general principle, and have the students (preferably working in groups) see how far they can get toward inferring the latter (inductive). For example, rather than giving the students Ohm's or Kirchoff's law up front and asking them to solve for an unknown, give them experimental voltage/current/resistance data for several circuits and let them try to figure out the laws for themselves.
6. Provide the class time for students to think about the material being presented (reflective) and for active student participation (active). Occasionally pause during a

lecture to allow time for thinking and formulating questions. Assign brief group problem-solving exercises in class that require students to work in groups of three or four.

7. Encourage or mandate cooperation on homework (every style category). Hundreds of research studies show that students who participate in cooperative learning experiences tend to earn better grades, display more enthusiasm for their chosen field, and improve their chances for graduation in that field relative to their counterparts in more traditional competitive class settings.

8. Demonstrate the logical flow of individual course topics (sequential), but also point out connections between the current material and other relevant material in the same course, in other courses in the same discipline, on other disciplines, and in everyday experience (global).

Applications of the Felder-Silverman Model

Felder has used the Felder-Silverman model in teaching five sequential chemical engineering courses in a way that would appeal to a range of learning styles. The results of his survey show a considerable improvement in the learning outcomes of his students [89].

Woods and Tindal, both educators in mechanical engineering at the University of London (UK), have used the Felder-Silverman model in teaching a course with particular reference to thermo-fluids [99]. They have used a simple analytical approach in teaching a confusing issue in their course, estimating the effect of compression ratio and spark ignition timing on power output. The results of their study show that the confusion between thermodynamic heat engines and internal combustion engines is considerably reduced when different types of learning and teaching styles are considered.

Felder and Soloman have recently developed an Index of Learning Styles (ILS) that classifies students on four of the five Felder-Silverman dimensions (all but inductive/deductive). The ILS is in a beta version, and some professors are already testing it with their students [100].

Rosati, a civil engineering professor at the University of Western Ontario, has used the ILS to assess the learning styles of engineering faculty members and first-year and fourth-year engineering students at his university [101]. Rosati found that faculty members were significantly more reflective, intuitive, and sequential than the students. The results suggest that professors could improve engineering instruction by increasing the use of methods oriented toward active learners (participatory activities, team projects), sensing learners (guided practice, real-world applications of fundamental material), and global learners (providing the big picture, showing connections to related material in other courses and to the students' experience).

3.3.4 Herrmann Brain Dominance Instrument (HBDI)

The Herrmann Brain Dominance Instrument (HBDI) was developed by Herrmann in the late eighties [102]. This method classifies students in terms of their relative preferences for thinking in four different modes based on the task-specialized functioning of the physical brain. The four modes or quadrants in this classification scheme are as follows:

- Quadrant A (left brain, cerebral): Logical, analytical, quantitative, factual, and critical
- Quadrant B (left brain, limbic): Sequential, organized, planned, detailed, and structured
- Quadrant C (right brain, limbic): Emotional, interpersonal, sensory, and symbolic
- Quadrant D (right brain, cerebral): Visual, holistic, and innovative

According to Lumsdaine and Lumsdaine [103]:

Engineering professors on the average are strongly Quadrant A dominant and would like their students to be that way as well. Most engineering instruction consequently focuses on left-brain Quadrant A analysis and Quadrant B methods and procedures associated with that analysis, neglecting important skills associated with quadrant C (teamwork, communications) and quadrant D (creative problem solving, systems thinking, synthesis, and design). This imbalance is a disservice to all students, but particularly to the 20-40% of entering engineering students with strong preferences for C and D quadrant thinking.

Applications of the Herrmann Brain Dominance Instrument

Lumsdaine and Voitle studied the HBDI types of the college's students and faculty members in the early nineties [89]. They found that many engineering students and professors were left-brain thinkers - logical, analytical, verbal, and sequential. Their data also indicated a strong attrition rate among right-brain thinkers, with many of them dropping out despite earning top grades in analytical courses. Based on their research, Lumsdaine and Voitle later claimed that a dominant reason for their choosing other majors is the inhospitable learning climate in engineering, which does not accommodate their thinking preferences, even though voices in industry are increasingly demanding engineers with precisely those thinking skills.

They reviewed their existing mechanical engineering curriculum, found it skewed toward left-brained thinking skills, and set out to provide a better balance by introducing more creativity, design, innovation, and teamwork into selected courses. One course, "Introduction to Computing," originally consisted of 20 percent quadrant A activities (structured programming) and 80 percent quadrant B activities ("following the rules" in canned, routine programs). The redesigned version involved approximately 20 percent each for quadrants A and B and 30 percent each for quadrants C and D (student experiments, question formulation, design, modeling, and optimization). Students worked in teams formed by the professors to provide balance in HBDI types. Student performance levels and attitudes to the course improved considerably because of these changes [103].

3.4 Summary

The material presented in this chapter leads this research to three main ideas about different types of learners and the learning process itself:

- The idea of different levels of information processing is well established in the psychological, educational, and engineering psychology literature on human memory and information processing. Despite many approaches to the information processing, models of human memory are still based on a sequential information processing that consists of three distinct types of memory (sensory, short-term and long-term memory).
- Five general approaches were studied for the typical developmental theories or models of student change in the university environment. Each of these models has their own advantages and disadvantages, while all focus on the same issue, namely the nature and processes of student change.
- A family of other models, that more often are used in the field of engineering education, and their main emphasis are on distinctive, but relatively *stable*, differences among learners are reviewed. These models categorize students into groups based on the characteristic differences in the ways they perceive the learning tasks and their environment. The models focus on learning styles (Kolb and Felder-Silverman), personality (Myers-Briggs and Felder), or thinking preferences (Herrmann). The models have several characteristics in common:

= The styles or preferences that characterize learners of a given type and differentiate them from learners of another type are believed to be relatively stable (although not unchanging) over time.

= A learner may demonstrate characteristics indicative of other types within model, but that learner tends to think or learn in ways consistent with the distinctive characteristics or performances of the dominant type.

= Type categories used in the models may describe areas of tendencies or preferences that learners have in common.

= These models generally do not explain the process of change or development in students and if change is treated at all, it is not central to the model.

Chapter 4
Towards Building the Model

This research uses the system dynamics approach for building a model of the teaching/learning process. System dynamics means exactly what its name implies. It is concerned with creating models or representations of real world systems and studying their dynamics or behavior. In particular, it is concerned with controlling and improving problematic system behavior. The main purpose in applying system dynamics is to facilitate understanding of the relationship between the behavior of a system over time and its underlying structure and strategies/policies/decision rules.

In line with employing the system dynamics approach for the purpose of this study, this chapter starts with an introductory look at this methodology. Then in a closer look, the following six steps that are involved in the system dynamics approach are discussed:

- Defining the system of interest (e.g., a teaching/learning system)
- Constructing the model
- Simulating the model
- Designing alternative policies for the model
- Trying proposed policy changes
- Implementing changes in the structure of the system or system re-engineering

To start with the first step, a teaching/learning system should be clearly defined and described in its main components. Applying the first step of the system dynamics to this study is the most difficult and challenging part of the research. The diversity of opinions, theories, viewpoints and ideas about the nature and characteristics of the teaching/learning system add up to the complexity of this matter. In other words, this inevitably requires a thorough analysis of the various aspects of the teaching/learning processes that were reviewed in the literature search in the two previous chapters.

The effort to define and map the teaching/learning system on an acceptable engineering standard, covers almost the whole of this chapter and part of the next chapter.

The analysis of the countless views about the teaching/learning processes would result in a solid classification of these viewpoints. Subsequently, a synthesis of the similarities within these ideas by a systematical approach, leads to the recognition of the two main building blocks in a student learning system, that is; the *ability to learn* and the *desire to learn*. This, in return, sets the stage for working out the details of each of these two building blocks. Two separate models will be proposed by this study for this reason. The first proposed model is a schematic representation of the mind of a learner that depicts how a student takes in, processes, and retrieves each piece of information. The second proposed model, similarly, represents the details of the student motivation.

Finally, at the end of this chapter, these two models will be combined in a single diagram. The result is an illustration of a preliminary unified theory that describes explicitly a typical teaching/learning process.

4.1 System Dynamics: A Short Review

4.1.1 An Introductory Look at the Method

There have been numerous definitions for system dynamics. A definition that indicates the broad use of this approach is stated as follows [114]:

System dynamics is a rigorous method for qualitative description, exploration and analysis of complex systems in terms of their processes, information, organizational boundaries and strategies that facilitates quantitative simulation modeling and analysis for the design of system structure and control.

The dynamics or behavior, of systems can be studied at many differing degrees of mathematical sophistication. The methodology used in this research is centered on the ideas of Forrester who created a subject area originally known as industrial dynamics, but now referred to as system dynamics [115]. This creation was in response to the recognition that many problem-solving methods, particularly those linked to Operation Research/ Management Science, were not delivering their promise of providing insight and understanding into strategic problems in complex systems [116].

The method is aimed at providing a distinctive set of easily usable tools which might be used by a system analyst centered on a very generic set of building blocks which are universally applicable. The procedure is to observe and to identify problematic behavior of a system over time and to create a valid diagrammatic representation, or model, of the system, capable of reproducing, by computer simulation, the existing system behavior, and of facilitating the design of improved system behavior. For example, this might involve changing behavior from oscillations to stability or from poor performance to improved performance.

During the early years of development of the method, applications were largely industrial [115]. Later the subject broadened and a number of global and other large-scale studies emerged [117]. During the late 1970s and 1980s, the scale of individual studies has been reduced, but the scope of application of the method has become extremely wide, covering most traditional academic disciplines of study, but with a strong emphasis on socio-economic areas [118, 119]. The subject now has its international society and journal (the *System Dynamics Review*) and links between system dynamics and other fields are rapidly being forged.

In addition to the broadening of applications of the traditional method, a broadening of the method itself has emerged in recent years. In particular, there has been a move away from an obligatory use of quantified simulation models towards an increasing recognition of the relevance of the diagramming phase of the subject [120, 121].

The holistic approach of system dynamics also has much in common with other cross disciplinary methods of industrial engineering and management, such as Business Policy and Total Quality Management [114]. Two characteristics of system dynamics arising from its holistic view are worth mentioning here. The first is its ability to generate structures that can be transferred to create insights in other systems. The second is its ability to help in identifying the counter-intuitive behavior of systems. Often the implementation of new policies in systems results in unintentional side effects and system dynamics provides a means of helping to determine what these might be.

4.1.2 A Closer Look at the Method

Fig. 4.1 illustrates the system dynamics steps from problem description to the improvement. Step one starts with the description or mapping of the system [6]. It is the most important and the least straightforward of the stages in system analysis. In this step, the model of a real system should be described. A model is a theory of behavior. A model represents the way in which some part of the real system works. It requires taking various bits of information about the system in the real world and turning them into a unified theory.

Step 2 begins the formulation and construction of a simulation model. The system description is translated and converted into the level and rate equations of a system dynamics model by providing the requisite parameters. As with every step, active

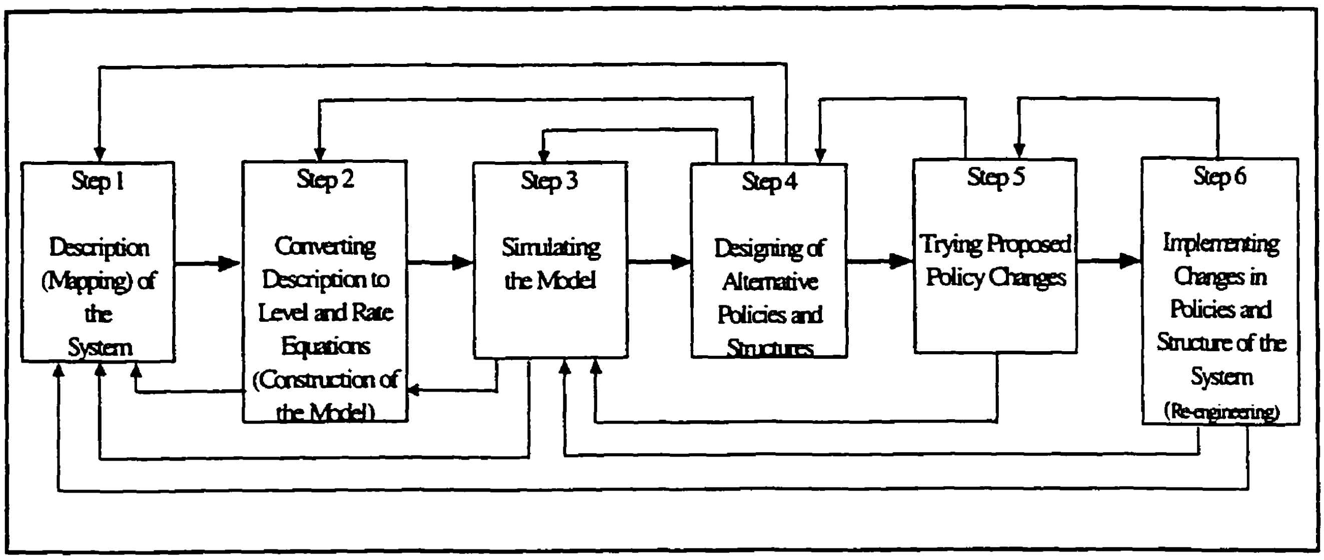


Fig. 4.1: Steps of System Dynamics Approach
Adopted and Modified from Forrester [6]

recycling occurs back to prior steps. In this step, writing equations reveals gaps and inconsistencies that must be remedied in the prior description.

Step 3, simulation of the model, will start after the equations of step 2 pass the logical criteria of an operable model, such as all variables being defined, none being defined more than once, and consistent units of measures. System dynamics software packages provide such logical checks. Simulation may at first show unrealistic behavior. As a result, simulation leads back to the problem description and to refinement of the equations. Step 3 should conform to an important element of good system dynamics practice. That is, the simulation should show how the difficulty under consideration is being generated in the real system. Unlike methodologies that focus only on an ideal future condition for a system, system dynamics should reveal the way one arrived at the present and then, in a later step, the path that leads to improvement. The first simulations, base runs, at step 3 will raise questions that cause repeated returns to steps 1 and 2 until the model becomes adequate for the purpose under consideration. The point at this stage is that "adequacy" does not mean proof of "validity." There is no way to prove validity of a theory that purports to represent behavior in the real world. For instance, there is no proofs for any of the laws of physics, only practical confidence that the laws are useful within a bounded region [115]. One can achieve only a degree of confidence in a model that is a compromise between adequacy and the time and cost of further improvement. The proper basis of comparison lies between the simulation model and the model that would otherwise be used. That competitive model is almost always the mental model in the heads of the people operating in the real system. A system dynamics model creates so much more clarity and unity, compared to prior mental models, that the "adequacy" decision usually generates little controversy among real-world operators who are under time and budget pressures to achieve improved performance.

Step 4 identifies policy alternatives for testing. Simulation tests determine which policies show the greatest promise. The alternatives may come from intuitive insights generated during the first three stages, from experience of the analyst(s), from proposals by experts in the field, or by an exhaustive automatic testing of parameter changes. However, in more complex systems, there will be many competing criteria for defining success. Also, there will be many peaks in the multidimensional behavior map so that the most favorable performance may depend on several simultaneous changes in the model. In addition, the best alternative behaviors will often come from changing the system structure.

Step 5 works toward a consensus for implementation. In this step, proposed policy changes will be tried to the model to maintain or obtain sustainable improvement in performance while considering the feasibility of implementing these changes in its real world. Questions will arise that require repeated recycling through steps 1-5.

Finally, step 6 implements the changes in policies and structure of the system. Difficulties at step 6 may arise mostly from deficiencies in one of the prior steps. If the model is relevant and persuasive, and if what has been done in step 5 has been sufficient, then step 6 can progress smoothly. Evaluation of the policy changes comes after implementation. Even with no evaluation at hand, the minimum benefit of system dynamics is the understanding of what is happening in the system.

4.2 Defining a Teaching/Learning System

The different aspects of teaching and learning processes with specific focus on the issue of student learning have been reviewed in Chapter 2 and Chapter 3. In this section, the intent is to define, describe, and map a system for a teaching/learning process. This endeavor will be made in line with the first step of the system dynamics approach. To define a solid system for a teaching/learning process and to specify the components and the boundaries of the system, an effort has to be made to classify all of these aspects in the first place. The intent is to consider all of the different views on teaching/learning and categorize them so that a detail analysis could be performed. Then, by recognizing and integrating the most significant components, the stage will be ready for developing a unified theory.

4.2.1 Classification of the Viewpoints

Fuhrmann and Grasha [105] have classified the different approaches of effective teaching as those based on personal viewpoints, quantitative approaches, and learning theories. This study believes that the same classification can be applied to the various approaches to teaching and learning processes. That is, in general, the different views on teaching/learning can be divided as those based on (1) personal viewpoints, (2) quantitative approaches, and (3) learning theories. A short description of each class is followed.

(1) Personal Viewpoints represent those ideas that experts in the field of education and anyone else with an opinion have about teaching and learning issues. The literature search performed by this study, indicates that there are as many perspectives as there are people trying to define them. Such perspectives range from concerns about

student learning to lists of ideal traits that teachers and students must possess. The most striking ideas in this group, as discussed in Chapter 2, are the Taxonomy of Educational Objectives developed by Bloom [42] and the studies made at Gothenburg University in Sweden by Marton [30], Saljo [31], Svensson [32] and others on qualitative differences in learning.

This approach provides a rich and broad set of perspectives on the nature of teaching/learning processes. The disadvantage of this approach is the variety of ideas with no consensus that lead people to defend their point of view rather than accept alternative views.

(2) The *quantitative approach* employs statistical methods for ranking the teachers and students. This approach assesses the extent to which teachers and students possess various characteristics that demonstrate the level of their effective teaching and learning respectively. In this view, students receive typical scores that rate them as below average, average, or above average on particular attributes.

The most noticeable studies in this group are those carried out by prominent educators, mentioned in Chapter 2, like Feldman [17, 106, and 107], Kulik [26 & 108], Marsh [21], Cashin [17 & 109] and others. This approach appears to be objective, although such appearances are deceptive. Underlying the numbers, are many different points of view about the important characteristics that teachers or students should possess. The disadvantage of this approach is that fixating on the measured characteristics prevents recognizing that learning situations differ. The advantage of having so-called objective data on learning from this approach is offset by these problems.

(3) *Learning Theories* often suggest classroom procedures and teacher behaviors that facilitate students' learning along certain lines. As mentioned in Chapter 2, these theories are classified as *behaviorist, humanistic, and cognitive views* on learning. To analyze these theories, their main points are stated below:

The behaviorist view of learning sees student learning behaviors under the control of different stimuli in their environments. It emphasizes that effective teaching/learning is demonstrated when the teacher can define the course objectives and classroom procedures (e.g., pacing, reinforcement), specify student behaviors needed to learn such objectives, and demonstrate that students have achieved the objectives afterward.

The humanistic view suggests that learning is something that students must do for themselves. The teacher should be able to demonstrate such personal qualities that facilitate students' learning. In this view, effective teaching/learning is demonstrated when students acquire the content that is relevant to their goals and needs, understand the thoughts and feeling of others better, and are able to recognize their feelings about the content.

The cognitive view, on the other hand, sees the learner at the center stage. Learners are not simply passive recipients of information; they actively construct their own understanding. The teacher becomes a facilitator of learning, rather than one who delivers information. From a cognitive view, teachers should use classroom procedures that are compatible with their students' cognitive characteristics. They have to organize and present information so that it promotes their students' problem solving and productive thinking [41].

4.2.2 A Short Analysis

Among all the ideas and theories classified in the previous section, cognitive theory adopts a much more comprehensive and realistic role for both students and teachers. This theory alerts learners to that what they think they absorb, read, see, or learn from practice may not be what the teacher intends. Their understanding of all these things is strongly influenced by a number of variables such as:

- their prior knowledge
- their interpretation of what is important
- the frequency with which they test themselves
- their understanding
- their perspectives on how all these relates to future use
- other variables

This theory also emphasizes, whether learners realize it or not, and whether they like it or not, that what they learn depends on the following three dimensions:

- *who* they are (their personal traits, learning abilities, motivation and values)
- *where* they have been (their prior knowledge and skill, their environment)
- *what* they do (the amount of time and effort that they intend to put into the task)

Hence, in the cognitive view, effective learners should be aware of how their own biases and behaviors *filter* the information they receive. On the other hand, for the instructor's role, the first implication of shifting to a cognitive perspective is that neither the teacher nor the content is at the center of the learning universe. Instructors become facilitators of learning [41]. What they say is not necessarily what students receive, unless they are very deliberate about how it is presented. Their job becomes one of minimizing the noise in the transmission, so that all the learners interpret their statements as close to what is meant, and store information in their memory so that they can retrieve it in the future.

As was pointed out in Chapter 2 (section 3), the weakest point of the above approaches, and especially of theories of learning, is their inability to agree on an acceptable typology for teaching/learning. None of these viewpoints offer a taxonomy that make sense in modeling of a teaching and learning process. The only taxonomy with some promise seems to be Bloom's Taxonomy [42] that divides learning skills and intellectual abilities into six major levels of acquisition of knowledge (memorizing); comprehension (understanding); application; analysis; synthesis; and evaluation. (Refer to Fig. 2.1) Bloom sees "memorizing" as the most common learning ability and as a basic requirement (in acquiring any typical learning task) for student's progress to the higher level – "understanding" [42]. On the contrary, the studies by Marton and his colleagues [30, 31, & 32] on learners' qualitative differences do not consider such hierarchical order in levels of abilities. According to their studies, students are either surface learners or deep learners. Surface learners intend to "memorize" things with no attempt to think about their purposes and so, they are permanent residents of the first level of Bloom's Taxonomy. Deep learners, on the other hand, intend to "understand" things by looking for clues to the organization and their purposes and so, they jump directly to the second level of Bloom's Taxonomy!.

Granting the behaviorists, humanists, cognitivists and others, their theoretical and methodological differences, this research will be faced with a fundamental question as follows:

What can this research borrow and reconcile for defining and building a solid model for a teaching and learning process?

The answer is almost clear:

In theory, there are insights and viewpoints that are useful, and in empirical research findings, there are some working generalizations that are worth applying.

Considering the research findings, each approach to the teaching/learning processes has a tremendous amount of empirical data to back it up. Disadvantages include the fact that in practice very few teaching/learning processes completely fit any one approach. Another disadvantage is the biases of educational researchers regarding their personal acceptance of the theories. This is a problem when an educator or a researcher who does not use these approaches in his or her teaching practice is in a position to judge or evaluate the performance of others who are practicing these theories.

4.2.3 Distillation of the Ideas

Despite the aforementioned problems, fortunately, the approaches to learning theories have at least one issue in common. As discussed in Chapter 2, they assume that there are common ideal characteristics for effective teachers and learners. In fact, they provide lists of particular skills and abilities of a prototype of a good teacher and a good learner. Interestingly, this is the information that is required to start this research.

Table 4.1 is an effort to summarize and demonstrate all of the common ideal characteristics that have been assumed by learning theories and have been reported in the literature [104]. The learner and teacher's traits have been summarized in terms of their attitudes, skills, and resources. Asterisks have been used in the table to indicate the level of both learners and teachers control over a factor. A single asterisk indicates a limited level of learner and teacher control over a factor. Two asterisks indicate a potentially significant level of learner and teacher control over a factor. No asterisk indicates an insignificant potential influence of the learner and teacher. The attempt is to list the factors and roles in order of their importance to teaching and learning.

On the other hand, all viewpoints, implicitly or explicitly, imply that both the objectives and the outcomes of a teaching/learning process can be distilled into the following three major, dominant dimensions:

- Knowledge or conceptual learning
- Competence or skills learning
- Values or attitudes and beliefs.

Table 4.1: Summary of the Learner and Teacher's Traits
Based on Flammer [104]

The Learner	The Teacher
ATTITUDES * Educational and life goals/values/priorities **Perception of relevance **Interest in the subject * Anxiety, self-confidence	** Knowledge of subject matter ** Knowledge of teaching and learning theory ** Knowledge of instructional development theory, interactive learning, evaluation, etc.
SKILLS **Learning **Study	** Teaching skills ** Personality characteristics
RESOURCES * Achievement motivation * Intellectual maturity * Independence, responsibility * Work and study habit * Self-image * Background preparation – knowledge and skills Intelligence Aptitude Learning style	** Attitudes and expectations a) ** Commitment to teaching b) ** Commitment to students and to learning ** Advising skills ** Values, motives, and goals

Although there might be many variations to the above assumption, nevertheless, various characteristics suggested by both behaviorists [43] and cognitivists [41] could be boiled down in similar classifications. It would seem reasonable that neither conceptual learning nor skills learning is strictly behavioral or cognitive in form and substance. However, no serious harm is done if this research proposes the following:

- Conceptual learning could be assumed as primarily cognitive;
- Skills learning could be assumed as mostly behavioral;
- Values could be assumed mainly as humanistic.

Moreover, mastery of a learning task could be a useful way of identifying the outcomes of both conceptual learning and skills learning. Of course, mastery in skills learning will be easier to specify because it would be more observable. However, the focus in this research will be mainly on the other two dimensions, that is; conceptual learning and values.

In brief, although there are many differences in the way that different approaches view a teaching/learning process, there are also many similarities. The attempt to synthesize cognitive, behaviorist and humanistic concepts into a three-dimensional approach for a teaching/learning process is just an example effort to blend these approaches into a single perspective. Although, there are occasions when the similarities should be underscored and the differences should be highlighted.

Another effort in this study was focused on reaching a common definition for the rate or degree of learning. Some theoretical generalizations that could be acknowledged as general principles of student learning were blended. Among the most visible were the following:

- Degree of learning depends on the learning capacities or academic ability of the learners. Learning capacity is part of the characteristic differences of learners. It could be defined as their aptitude, their perseverance, time they need to master the learning task and their ability to acquire a meaningful insight.
- Degree of learning is related to the degree and quality of the learner's motivation. Degree and quality of learner motivation is part of the characteristic differences of the learners. It includes the learner's personal attitudes, needs, goals, and interests. It also includes all of the external motivational factors.
- Degree of learning is a function of the learner's expectation for success or failure (learner's level of aspiration and the learner experiences with success or failure).
- Degree of learning is related to the quality and style of teaching (conditions of practice, guidance, mode of presentation, feedback, and other teaching dimensions).
- Degree of learning is a function of the nature and organization of the subject matter. Learning materials and tasks are more easily mastered when they are organized and have logically related parts or components. Also degree of learning could be reinforced on the similarities of learning tasks.

- Degree of learning is a function of the teaching conditions imposed on the learner. Teaching conditions could include those environmental factors that are merely related to instruction medium or situational or environmental variables that may be either direct or indirect in their influence on learning outcomes. For instance, conditions affecting teaching/learning processes include those as simple as class size and those as complex as the various forms of reinforcement.

Moreover, as stated in 2.2, the literature search revealed that with respect to aspects related to teaching/learning processes, there seems to be a consensus on some general items:

- Teaching and learning are dual and complementary processes.
- The process of learning essentially includes cognitive, behavioral, and experimental dimensions or components.
- In any attempt to define or to model a teaching/learning system, the greater focus should be on the "learning side" rather than on the "teaching side."
- A learning process could be represented by a system of students who are interacting with the teaching method and subject matter variables.
- Some student learning results from conceptual learning and some from other forms of organized experience or skill learning.

4.3 Mapping of a Teaching/Learning System

The analysis of the different ideas on a teaching/learning process in the previous section, dictates the next step that might be taken. That is, the work toward developing a graphical model for a teaching/learning process could be started by focusing on the "student side" of the process. Fortunately, the main building blocks in the student learning side already have been identified. Referring to the student's traits mentioned in Table 4.1, these building blocks could be translated as student "abilities to learn" and "desire to learn." In other words, the interaction of these two building blocks is the necessary condition for occurrence of a learning process (Fig. 4.2). While it is noted that the sufficient condition will be the interaction of these blocks with the other sides of a teaching/learning process – "teaching" and "subject matter." With this conclusion, the research enters into a new stage, namely examining the following two relevant models:

- The model of a learner's mind for investigating what is it that is *learned.*
- The model of student's motivation for realizing the student's intrinsic and extrinsic values and motives to learn.

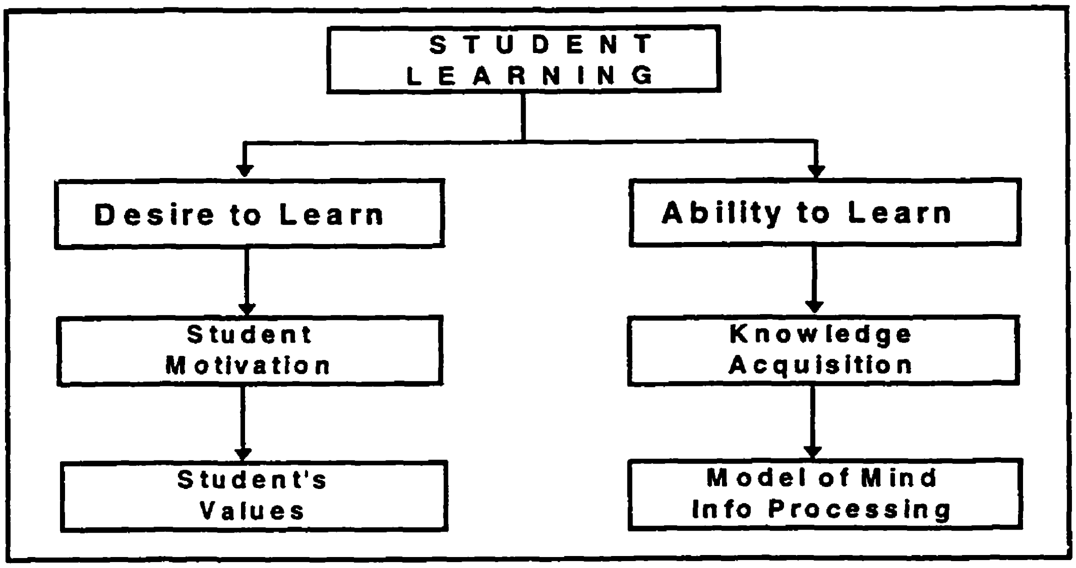


Fig. 4.2: A Simple Mechanism for a Model of Student Learning

4.3.1 The Model of Mind

What goes on in the mind of the learner? How is knowledge acquired, maintained, and retrieved? How can one understand the representation of knowledge within the human mind? These are the first questions that are expected to be answered by examining and reviewing the model of mind [110]. Fortunately, the idea of different levels of information processing has been well established in the literature on human memory and information processing. To understand the processes that learners use to take in and process information, this study employs a traditional model of human memory. As was discussed in Chapter 3 (section 3.1), the traditional mechanistic, three box models are based on different levels of processing. These models of human memory have generally described three major components namely, sensory receptor, short-term memory (STM), and long-term memory (LTM).

In reality, the human memory is best described as a continuum, ranging from short-term memory (STM) to long-term memory (LTM). As one moves along the memory continuum, he or she holds on to the new information for longer and longer periods and finds it easier to remember and use. In moving along the continuum, for instance, one can remember information about where his or her classes meet each semester. Much farther along the continuum is the important information that he or she wants to remember for a very long time, such as major principles in his or her field.

As was discussed in Chapter 3, the sensory receptors act as the input devices for all information that passes through the STM and LTM memory. The STM is where one actively processes information and constructs knowledge before it can be stored in LTM. LTM is the storage house of the memory system and has infinite capacity. LTM is divided into two storing places for information as episodic and semantic. Episodic memory stores episodes of information or episodes of experience. Information can be held in store for longer periods by internal repetition, and, if repeated sufficiently often, it will become a permanent memory trace. Semantic memory, on the other hand, stores the kind of information that has already been reassessed and categorized in STM, and relates concepts and generates new ideas. As was mentioned in Chapter 2, Marton [30] in his striking findings has used these processes to define what would normally be called "surface level processing" (rote memorization) and "deep level processing" (meaningful learning) respectively. Understanding depends on a deep level of processing and elaboration while reproducing more likely involves repetition at a shallow level of processing with little use of elaboration.

A type of knowledge that is crucial in retrieving information from the LTM is prior knowledge. The term *prior knowledge* refers to the knowledge that learners bring to a particular learning task. To be useful for information processing, knowledge must be organized and integrated in a meaningful way. Recalling and using what they already know about a subject area can help learners' minds add meaning to what they are trying to learn, as well as help them store related topics together. Relating new information to prior knowledge not only aids immediate learning but also helps move things from the foreground to LTM storage, so that it can be used in the future [113].

Fig. 4.3 is an effort by this research to combine the aforementioned concepts. It demonstrates how units of information enter the mind of a learner, pass through different stages, and can be treated (processed) in different ways and at different levels.

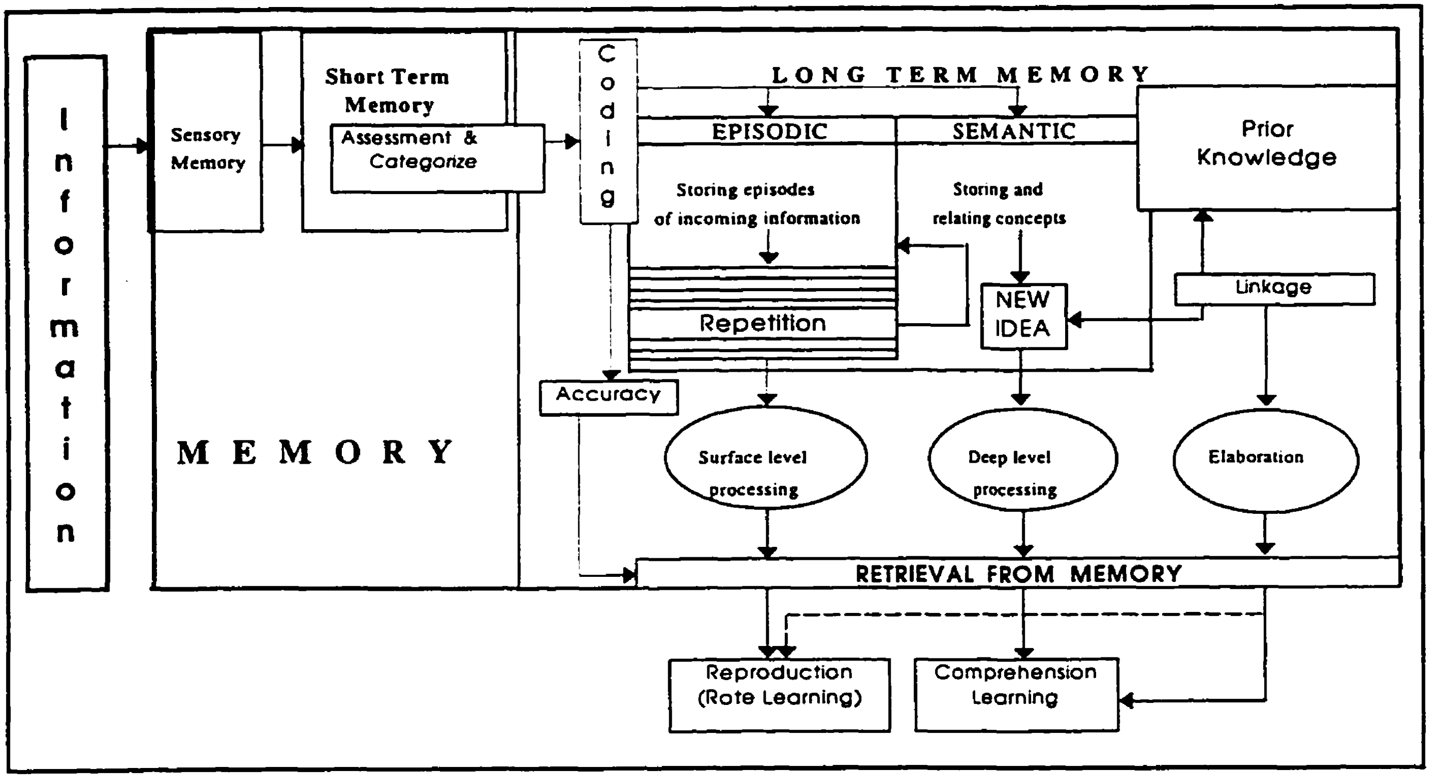


Fig. 4.3: The Model of Mind

4.3.2 Models of Student Motivation

As noted in chapter 3, there are many models of motivation that may be relevant to student learning. They basically vary from behavioral to humanistic, to models based on various classes of thought in cognitive theory. This work takes a collective approach and looks at motivation in a way that gives answers to a fundamental question: "What do different theories of motivation offer to a teaching-learning system to enhance the process of student learning?" In other words, the main concern is why some students are more involved in class, better prepared for discussions, ask more questions, and, in general, simply try harder than other students with equal or better ability. Before trying to answer these questions by developing a model, some assumptions, based on the literature review, need to be clarified.

First, students can be motivated to greater involvement and higher achievement. Theoretical perspectives have been translated into applied research to show that appropriate instructional behaviors and course structures will enhance students' motivation.

Second, motivation concerns three fundamental questions:

- What originates or initiates a student activity?
- What causes a student to move toward a goal?
- What causes a student to persist in striving toward a goal?

Theories of motivation have been concerned with one or all three questions. As Weiner suggests (Chapter 3), early research in motivation emphasized the first question, seeking to identify physiological influences such as instincts, appetite, and chemical control that seem far from college classrooms [53 & 60].

Third, motivational theories tend to emphasize factors within individuals or factors in the environment. Factors within individuals are traits that students bring to the classroom, such as fear of failure and its accompanying anxiety or the strong need to achieve high grades and get into graduate school. Other theories are concerned with environmental factors, such as the manner in which lectures are given, the competitiveness of the grading system, or the rapport the teacher establishes with the students [52].

Fourth, while questions concerning motivation are simple, the answers are complex, involving a multitude of factors in both the students and the environment. Consequently, no one theory or perspective can be applied to every situation. Each one is insufficient by itself, and thus many theories must be considered simultaneously, in order to take action that will increase the students' involvement in learning. The model of student motivation that will be developed by this study is a heuristic one that helps organize these theories.

Fifth, most theories of classroom motivation focus on needs or congnitions of students. Needs are deficiencies within students that can be influenced significantly from external sources. Cognitive theories, which maintain that thoughts and mental processes are crucial in determining motivation, currently dominate the motivational literature.

Apart from the above discussion and as described in Chapter 2 and 3, a very important part of the studies of student learning carried out in Gothenburg University [30, 31, & 32] was the demonstration of connections between students' approaches and the context of learning. Marton has stressed that the approach to learning should be seen as a characteristic of the student, but also as a response to a situation. According to his empirical findings, the natural approach to learning seems to be a deep one [111]. The most crucial variable in the student's approach to learning is the student's perception of what he is required to do. The effects of contrasting perceptions can be seen at more than one level [112]. For example, at the level of the learning task itself, perceived interest and relevance undoubtedly increase intrinsic motivation and make a deep approach more likely to occur. Learning tasks which are perceived as requiring only reproduction, or on which the student is mainly extrinsically motivated, increase the probability of a surface approach. Based on the same studies, the student's interest in the subject matter is a crucial component of a deep approach, especially in arts and social science subjects, while prior knowledge was most often mentioned in relation to science tasks [78].

The second level at which the effects of learning context operate is that of individual teachers. The attitudes and enthusiasm of the teacher, his or her concern for helping students to understand, and particularly his or her ability to understand the difficulties experienced by students in dealing with a new topic, are all likely to affect students' approaches and attitudes to studying. The final level at which perceptions affect student learning is related to the ways that departments treat them. Among them, the most crucial influences on approaches to learning concern the forms of assessment. Unfortunately the most apparent effects are negative - students are pushed towards surface approaches by forms of assessment which seem to invite and reward, reproductive answers [113].

4.3.3 A Proposed Model of Student Motivation

This study has developed a model to organize the most important influences of one's personal motivations on learning. The proposed model is based on the premises that students' motivation is heavily influenced by their thinking about what they perceive as important and what they believe they can accomplish. This model of motivation suggests that two sets of factors – values (that represent the student's perception of the task value) and the external reinforcements (that represent the impact of external motivational factors on these values) – are primary influences of motivation (Fig. 4.4).

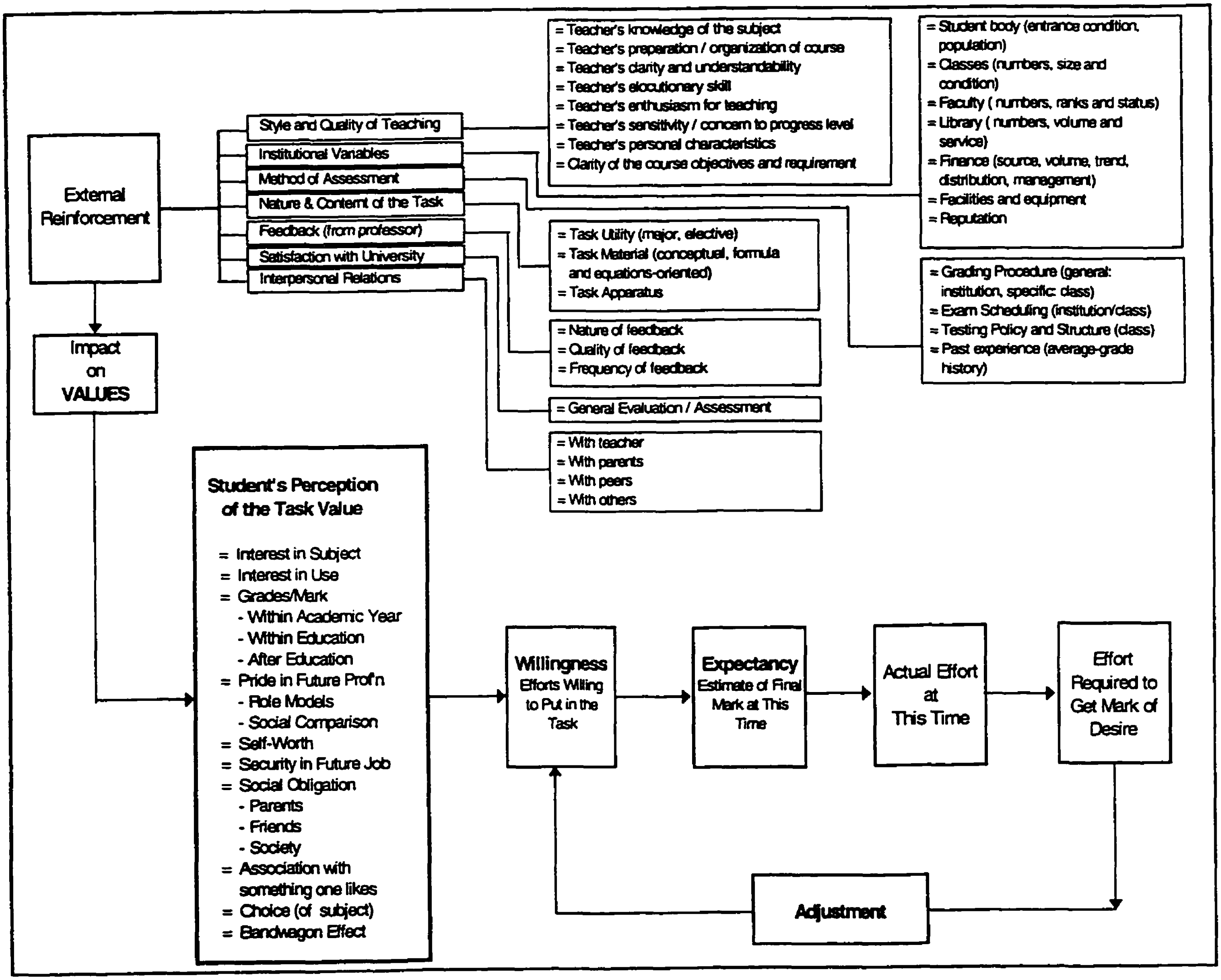


Fig. 4.4: A Proposed Model for Student Motivation

The student's task value comprises a wide range of sub-values with each sub-value having its own weight on the student's attitude and willingness toward the learning task. Sub-values like interest in the subject (matter), interest in (future) use, and interest in grades/marks are the most known values of this kind in the literature. The other main sub-values also have been classified based on the personal judgement and considered according to their significance. For instance, the amount of "pride in future profession" is another value which a student sees in the learning task. This sub-value might originate either from the student's general feeling about the life of a role model or from a social comparison that he or she makes. Self-worth, security in future job, social obligation toward parents, friends, and society, choice of subject matter; whether it is a major or elective course, bandwagon effect, and association of the learning task with something which the student likes are the other internal perceived (sub-)values.

A similar effort has been made for identifying the external reinforcement factors that have their own impact on the student's learning task values. They have been classified in seven categories, each with its own corresponding sub-categories. These external factors vary from parameters such as characteristics of the teaching system and the nature and quality of the subject matter, to interpersonal relations. The impact of environmental factors such as satisfaction with the institution or the attitude of others toward the student have been considered as well.

Therefore, the model proposed by this work (Fig. 4.4), first tries to recognize the student's primary values and then, identifies the external factors that promote student learning behavior. The interaction between these two categories of parameters, and their sub-categories, determine the amount of effort that each student puts into his or her learning task at any given time. It should be noted that the subsequent progression of the motivation, that is; the effort students are willing to put into the task, results in the student's "expectancy." In fact, this stage connects the input side of the process to its output side which is the students' quantifiable outcomes (marks or grades of desire) at any time.

Unfortunately, the research review indicates that not much research has integrated the various theories of motivation that suggest determinants of task values. It can be concluded, however, that students are likely to be motivated if they see value in what they are learning, if they receive positive reinforcement from the teaching system and their environment regarding the learning task, and if they believe that they are able to succeed with reasonable effort. When all three of these factors are high, motivation will also be high. If students see little value in what they are learning or in the results of their effort, their motivation will be lessened, even if they believe that they are capable of success.

4.4 Towards A Unified Theory

In line with the first step of the system dynamics methodology, the teaching/learning system must be described and a hypothesis (unified theory) must be generated. Fortunately, the stage is now ready to move towards describing the whole system. The proposed unified theory in this study, could be built based on the notion that if students believe that they are able to succeed with reasonable effort (ability to learn) and if they see value in the learning task (motivation to learn), then a typical learning process will take place. These two building blocks namely *ability to learn* and level and *desire (motivation) to learn*, undoubtedly play an important part in student performance. The relationship between these variables and student success in a subject is not necessarily direct or linear. However, it is to the interactions and clustering of the elements of these building blocks that this research must look if wants to understand how students tackle particular learning tasks.

On the other hand, the prior analysis in the literature review and the information resulting from Fig. 4.3 and Fig. 4.4, have given this study a momentum to claim that creating a preliminary model for teaching-learning processes, at this stage, is feasible. In fact, this model could be built by combining models of the student's "abilities" and the student's "motivation." Fig. 4.5 comes from Fig. 4.3 and Fig. 4.4 and demonstrates how these two major sets of components can be combined and simply interact with each other.

The diagram consists of four main blocks. At the top-left is the block for external reinforcement factors. This block includes seven basic external reinforcement factors including different types of teaching systems, instructional materials and other parameters. The block for student's values is the next on the bottom left. This block is directly under the influence of the previous block and includes ten proposed sub-values as mentioned earlier. The block for the amount of effort that the student puts into the task is the subsequent block located in the center of the diagram. This block leads to the final

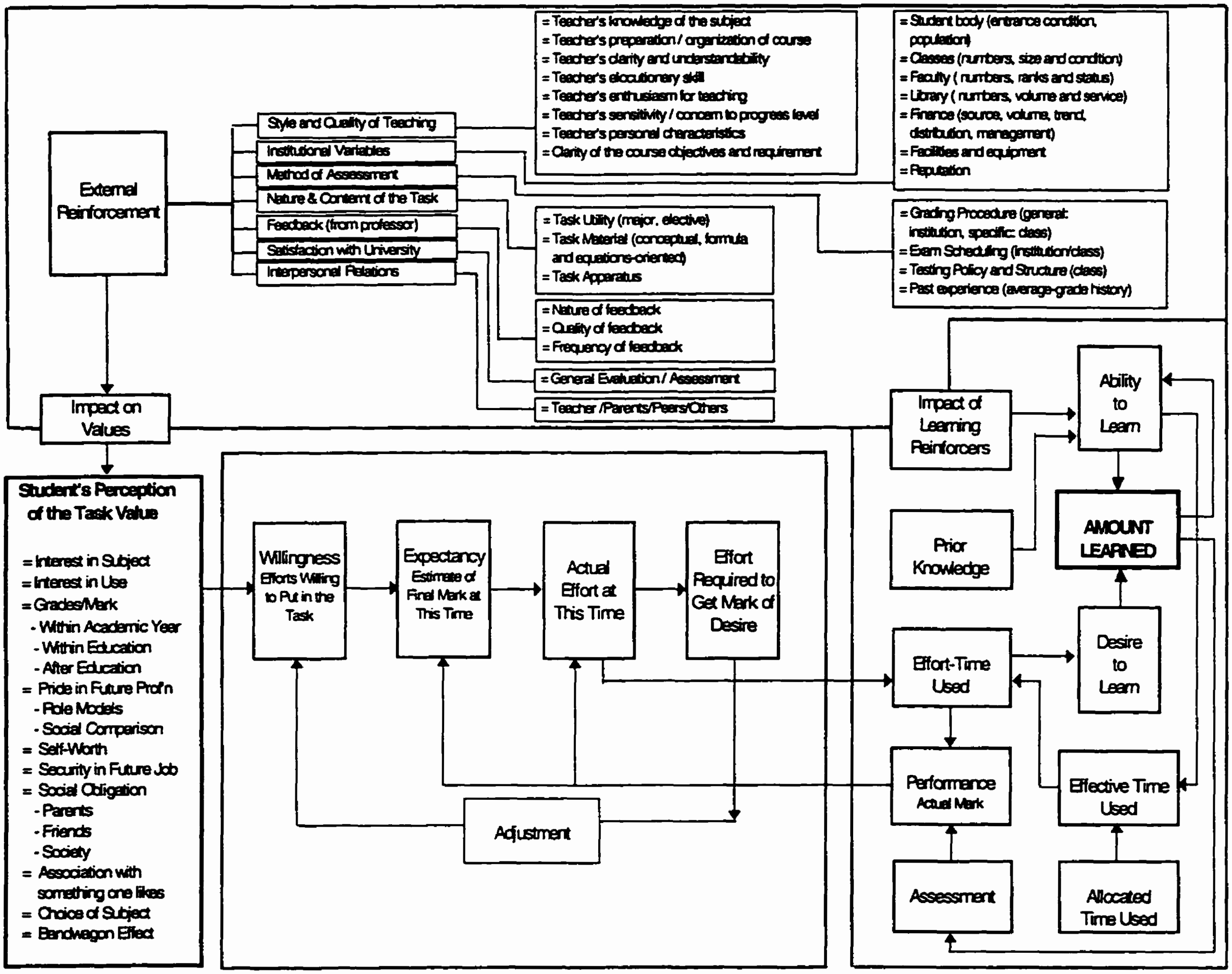


Fig. 4.5: A Proposed Mapping for a Teaching/Learning Process

block for the student's outcome (amount learned by the student). The last block is the product resulted from the combination of student's learning abilities and desire. The stock of "abilities to learn," at any time, is influenced by the level of "prior knowledge" and amount of "learning reinforcers" ("impact of learning reinforcers"). It should be noted that the adjustment feedback could return from "amount learned" at any time.

"Impact of learning reinforcers" represents the effect of the "external reinforcement" factors on the learning abilities of a student. The notion is to show how the external motivational factors may directly reinforce the process of knowledge acquisition as well as the "availability" of the acquired knowledge (output of the process). The impact of these factors are defined and detailed in accordance with the available statistical results from the studies in the literature.

The box of "abilities to learn" simply represents that part of the system that deals with what happens in the mind of a typical student during an information processing operation. This part will be expanded later in Chapter 5 in a way that gives a better idea about different elements that are involved in the operation.

Different types of learners can be assumed but the focus will be mainly on two extreme types of students: Learners who intend to memorize and learners who intend to meaningfully understand. Again, this part demands more work and will be dealt with sufficiently in the next chapter.

The diagram itself is kind of a preliminary influence diagram. The impact of any "external reinforcement" factors on any of the student's values has a subsequent effect on the amount of effort that a student puts into the learning task. This, consequently, influences the level of the desire to learn. In the mean time, the level of "prior knowledge" from one side, and the "impact of learning reinforcers" from the other side build up the existing level of the student's abilities to learn and availability of the acquired knowledge respectively.

Finally, the levels of both a student's learning abilities and a student's values determine the "amount learned" by the student. Apparently it is a cause and effect mechanism that drives the teaching-learning process. Many feedback loops exist in the system, which have not been shown in the diagram for the sake of simplicity. Also, the impact of each external reinforcement factors on different student's values should have been studied in both their local and global senses. This issue can be better examined in later steps when the mapping of the components and their interconnecting flows will be done with the help of the STELLA simulation software.

Chapter 5

On Minds of Learners: A Soft OR/ Systems Thinking Approach

Before an attempt is made to construct a level and rate model for the teaching/learning process (in line with step 2 of the system dynamics method), three crucial questions should be answered:

(1) What are the types of minds that learners possess?

(2) What are the types of incoming information (from the information-issuing source) to the minds of learners?

(3) How is each type of information accommodated by each type of mind?

To answer the above questions, this chapter, first, introduces the method of investigation (soft OR and systems thinking). Second, it compares the three overlapping terms of "learning style," "learning ability," and "learning strategy," and through an analysis, selects the "learning style" as the main basis for this investigation. Third, the four major models of learning styles that have been already introduced in Chapter 3 are re-examined and two of them are chosen for this purpose. The result of the analysis gives a new momentum to the study as it ultimately supports this view that within the context of different learners, two distinct types of mind can be recognized. The core of the endeavor is based on the following steps:

- Defining two distinctive types of learners as Type I and Type II learners by boiling down all those aspects in the literature survey that are related to the learners' approaches to learning.
- Developing a matrix to match the characteristics of the proposed Type I and Type II learners with the characteristics of the similar types of learners as deduced from the four striking approaches in the literature, e.g., Myers-Briggs Type Indicators, Kolb's learning cycle, Marton's surface and deep learning approach, and Bloom's Taxonomy.

- Judging the practical soundness of the proposed two types of learners based on the researcher's own personal experience.
- Defining Type I learners as form-oriented learners and Type II learners as function-oriented learners
- Defining two types of mind: form minds and function minds
- Conceptualizing and introducing a new theory: *Form-Function Theory of Types*
- Validating the proposed theory

Also, in a separate lengthy endeavor, this research attempts to recognize the different types of information and how each type of information is treated with each type of mind. A number of example short lectures in chemistry, arithmetic, and industrial engineering are used for this purpose. Each short lecture is divided into very simple, but meaningful and inter-related, pieces of information. Learners with different types of minds are assumed to be presented with different types of incoming information. Each example case examines the way that each learner deals with each type of information. This adventure, in return, results in recognizing eight types of information and identifying seven types of learning abilities for each type of learner.

A short lecture in the Introduction to industrial engineering course is worked out as an example case in this chapter. The learning objective of this short lecture is to introduce the issue of "productivity." The short lecture is divided into different stages, each of which includes a piece of information. The original knowledge of a form or a function learner as it is arranged in their minds, is defined. The lecture is presented, and the way they tackle different types of information in the lecture is described. Lastly, their final knowledge, as it is arranged in their minds will be demonstrated. Contrasting the original knowledge and the final knowledge as it is arranged in the form and function minds leads this research to a new idea about the pattern of knowledge in different minds.

5.1 Soft OR and Systems Thinking

Soft operations research (soft OR) has evolved during the last several years as a reaction against the inability of classical or "hard" operations research to deal with soft variables in social and non-physical systems. Practitioners of soft OR attribute ineffectiveness of hard OR to various causes [126]. They feel that fundamental difference between physical (quantitative) and non-physical (qualitative) systems prevent rigorous analysis. That is, the multiple criteria for desirable behavior, prevent specifying objective measures of system performance.

Moreover, some soft OR experts believe that the ineffectiveness of hard OR arose from two aspects of operations research practice. First, hard OR drifted into the adoption of inappropriate mathematical methods (linear planning, queuing theory, regression analysis, scheduling algorithms, and Monte Carlo simulation). These mathematical procedures are all essentially static and linear in character and are not able to capture the dynamic nature of important processes in the real world. Second, hard OR became an academic discipline rather than a practical profession. In its academic setting, hard OR drifted toward continued refinement of the very theories that kept it from engaging the real world [6].

Having given up the mathematical modeling part of hard OR, soft OR concentrates on defining the situation, resolving conflicting viewpoints, and coming to a consensus about future action [127]. As such, soft OR fundamentally could be imagined as a very helpful counterpart in any modeling process effort using the system dynamics method. In fact, one can see a close relation between system dynamics, soft OR and systems thinking. (See 1.4 for systems thinking). Systems thinking and soft OR fit, along with the conceptualization phase of system dynamic, into step 1 of Fig. 4.1. Actually, step 1 of Fig. 4.1 can be expanded as shown in Fig. 5.1.

Step 1 of Fig. 4.1 (Steps of System Dynamics Approach)

Description (Mapping) of the Teaching/Learning System

(1) Investigation / evaluation of case studies (research findings from literature review)

→ (2) Soft operations research

→ (3) Systems thinking

→ (4) System dynamics

→ (5) Conceptualization phase

Fig. 5.1: The modified Step 1 of System Dynamics Method
Created from Forrester [6]

The first three points in Fig. 5.1 (investigation, soft OR, and systems thinking) all tend to be soft approaches. The soft procedures, although they employ various organizational and presentation techniques, still depend on discussion and intuition. By definition, the soft methodologies operate without a rigorous quantitative foundation. The soft OR literature does not reveal the counterpart of steps 2 and 3 in Fig. 4.1. There is no explicit language as at step 2 for revealing incompleteness and contradictions in the description of step 1. There is no generally accepted simulation process for testing the dynamic assertions.

In other words, the conceptualization phase of system dynamics has much in common with the soft methodologies, but system dynamics is disciplined by an organizing framework that leads to model formulation and simulation. However, system dynamics shares all the steps within soft OR practice, and in addition inserts steps 2 and 3, which gives an explicit and rigorous foundation that dispels much of the weakness inherent in soft OR.

5.2 The Way Students Learn

The primary intention in this section is twofold. First, to make a distinction between three overlapping terms that are used frequently in the literature, namely learning abilities, learning styles, and learning strategies. Second, it is also important to contrast a number of learning styles that will provide this study with a solid ground for reaching a new perspective about the types of mind.

5.2.1 A Closer Look at Learning Strategies and learning Styles

According to the literature search, the distinction between learning abilities, learning styles and learning strategies are difficult to specify [14, 38, 122, 123]. As discussed in Chapter 2 and 3, most experts in the field emphasize that learning styles are generalized and unconsciously acquired by the learner while learning abilities and strategies are deliberately acquired and adopted respectively. However, this research, like many experts, places "style" somewhere midway between "ability" and "strategy." (Fig. 5.2)

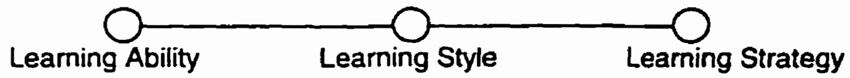


Fig 5.2: Learning Style: The position

More or less, it seems that learning strategies and learning abilities are the operations of "organizing" and "processing" of information respectively while learning styles are the consistent and stable manners in which learners do so. The extent to which abilities and strategies are a function of style is, nevertheless, a matter of investigation. Anyway, it seems that learning styles are more relevant to learners' perceptions of learning and their personality rather than what they do for the learning itself [45].

As discussed in Chapter 2.2, some experts view learning abilities (skills) and learning styles in terms of the conditions under which learning occurs, the content of what is learned, and the dominant mode by which students learn. They see learning strategies as a variety of techniques that help learners to analyze the learning task and understand the task better. Some researchers believe that if students know their learning styles, and if appropriate strategies are being taught to them, it will reinforce their learning abilities and facilitate their learning process. Efforts to measure or assess learning styles and learning strategies have been made by many researchers. Unfortunately for those educators who would use these techniques in their teaching, the technical advantage of such information is limited. The reliability of many of these scales is still in question. This is because of their brevity and the fact that they are yet far away from the point of being validated empirically [38].

However, the literature survey indicates that there are many learning strategies but their effectiveness is an open question. McKeachie and his colleagues have adopted a rather general framework for all kinds of available strategies in the literature. They have grouped strategies into three broad categories: cognitive, metacognitive, and resource management [45]. The cognitive category includes strategies related to the students' learning or encoding of material as well as strategies to facilitate retrieval of information. The metacognitive strategies involve strategies related to planning, regulating, monitoring, and modifying cognitive processes. The resource management strategies concern the students' strategies to control their resources (i.e., time, effort, outside support) that influence the quality and quantity of their involvement in the learning task.

When considering McKeachie's grouping, it seems that those strategies that involve resource management are more effective for use in a model of a teaching/learning process. In fact, items such as time, effort, and outside support are auxiliary variables that could be easily quantified or measured and used in the model. Moreover, since learning strategies are matters of deliberate adoption by learners, this research prefers to exclude them from the "basic" model of the teaching/learning process. That is, these variables might be viewed as strategy or policy rules that would be employed to improve the basic process. Learning styles, on the contrary, are part of the learners' personalities, and hence, should be included in the basic process.

5.2.2 Learning Styles: A Detailed Analysis

Learning styles have been defined in the literature in a number of ways, but basically refer to the preferred way an individual learns, processes information, and solves problems. Learning styles do not measure ability or intelligence, but the way an individual perceives situations, understands, processes, and learns information [123, 124]. Researchers and theorists have developed various models to describe the different ways that students learn. Accordingly, there are teaching and learning implications for each of the learning styles.

The four most popular models of learning styles that have been used effectively in engineering education research were described in Chapter 3. In this section, a detailed analysis of these models is made for the purpose of achieving a possible global definition for the different types of learners.

The Myers-Briggs Type Indicator (MBTI)

As mentioned in Chapter 3, the Myers-Briggs Type Indicator (MBTI), shows the different ways learners prefer to receive information (perception functions) and reach conclusions or make decisions (judgement functions). Within each of these functional areas are two preferences. In receiving information (perception function), one may prefer Sensing (S), or using the five senses, or alternatively, one may prefer Intuition (N), involving insight and unconscious associations. In reaching conclusion (judgement functions), a learner may prefer either Thinking (T), or Feeling (F), as a basis for choosing or making decisions.

An important point in MBTI is that type is presumed to be "dynamic" rather than "static." A learner may use four functions at different times. Each learner, however, has a preference for using one or the other perception function and one or the other judgment function. The favorite function is called *dominant* and is either a perception process, or a judgment process. The dominant function is the unifying process in one's life.

Also as pointed out in Chapter 3, the MBTI includes two additional dimensions, called attitudes or orientations [68]. These attitudes reflect which function is dominant and which auxiliary, as well as where they are used. The first attitude, Extraversion (E) or Introversion (I), describes the learner's focus of attention and source of energy toward the environment. This attitude could be whether outward, toward people, objects, and actions or inward, toward ideas and concepts. The second attitude, Judgment (J) or Perception (P), reflects the learner's preferences for interacting with the environment. A Judgement orientation is toward organizing, planning, and control of one's world, while a Perception orientation is toward openness, flexibility, and spontaneous reactions to events. Knowledge of a learner's preferences within each of the two functions (perception and judgement), as well as his or her preferences on the two-attitudinal dimensions, permits classification of that learner into one of sixteen types. These types have been largely used for research purposes or in the design of academic programs [68].

Research based on application of the Myers-Briggs Type Indicator (MBTI) has indicated that engineering students (and engineering professors) are usually INTJ (Introverts/Intuitors/Thinkers/Judgers) oriented [101]. That is their style orientation is a combination of the following preferences:

- focus on the inner world of ideas
- focus on meaning and possibilities
- tend to make decisions based on logic
- seek closure even with incomplete data

Worth mentioning is that according to the findings of the same studies, the ISTJ oriented learners (Introverts/Sensors/Thinkers/Judgers) rely too heavily on memorization.

The Kolb's Learning Style Model

The core of the Kolb's model is a simple description of the learning cycle – of how experience is translated into concepts, which, in turn, are used as guides in the choice of new experiences. This model classifies students as having a preference for how they take information in (the way students perceive information) or how they internalize information (the way they process information).

As mentioned in Chapter 3, teaching the learning objectives in order creates what Kolb calls the "learning cycle," which is a pattern for learning new concepts. The cycle begins with the question "Why?"(divergers) and progresses to "What?"(assimilators), "How?"(convergers), and then "What If?"(accommodators). Kolb believes that this progression forms a natural cycle of learning [94] (Fig.5.3).

On the other hand, according to Kolb's model, learning involves a cycle of four processes, each of which must be present for learning to occur most completely. The cycle begins with the learner's personal involvement in a specific experience. The learner reflects on this experience from many viewpoints, seeking to find its meaning. Out of this reflection the learner draws logical conclusions (abstract conceptualization) and may add to his or her own conclusions the theoretical constructs of others. These conclusions and constructs guide decisions and actions (active experimentation) that lead to new concrete experience.

Research based on the application of this method on testing of undergraduate engineering students at several universities in the United States (University of Texas, Oregon State, Brigham Young, Vanderbilt) have shown that there are about [89]:

- 10% Why-oriented learners,
- 40% What-oriented learners,
- 30% How-oriented learners, and
- 20% What If-oriented learners

in engineering student population. This means that about three-fourth of engineering students prefer What and How-oriented learning styles.

Fig. 5.3 is an effort by this research to demonstrates the Kolb's four different learning orientations that were discussed above. Note that this diagram is a different version of Fig. 3.7 and includes complementary information. It seems that Thinkers (middle bottom) and Doers (left end) from one side, and Feelers (middle top) and Watchers (right end) from the other side, have some similarities in their learning approaches to the different learning tasks.

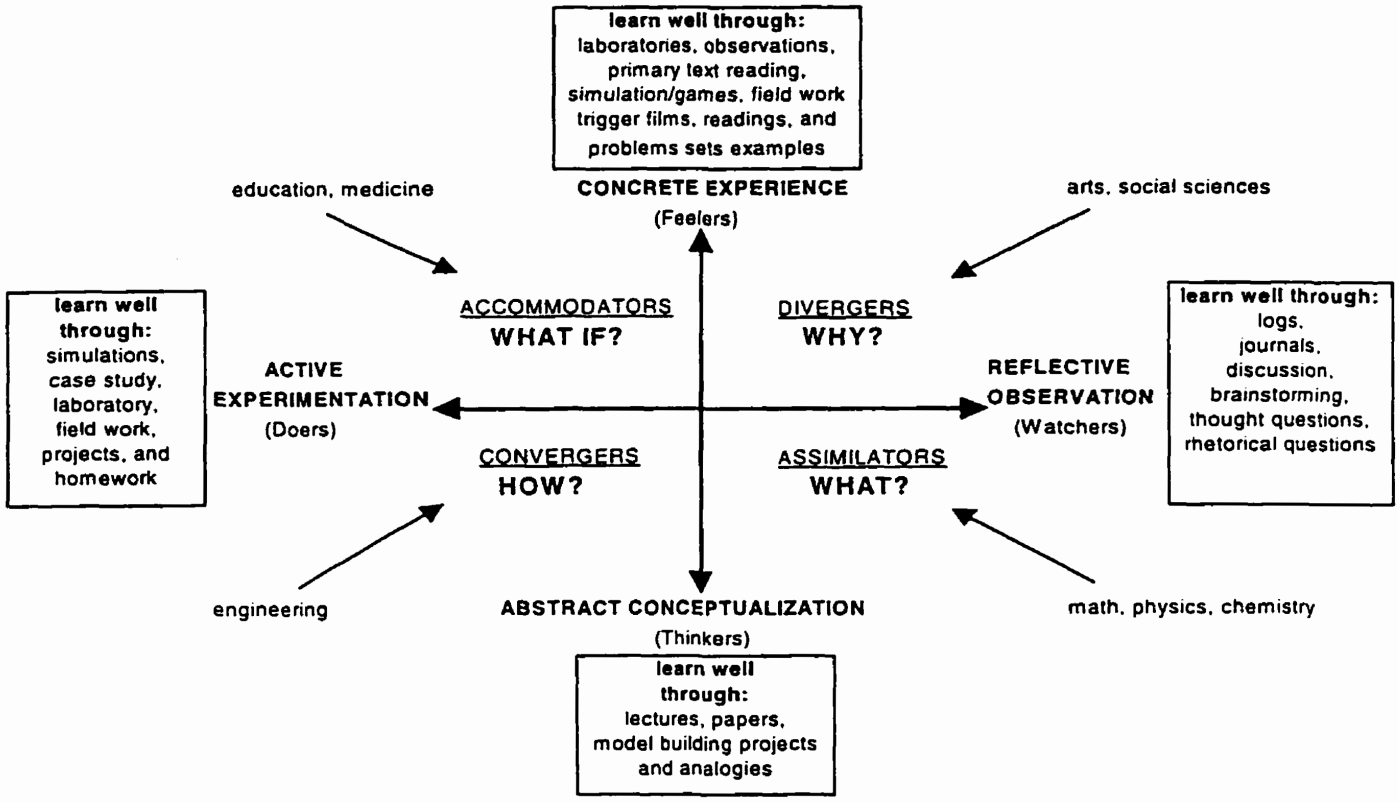


Fig. 5.3: Kolb's Learning Cycle
Adopted and Modified from McCarthy [94] and Sharp, et al. [96]

Felder-Silverman Learning Style Model

As described in Chapter 3, this model divides learners into those who are

- sensors (practical) or intuitive (conceptual) learners,
- visual or verbal (or written) learners,
- inductive or deductive learners,
- active or reflective learners, and
- sequential or global learners.

Research based on the application of this model has suggested that, most engineering teaching has been heavily biased toward intuitive, verbal, deductive, reflective, and sequential learners [89]. That is, the teaching style that has been used matched well with a combination of the following learning orientations respectively:

- conceptual, innovative, oriented toward theories and meanings
- written and spoken explanation
- presentations that go from the general to the specific
- learn by thinking things through, working alone
- linear, orderly, learn in small incremental steps

However, relatively few engineering students fall into all five of these categories. Thus according to the same studies, most engineering students receive an education that is mismatched to their learning styles.

Herrmann Brain Dominance Instrument (HBDI)

As described in Chapter 3, this method classifies learners in terms of their relative preferences for thinking in four different modes based on the task-specialized functioning of the physical brain. The four modes in this classification scheme are as follows:

- cerebral left brain thinkers (logical, analytical, quantitative, factual, and critical)
- limbic left brain thinkers (sequential, organized, planned, detailed, and structured)
- limbic right brain thinkers (emotional, interpersonal, sensory, and symbolic)
- cerebral right brain thinkers (visual, holistic, and innovative).

Research findings based on the application of HBDI have suggested that, most engineering teaching focuses on left-brain (cerebral) analysis and left-brain (limbic) methods and procedures associated with that analysis. Research findings also have indicated that:

- 20% to 40% of entering engineering students are with strong preferences for right-brain (limbic) thinking
- 20% to 40% of entering engineering students are with strong preferences for right-brain (cerebral) thinking

It should be noted that while the former group of students are sensory and interpersonal mode learners who like teamwork and communications, the latter group are those learners that prefer creative problem solving, systems thinking, synthesis, and design.

5.2.3 Towards Defining Two Types of Learner

The analysis of the four learning styles in the previous section has made the stage ready for this research to conceptualize a new model for the types of learner. Fig. 5.4 is a starting point for this purpose. It is an effort by this study to summarize and contrast the main characteristics of the fore-mentioned models in a single diagram. The four models have been placed intentionally in a chronological order. Both the Myers-Briggs Type Indicator and the Kolb's learning style model have influenced significantly the extent of knowledge and pace of progress of later research on the learner's characteristics.

As noted earlier, all of these models have a common orientation to the learner.

The Myers-Briggs Type Indicator - 1980	**Kolb's Learning Style Model - 1982**	**Felder-Silverman Learning Style -1988**	**Herrmann Brain Dominance Instrument (HBDI) - 1990**
Extraverts (E) (try things out, focus on the outer world of people) <u>or</u> **Introverts (I)**(think things through, focus on the inner world of ideas)	**Type 1: divergers** (concrete, reflective - characteristic <u>Why?</u> type learners) respond well to explanations of how course material relates to their experience, their interests, and their future career.	**Sensing Learners** (concrete, practical, oriented toward facts and procedures) <u>or</u> **Intuitive Learners** (conceptual, innovative, oriented toward theories and meanings)	**Quadrant A** (left brain, cerebral), think in a mode that is based on the task-specialized functioning of this quadrant of their physical brains. That is; logical, analytical, quantitative, factual, and critical.
Sensors (S) (practical, detail-oriented, focus on facts and procedures) <u>or</u> **Intuitors (N)** (imaginative, concept-oriented, focus on meanings and possibilities)	**Type 2: assimilators** (abstract, reflective - characteristic <u>What?</u> type learners) respond to info presented in an organized, logical fashion and benefit if they have time for reflection.	**Visual Learners** (prefer visual representations of presented material - pictures, diagrams, flow charts) <u>or</u> **Verbal Learners** (prefer written/ spoken explanations)	**Quadrant B** (left brain, limbic), think in a mode that is based on the task-specialized functioning of this quadrant of their physical brains. That is; sequential, organized, planned, detailed, and structured.
Thinkers (T) (skeptical, tend to make decisions based on logic and rules) <u>or</u> **Feelers (F)** (appreciative, tend to make decisions based on personal and humanistic considerations)	**Type 3: convergers** (abstract, active-characteristic <u>How?</u> type learners) respond to having opportunities to work actively on well-defined tasks and to learn by trial-and-error in an environment that allows them to fail safely.	**Inductive Learners** (prefer presentations that proceed from the specific to the general) <u>or</u> **Deductive Learners** (prefer presentations that go from the general to the specific)	**Quadrant C** (right brain, limbic), think in emotional, interpersonal, sensory, kinesthetic, and symbolic modes, like teamwork and communications.
Judgers (J) (set and follow agendas, seek closure even with incomplete data) <u>or</u> **Perceivers (P)** (adapt to changing circumstances, resist closure to obtain more data)	**Type 4: accommodators** (concrete, active - characteristic <u>What if?</u> type learners) like applying course material in new situations to solve real problems.	**Active Learners** (learn by trying things out, working with others) <u>or</u> **Reflective Learners** (learn by thinking things through, working alone).	**Quadrant D** (right brain, cerebral), think in a mode that is based on the task-specialized functioning of this quadrant of their brains namely visual, holistic, and innovative. (this type learners prefer creative problem solving, systems thinking, synthesis, and design).
		Sequential Learners (linear, orderly, learn in small incremental steps) <u>or</u> **Global Learners** (holistic, systems thinkers, learn in large leaps).	

<u>Fig. 5.4: Four Major Models of Learning Styles</u>

They emphasize "distinctive" and "stable" differences among learners. Typically, they are a good way to understand differences among learners and to illuminate why students respond differently to their learning tasks. Nevertheless, there exist, more or less, some differences in their approaches to student learning. For instance, MBTI has basically a personality-oriented perspective to the learners. Kolb's learning cycle is purely a learning style model. Felder-Silverman might be considered similar to MBTI in the way that it divides the different types of learner. HBDI highlights a higher level of processes and deals with the thinking preferences of the learners.

On the other hand, judged by the number and quality of research applications among these four methods, the Myers-Briggs Type Indicator (MBTI) and Kolb's learning style model seem most promising. Specially, when taking into consideration the specific approach of each model (MBTI in personality and Kolb in learning style), if this study accommodates the combined empirical results of these two methods, it might come up with a proposed model that is more defensible. However, the general interpretation of this research from the types of learner described in the Felder-Silverman learning style is similar to those given by MBTI. Furthermore, since the focus of this study is on "learning" rather than "thinking," the HBDI classification will not be considered in the following synthesis.

However, to develop a proposed model for the different types of learner, this study employs the similarities that exist in the types of learner in both MBTI and Kolb's model. Table 5.1 illustrates how two distinct types of students (Type I learners and Type II learners) could be conceptualized and developed by comparing the identical learners' characteristics found in both MBTI and Kolb's models from one side and those from the striking studies made by Marton and his colleagues [30 - 32], and Bloom [42] from the other side. Worth mentioning is that these four approaches to the types of learner, from the literature of education and learning psychology are the most relevant to the theme of this research.

As shown in Table 5.1, Type I learners could be defined as those learners whose learning characteristics match with Sensing (S) type learners in MBTI, the combination of Feelers and Watchers (combination of Reflective Observers and Concrete Experiencers respectively) in Kolb's model, surface type students in Marton's view, and students with lower order of learning skills in Bloom's Taxonomy. Similarly, Type II learners could be defined as those learners whose learning traits match with Intuition (N) type learners in MBTI, or the combination of Thinkers and Doers (combination of

Table 5.1: Introducing Two Types of Learners

Dimension	Type I Learner	Type II Learner	Remarks
Personality: **MBTI**	S type students: - like step-by-step instruction - like lots of numerical examples - attention to detail - read the topic more carefully for details - try to picture problem - when presented with a test problem, try to recognize it as an exactly similar problem that have previously solved	N type students: - like theoretical principles followed by examples and application - tend to skim the material - hook the topic into the overall context of the subject - like to grasp the overall concept and global ideas first	- The N/S and E/I are the most significant qualities for learning styles. N/S is particularly the most. - most of engineering students are INTJ - ISTJ rely too heavily on memorization - engineering program attracts I_TJ types [125] - students graduating in four years are significantly more INTJ - E_FP types are less successful
Learning Style: **KOLB**	CE/RO (Feeler/Watcher) type students: - like learning by primary text reading and observations - need to find reason (s) why the task is important - called *divergers* because they see things from different perspectives and easily generate ideas - if too divergent, they can be paralyzed by alternatives and unable to make decisions - if less divergent, they find it hard to generate ideas - excel at brainstorming - not adaptable to change	AC/AE (Thinker/Doer) type students: - do not like much lecturing - like learning by logical analysis - act on understanding of a situation - have practical approach for what really work - ability to get things done - willingness to take risk - ability to make quick decisions - good at defining and solving problems - good at making decisions - if too convergent, they may solve the wrong problems and make wrong decisions - if less convergent, they may have scattered thoughts and lack focus	- although an orderly progression of the cycle is helpful, research indicates that using various activities from each learning style preference is beneficial to all learners, whether the activities are in sequential order or not. - qualities are grouped in thinkers/ and watchers/feelers - three-fourth of engineering students are, more or less, thinkers/doers
Learning Strategy: **MARTON**	Surface approach type: - intends to memorize those parts of information that they consider to be important - guide by the type of questions anticipate being asked subsequently. - mainly have a reproductive or rote learning concept of study - consider learning as equated with "committing to memory" - see value of learning in a quantitative sense	Deep approach type: - extract meaning from what they read - interact actively with the argument - relate general principles to their current stock of ideas - try to see to what extent the evidence presented justifies the statement. - see value of learning in a qualitative sense	- refer to 2.1.5: The move from teaching to learning [30 - 32]
Learning Ability: **BLOOM**	possess lower order of intellectual abilities (more knowledge or memorizing and less comprehension or understanding)	possess higher order of intellectual abilities (application, analysis of meaning, synthesis, and evaluation)	- refer to 2.2.3: Learning theory and research [42]
Personal Judgment (Based on the own personal experience)	Type I engineer: - can employ equations that have studied in school, or can be found in textbooks and handbooks, to calculate various design values	Type II engineer: - have a grasp on problems and how things hang together - know what theory/equations are appropriate in various situations, and know limitations of equations - can direct others to solve a wide range of usual as well as new and unusual problems	Assumption: a thought of the future: Type I and Type II students have been graduated and now are working as design engineers in XYZ company.

Abstract Conceptualizers and Active Experimenters respectively) in Kolb's model, deep type students in Marton's view, and students with higher order of learning skills in Bloom's Taxonomy. Obviously, the totally different approaches of each of these learners to the process of learning originate from their own totally different characteristics. Type I learners seem to be method-paced individuals who are generally interested in following pre-defined guidelines. On the other hand, Type II learners seem to be innovative individuals who are generally interested to create new methods and procedures.

The different characteristics of the above discovered learners have been further examined in a practical point of view based on the researcher's own industrial experience. The personal judgement (last row in Table 5.1) indicates the researcher's perception about two engineers with totally different approaches to decision-making and problem-solving at work. In fact, the problem-solving characteristics of the two different engineers represent the projection of their past learning characteristics into the future. As the table shows, the forecasting results are entirely consistent with the two proposed types of learner.

5.2.4 Types of Mind: A Proposed Theory

Before discussing different types of mind within the context of types of learner, some elaboration on the study that resulted in the above proposed Type I and Type II learners seems necessary. This study was in parallel with the effort of collecting the significant information about the learning characteristics of the various learners from the literature. Interestingly, the collected information showed a natural tendency for fitting roughly into the two emerging types of learner. All of the collected learning characteristics were grouped with no difficulty (based on their similarities) into two different types of learners. Interestingly, it was found that the characteristics of each types of learner fit well with ones of the above-proposed Type I and Type II learners. This information has been refined and boiled down to the following characteristics for the Type I and Type II learners respectively:

<u>Characteristics of Type I Learners</u>

- rely almost exclusively on a surface approach
- are external towards the information and its requirements

- intend to keep information for a limited period to satisfy the external demand
- are guided by the type of questions they anticipate being asked subsequently
- concentrate on aggregating the parts without interrelating or integrating them
- their retrieval from the memory depend on the accuracy of a coding process which determines where information will be stored and expected to be found
- their long-term memories (LTM) contain a data base of records of information tied together within inter-connecting systems
- store episodes of information in episodic memory
- hold the information for a longer period in episodic LTM by repetition and convert it to a permanent memory trace by sufficient repetition
- reproduce the required information with little use of elaboration

Characteristics of Type II Learners

- adopt a deep level approach to the information
- are mostly internal to the content of the information
- usually look for meaning and likely are interested in the information itself
- focus on relationships and procedures
- actively interact with the information (relate it to the previous knowledge and their own experience and develop linkage between them – elaboration)
- integrate the main parts into a structured whole
- store and relate concepts

  (Note: concepts are built up by repeated comparisons of incoming information with pre-existing concepts or linkages between images)
- reassess and categorize each piece of information in short-term memory (STM) before being passed to semantic LTM
- their LTM contains a data base of concepts tied together within inter-connecting systems

Summing up and taking into consideration the above characteristics and the previous analysis about the learning traits of the Type I and Type II learners, this research finds itself at a position that can shape a new theory for the different types of learners. Of course, this theory should have such power and capacity that gi.‚ ɜs clear answers to both questions of "what are the types of minds that Type I and Type II learners possess?" and "how does each type of learner take in and process the information?"

In fact, this research, during different stages in conceptualizing a solid theory for the two types of minds, has come up with various views. In the beginning stages, Type I and Type II learners, though not defined so extensively as above, were considered as "rote-type" and "deep-type" learners respectively. Rote-type learners were seen as individuals that had a dominant string-type memory. That is, they hang information onto hooks and had the ability to create large strings of hooks. Deep-type learners, on the other hand, were seemed to be individuals that had dominant associative memory. They associated new information with previous knowledge and developed new relationships.

Later, upon more investigation on the mechanism of a learning process, this research re-defined two types of learner as "memorizers" and "relators." Memorizers were described as the type of learners who memorize episodes of information as "things," "relationships," and "procedures." They use pre-memorized methods in memorizing and retrieving all kinds of information. Relators, on the other hand, were described as the type of learners who use relationships to memorize things, relationships and procedures in their semantic memory. To retrieve information, they employ their methods to reach to the relationships among "things" and from the relationships to the "things," themselves.

Finally, the latest investigation into the characteristics of the different minds, has led this study to a new stage. In other words, examining and debating various cases, have given this research a solid ground to suggest the following:

- ❑ **Type I Learners might be known as *Form** type learners who possess *form-oriented minds*.**

*Form-oriented learners view learning tasks as their forms and their outside appearances. In general, they see things in the way they *look* and not in the way they *work*. They are primarily memory-type learners and are oriented toward *what* and *how many* type questions. Their minds hang all types of in-going information (things, relationships, and procedures) onto hooks without active thought. In other words, in a form mind, things, relationships, and procedures, once defined, all become *forms*. Form learners employ learned procedures to use the relationships and things on the hooks or episodes of information. In their worldview, a knowledgeable student is someone with a good store of memorized information and a ready recall system.

- **Type II Learners might be known as *Function*** type learners who possess *function-oriented minds*.**

  ** Function-oriented students are primarily relationship-type students and are oriented toward *why* and *how* type questions. They view learning tasks in their functions and in their reasons for being used. In general, they look at things in the way they *work* and not in they way they *appear*. Function-oriented students see learning experiments as methods and procedures that determine relationships that, subsequently, determine parts or things. Their minds create methods and procedures as possible on a continuing basis. In their worldview, a knowledgeable student is someone with insight and the means to solve new problems.

The above definitions for the form type and function type learners (minds) could be solidified and expressed in a general theory as shown in the following box:

THE FORM-FUNCTION THEORY OF TYPES

The Form-Function theory of types suggests that individuals, in general, possess two different types of mind. They either possess a form-oriented mind or a function-oriented mind. Form-oriented minds view the incoming information as related to its outside appearance (forms), while function-oriented minds interpret incoming information as related (cause-effect relationship) to its inside organizations (functions).

Apparently, the difference between the form and function ability is the ability to memorize in the "form" case and the ability to see the logic of a relationship in the "function" case. Such a statement by this study, implicitly induces a new and challenging notion about the different types of mind in the way they take and process information.

As a disclaimer, it is worth mentioning that, what this study is chasing in this research is the two extreme types of learners. In fact, the proposed form and function learners represent the two opposite poles of a learning continuum. Obviously there will be numerous learners in-between with a different combination of form and function characteristics.

Table 5.2 is an exclusive effort by this research to demonstrate the internal structure of a form type versus a function type mind.

Table 5.2: Form Type Mind vs. Function Type Mind

FORM TYPE	FUNCTION TYPE
Internal Structure	Internal Structure
• Memorize forms easily	• From forms, work to find background functions
• Compare forms	• Memorize most found functions
• Perform procedures	• Memorize most forms around found functions
Note: If a form is memorized and a conflicting form is presented, both may be memorized. The two memorized forms will conflict with each other for dominance, or either might be discounted.	• Perform procedures

It is noteworthy that the creative or investigative effort by a learner to find new relationships may have nothing directly to do with form and function but relates to a separate creative ability. Also, it may be reasonable to suggest that most function students will see the logically, directly-related relationships and procedures without the relation or procedure being described in the course. A simple example is the ability of a learner with a function mind to count down once the ability to count up is understood.

5.2.5 Validating the Form-Function Theory

Probably, the most effective way to check the validity of the proposed theory is to see whether or not it is consistent with the renowned approaches of the knowledge acquisition in the literature. As discussed in Chapter 2, generally, there are two basic theories of knowledge acquisition, absorption theory and cognitive theory. Absorption theory views knowledge as a collection of facts (associations) that are learned by means of memorization. This theory suggests that the knowledge expansion is an accumulation process that basically increases the number of associations. Cognitive theory, on the other hand, views knowledge as structures that are organized by relationships. Meaningful understanding occurs by active construction (assimilation or integration) of structures. This theory suggests that the knowledge acquisition involves more than accumulating information and it is a change in the thinking pattern of the learner.

By reviewing carefully these two approaches and comparing them with the characteristics of a form and function learner, an interesting fact is uncovered. The way the form-oriented mind approaches learning fits exactly the absorption theory while the way the function-oriented mind approaches learning fits very well with the cognitive theory. To the greater enjoyment of the researcher, this study, by using its proposed Form-Function Theory of Types, claims that proponents of the absorption theory are most likely form type individuals and proponents of cognitive theory are most likely function type individuals! Any fair judgement by the reader on this comprehensive conclusion, gives no doubt to the validation of this proposed theory.

5.3 Investigating the Mechanism of a Learning Process

In the previous section, this research study came up with a theory on two types of minds that learners possess. Now, the two remaining questions are "what are the types of incoming information" and "how is each type of information treated with each type of mind?" In fact, in an engineering perspective, what is the mechanism of a learning system and what does one mean when he or she says something has been *learned*?

Actually, these two questions have challenged this research from the beginning. As mentioned earlier, the proposed form-function theory is the result of a systematic investigation over a long time (almost three and half years of continuous study). The conceptualization of this theory should not be seen as an isolated endeavor. The development of the theory was based on a "cause-and-effect" rule. In fact, the findings in one front caused new effects on the other fronts and vice versa. Accordingly, the answers to the above questions have not been the same at the different stages of the study.

Therefore, to give a better picture about how the answers to the subject questions took their final shape, the situation at three periods: earlier, interim, and later stages of the study will be briefly discussed. Each period took roughly one year.

5.3.1 The Earlier Approach

The research focused on two (extreme) types of learners: one with a strong string memory and the other with a strong associative memory. The former took the incoming episodes of information and hung them as "hooks of information" in his or her mind. This type of learner had the ability to generate many hooks and make strings of information with no difficulty. The latter took the incoming information and associated them with his or her previous ideas or concepts. This type of learner had the ability to generate many associations and link them together with no difficulty. Both learners had a comparative engine as well. This memory engine kept hooks and associations and checked for some parts that fit the hooks, sets of rules, mathematical relations, and so on.

Preliminary efforts started by performing some experiments with the help of a number of theoretical short lecture cases from different courses in engineering. Each short lecture had to have at least one pre-defined learning objective and had to be as the part of a complete class lecture. The primary intent was to concentrate mainly on the short lectures from the first year engineering courses. For this purpose, a number of short lectures from the beginning chapters of the Introductory Chemistry text, taught to the first year engineering students in the University of Manitoba, were chosen. The short lectures dealt with the formulation and application of the different gas laws. Each short lecture was broken down into 15 to 30 steps and each step included a small piece of information that could perform a meaningful statement.

To master each learning objective, students had to have some background knowledge of chemistry as well as mathematics, physics, and other types of basic knowledge. Therefore, the level and the content of the starting knowledge for each type of mind was defined clearly and categorically. All pieces of information within every short lecture were analyzed and examined for their sequence, integrity and difficulty. In the mean time, an effort was made to identify the different types of information within the short subject lectures. At this stage, the types of information were classified into three traditional groups as follows:

- Rote-memory-type information
- Closed-problem solving
- Open problem solving

Knowing the type of each piece of information, each learner was theoretically presented a short lecture. The way that each type of student takes in, examines, evaluates, and processes each piece of incoming information was guessed at the end of each step. Based on the available knowledge at this stage, the study came up with three types of learning abilities for the student as below:

- Ability to create a linear string.
- Ability to make available immediately, a set of hooks of information to hang the information on.
- Ability to start problem-solving immediately or to work in the background. (Associative engine drives the brain and works in the background. It could be weak or strong.)

At this stage, the information processing was assumed to be based on the traditional approach. That is, after obtaining each piece of information, learners would assess it, categorize it, code it, and then, depending on the situation and the learner, generate a new hook or association or extend an already-existing hook or association in their memory. The main difference among the two types of learner was the way in which their string memory and associative memory functioned respectively. This approach had its own weak points, but enabled this research to start investigating the uncharted area.

5.3.2 The Interim Approach

Further investigations generated a better idea about the types of learner. Now, the two different types of learner were known as "memorizers" and "relators" (see 5.2.4).

Similar experiments were performed on a number of very simple arithmetic cases, and the results of the findings were used and re-tested in the chemistry cases. Each experiment used some sort of time-wise tables that demonstrated how an organized short lecture in a typical teaching process is presented to a learner. In fact, the insight provided from these cases shed new light on the knowledge of this study concerning the mechanism in a learning process.

Based on the available knowledge at this stage about memorizer and relator orientations toward the different types of information, the study switched to a different view about the types of information. Now, the types of information were classified in three groups as follows:

- Rote-type information: A sort of information that is memory-oriented with no link to one's real life experience
- Relationship-type information: A kind of information that recalls past pieces of knowledge, ideas, concepts, or experiences, and can be directly or indirectly connected to it.
- Procedure-type information: A type of information that has a classification, method, or stepwise scheme, and involves relationships.

Similarly, considering the different approaches of the memorizers and relators to the learning, a new classification for their types of learning abilities were identified as follows:

Memorizers:

Upon receiving new information, they bring forward similar hooks. If new information fits one of them, they hang it on the hook, otherwise, they

- Generate new hooks of elements and relationships as they are given.
- Memorize hooks of elements and relationships by repetition.

Relators:

- Upon receiving new information (elements/relationships), they use relationships to
- link it to the other parts or generate new relationship.
- Upon receiving new information (elements/relationships), they create and use procedures to link it to the other parts and or generate new parts.
- Generally, they use procedures to reach relationships to reach elements.

5.3.3 The Later Approach

The beginning of this stage is concurrent with the conceptualization of the proposed theory for form and function learners. At this stage, question statements were added to the short lecture trials. The two types of mind were subjected to the pre-designed single short tests (true/false, multiple choice, short answers, and problems) and the possible way that they tackle questions were worked out. The most likely answers were guessed by the researcher himself and based on his past teaching/learning experience and marked accordingly. Analyzing the way that each type of mind handles the test questions led this researcher to new findings. For instance, the different types of information were further modified to the following:

- Only memorizing (rote-type) information
- Relationship-type information (quasi or rote-oriented – non-verifiable)
- Relationship-type information (real – verifiable, cause-and-effect type)
- Procedure-type information (quasi or rote-oriented methods – follow rules type)
- Procedure-type information (real – inter-relational cause-and-effect type)
- Question-type information (true/false or yes/no)
- Question-type information (short answer required)
- Question-type information (closed problem-solving oriented)
- Question-type information (open problem-solving oriented – most likely needs critical thinking ability)

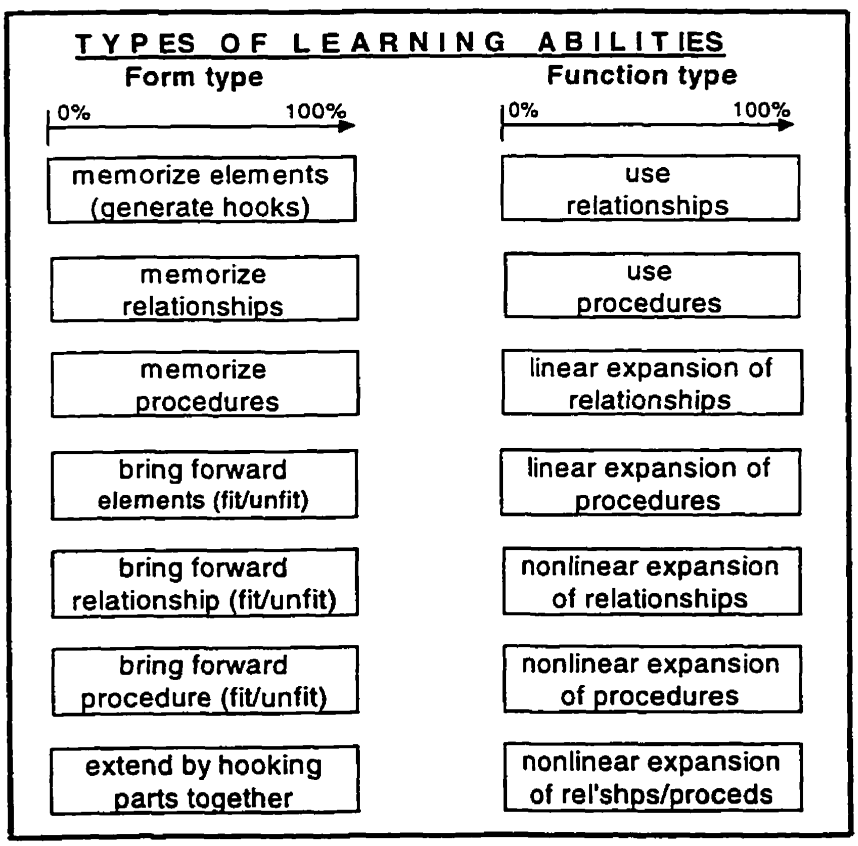
Apparently, the first five types are the *main* constituents of any narratives, presentations or lectures. On the other hand, the second four types, are the *auxiliary* constituents of a lecture and represent different groups of question type information. Although they are not used as frequently as the first five types, more or less, they are included in a well- designed and quality lecture. However, as it can be seen, the main constituents of a lecture are composed of the "rote-type," "relationship-type," and "procedure-type" information.

Worth mentioning, is the way that this research defines the two proposed kinds of relationship-type information. An example for each will clarify their differences. "James

Watt invented the steam engine in 1970," is a typical relationship-type information that is rote-oriented and is not easily memorized by a relator. On the other hand, "a particular ball fits exactly within a particular hoop," is a typical example for real relationship-type information that, since it expresses a verifiable cause-and-effect relationship, could be memorized easily by the relator.

Moreover, in a separate effort on the different learning abilities of form and function learners, the previous classification was further modified. According to the new results, each form and function learner could possess seven different types of learning abilities where each ability could vary from 0 (weak) to 100% (strong). Fig. 5.5 shows the modified types of the learning abilities for each type of learners. The linear and nonlinear expansion of relationships and procedures (the five boxes at the right bottom of the diagram will be clarified by an example short-lecture case that will be discussed later).

Fig. 5.5: Different Types of Learning Abilities



As mentioned earlier in this chapter, it should be noted that, the focus of this research is on the two extreme types of learners. In fact, there exist countless variations of learner in-between, and any one learner would have some combination of form and function learning abilities.

In the latest effort, that includes all of the new findings, another trial was performed by using a second year engineering course namely, Introduction to Industrial Engineering. This course had the advantage of being taught by the researcher himself for two consecutive years. Mastering this course, requires a quantity of mathematics, analysis, memorization, dexterity, and other abilities. This research, intentionally, chose a lecture on the "productivity issue" which covers a part of the first regular lecture in the course. Typical learners find it to be a section of moderate difficulty within the program because of the mixed use of simple mathematics and common sense materials. The learning objective was defined as:

- defining "productivity,"
- learning how to measure "productivity" and
- mastering how "productivity" is used to measure the performance of a firm.

Therefore, the content of the lecture was composed of a basic definition and some rules and principles that described the concept to be learned.

The "productivity" case was created in a similar manner to the previous cases. It comprised the following constituents:

- original knowledge as it is arranged in the form and function mind
- steps (sequences) of information, each with a meaningful statement
- types of information
- final knowledge as it is arranged in the form and function mind at the end of the case
- short tests
- answers and mark

Fig. 5.6a, 5.6b, and 5.6c demonstrates three important parts of the short lecture trial on "productivity" for a form type learner. Fig. 5.7a, 5.7b, and 5.7c demonstrate similar parts for a function type learner.

Note that Fig. 5.6a and 5.7a show the original knowledge as it is arranged in the minds of the form and function types respectively. The interesting points in these diagrams are the differences in the patterns of the knowledge and the location (episodic or semantic memory) of the original knowledge in the mind of each learner.

Fig. 5.6b and 5.7b depict steps 1-17 of the short lecture and the way that form and function minds treat the incoming information respectively. Note that the words which are underlined in the left column of the diagram indicate the keywords within each statement. Also, the words that are shown in bold in the right column represent the different types of the learning abilities that are used by each of the learners for the situation.

Fig. 5.6c and 5.7c demonstrate the final arrangement of the knowledge for the form and function minds (at the end of the lecture) respectively. A simple contrast of these two diagrams with Fig. 5.6a and 5.7a depicts the volume of the knowledge acquisition by the form and function minds respectively.

A few points are worth mentioning:

1. The total information presented by a teacher during a lecture could be analyzed for its types. If relationship-type and procedure-type information are dominant, then the teacher is most likely a function-oriented type teacher and vice versa. This is really exciting! The Form-Function Theory of Types is at work!
2. The total information presented by a teacher during a lecture also could be analyzed for the prediction of the learners' performance beforehand. If the stress is on the memory (rote) type information, then the form type students, most likely, will achieve better marks.
3. The order of the steps or the sequence of information in the left column in Fig. 5.6b and Fig 5.7b could be changed. Depending on the type of the information, a change in the performance of the function or form learners or both is predictable accordingly. To test this idea, some different random trials were performed in this study. However, time limitations and other concerns did not allow for more in-depth analysis.
4. The form and function type learners can be identified in advance, by using a well-designed questionnaire, provided that the questions are form and function-oriented

ORIGINAL KNOWLEDGE AS IT IS ARRANGED IN THE FORM MIND (AT T = Ti)

HOOKS OF INFORMATION IN THE EPISODIC MEMORY:

math knowledge

things	*relations*	*procedures*
numbers	associations:	= how to add?
plus	a + b = c	[statement: as per sheet 2]
minus	c - b = a	= how to subtract?
times	a * b = d	[statement: accumulation]
over	d / a = b	= how to multiply?
ratios		[statement: accumulation
percent		= how to divide? [accumulation]

experience

things	*relations*
workers	humans-work-pay
machines	things-operate-produce
tools	things use-do work easier
money	earn-wealth-buy things-survive
raw mat'ls	things-use-change-product
products	goods-made-use
factories	places-humans-machines
managers	humans-bosses-order-do
assignment	problems-solve-mark
textbook	book-course-materials-read
tests	questions-solve-mark/grade

procedures

= how textbooks should be read to pass courses? [statement: (1) identify each *key* term (2) if it is new, create a hook (3) if it's not, add it to a hook which fits]

= how factories work to make goods? [statement: ....]

= how the potential test questions can be realized from the lecture? [statement: ....]

this course (intro to IE)

things

industrial engineering
contributors
organizations/businesses
functions
marketing
P/OM = production and
inputs
outputs
operations management
finance

relations

industrial engineering-techniques-improve-performance-firm
contributors:
= Taylor-father of scientific management- use- scientific principles - work study-labor standards
= Gilbreths-time and motion study
= Gantt-bar charts
= Henry Ford-car assembly line
= Metcalfe-cost analysis/control
P/OM-management-activities-transform inputs-outputs
production-creation-physical products TV-bike-handtools
operations-creation-nonphysical products/services-a check being processed in a bank-a customer being served in a restaurant
organization/businesses-three main functions-marketing-P/OM-finance

procedures

(None)

Fig.5.6a: The Original Knowledge as it is Arranged (Form-oriented Mind)

info 1	this lecture is about productivity.	***brings forward*** different hooks: ***unfit***
(rote)	what is productivity?	***generates a hook: productivity***
info 2	productivity is a comparative tool for	***extends the hook by rel*** (hooks tool,
(rel/rote)	industrial engineers and production/	industrial engineers and production/
	operations managers.	operations managers to productivity)
info 3	we have to start with a production process	***brings forward*** a relation that fits:
(rel/real)	to see what productivity is.	*(production)*
info 4	a production process can be demonstrated as:	***extends*** the current hook by hooking
(rel/real)	inputs ----> transformation process ------> outputs	the relationship to it.
info 5	inputs are resources like labor, capital,	***generate new hooks:***
(rel/real)	and management.	***extends*** the current hook by hooking the elements to it.
info 6	outputs are goods and services, including	
(rel/real)	such diverse items as guns, butter,	***extends*** the current hook by hooking
	home appliances, education, improved	the elements to it.
	judicial systems, and ski resorts.	
info 7	so, we can write:	
(rel/real)	labor, capital, management ------>	***extends*** the current hook by hooking
	production process ------> goods or services	the relation to it.
info 8	now, we can define productivity.	
(rel/rote)	productivity is the ratio of the output	
	generated by a production or service over	***extends*** the current hook by hooking
	the input provided to create this output,	the relationship to it.
	that is: productivity = output / input	
info 9	now let's see how we measure	***brings forward matching procedure: unfit***
(proced)	productivity and how we can use it.	***generates new hooks (of procedures):***
		how we measure productivity?
		how we can use productivity?
info 10	what is productivity of a steel plant for 250	
(c.p.s.)	labor-hours used to produce 1000 tons of steel?	*no idea yet (waiting to receive a procedure)*
info 11	since: productivity = output / input	
(proced)	first we have to identify output and input,.	
	then substitute their relevant values in the	
	the above relation; value of output in the nominator	***brings forward the very recently made hooks:***
	and value of input in the dominator.	***extend the hook***
	finally solve to find productivity.	
info 12	what is productivity of the above steel	***brings forward the matching procedure:***
(c.p.s.)	plant for the same labor-hours used	(very previous procedure) and solves the problem:
	to produce 1100 tons of steel?	(1) output = 1100 tones of steel, input = 250 labor-hours
		(2) productivity = output / input
		productivity = 1100 / 250
		(3) productivity = 4.40
info 13	now compare the values we got for	
(o.p.s.)	productivity in both above problems	***brings forward the matching relation:***
	(4.0 and 4.40), what is your comment?	since 4.40 > 4.0, so productivity has increased.
info 14	productivity measurement is a way to	
(rel/rote)	evaluate performance of a firm or an industry.	***extends*** the current hook
info 15	for instance, in the above plant, since productivity	
	has increased, so performance has improved.	
	the higher productivity of a firm the	
	the better its performance is.	***extends*** the relation hook
info 16	the effective use of three variables of productivity;	
(rel/rote)	i.e., labor, capital, and management by production/	***extends*** the current hook by hooking
	operations managers improve productivity.	the relationship to it.
info 17	productivity can be measured in a variety of ways,	***extends*** the current hook by hooking
(rel/rote)	such as labor, capital, energy, material, and so on.	the procedure to it.

Fig. 5.6b: An Example Short Lecture Experiment To Show How a Form Learner Treats Incoming Information.

FINAL KNOWLEDGE AS IT IS ARRANGED IN THE FORM MIND (AT T = TF)

HOOKS OF INFORMATION IN THE EPISODIC MEMORY:

math knowledge

things
numbers
plus
minus
times
over
ratios
percent

relations
associations:
a + b = c
c - b = a
a * b = d
d / a = b

procedures
= how to add?
[statement: as per sheet 2]
= how to subtract?
[statement: accumulation]
= how to multiply?
[statement: accumulation
= how to divide?
[accumulation]

experience

things
workers
machines
tools
money
raw mat'ls
products
factories
managers
assignment
textbook
tests

relations
humans-work-pay
things-operate-produce
things use-do work easier
earn-wealth-buy *things*-survive
things-use-change-product
goods-made-use
places-humans-machines
humans-bosses-order-do
problems-solve-mark
book-course-materials-read
questions-solve-mark/grade

procedures
= how textbooks should be read to pass courses?
[statement: (1) identify each *key* term (2) if it is new, create a hook (3) if it's not, add it to a hook which fits]
= how factories work to make goods?
[statement: ....]
= how the potential test questions can be realized from the lecture?
[statement: ....]

this course (intro to IE)

things
IE = industrial eng.
organizations/firms
P/OM = production and operations management
marketing
finance
labor
capital

relations
industrial engineering-techniques-improve-performance-firm
contributors:
= Taylor-father of scientific management- use- scientific principles - work study-labor standards
= Gilbreths-time and motion study
= Gantt-bar charts
= Henry Ford-car assembly line
= Metcalfe-cost analysis/control
P/OM-management-activities-transform inputs-outputs
production-creation-physical products TV-bike-handtools
operations-creation-non physical products/services-a check being processed in a bank-a customer being served in a restaurant
organization/businesses-three main functions-marketing-P/OM-finance

productivity
tool-industrial engineers-P/OM
inputs ----> transformation process ----> outputs
inputs-resources-labor-capital-manag't
outputs-goods-services-butter-education
labor, capital, management ---->
production process ----> goods/services
productivity = output / input
the higher productivity of a firm the better its performance is.
the effective use of three variables of productivity; labor, capital and management by P/OM improve productivity

procedures
how we measure productivity?
(1) identify "output" and "input."
(2) substitute their values in productivity = output / input value of output in the nominator and value of input in denominator.
(3) solve to find the value of productivity.
productivity can be measured in a variety of ways, such as labor, capital, energy, material, and so on.
how we can use productivity?
= use it to evaluate performance of a firm?

Fig.5.6c: The Final Knowledge as it is Arranged (Form-Oriented Mind)

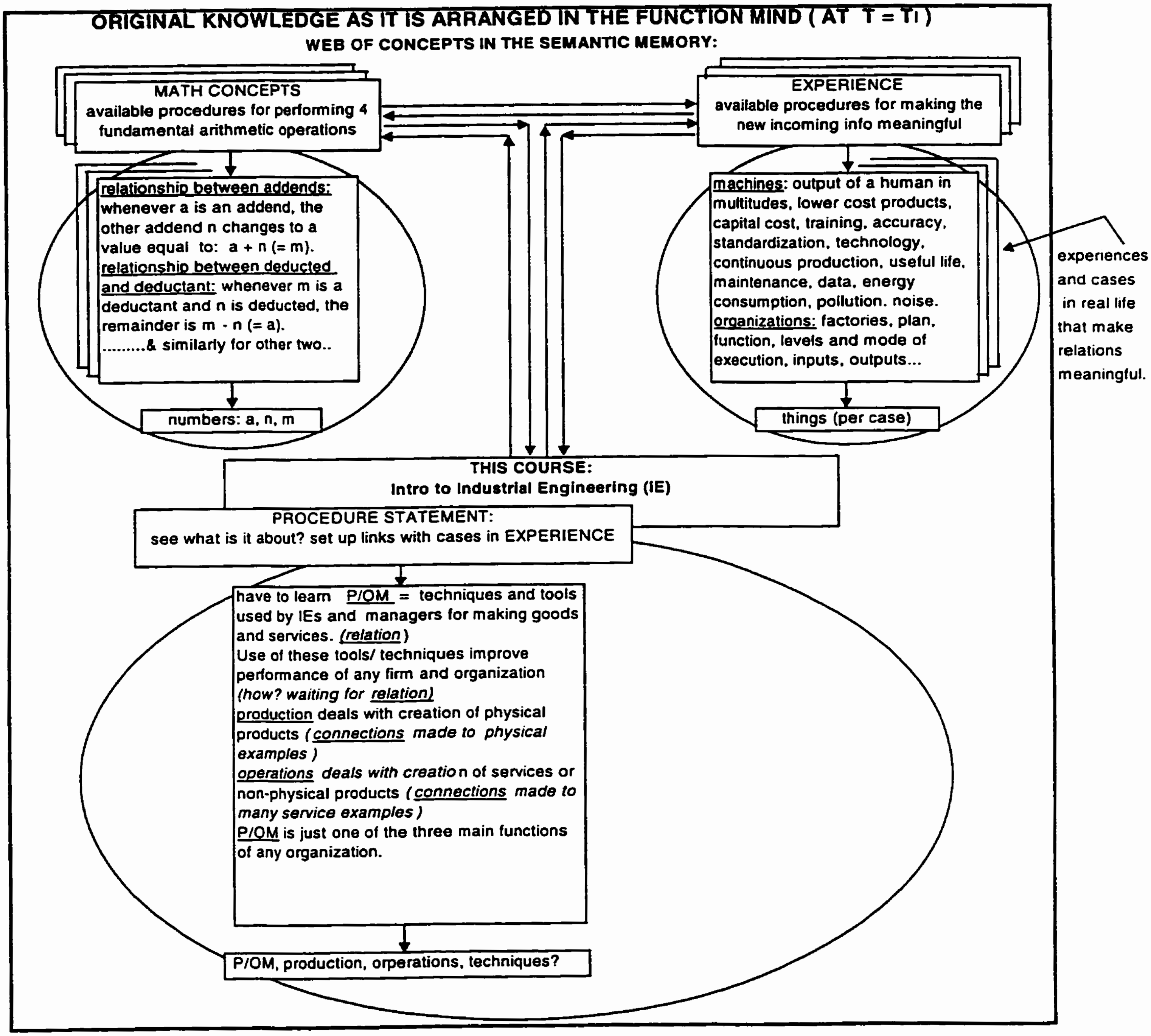


Fig.5.7a: The Original Knowledge as it is Arranged (Function-oriented Mind)

and subject students complete it carefully. Advance knowledge about the types of students could have a dramatic effect on the control and improvement of the teaching/learning processes.

info 1	this lecture is about productivity.	***attempts to generate a procedure:***
rote	what is productivity?	relationship?: production <-----------> productivity?
info 2	productivity is a comparative tool for	***attempts to find a procedure:***
rel/rote	industrial engineers and production/	productivity is a tool ----> a comparative tool ---->
	operations managers.	compares what? ----> used by IEs ----> ?
info 3	we have to start with a production process	***attempts to find a procedure:***
rel/real	to see what productivity is.	productivity ---> a tool ---> a comparative tool ---> production
info 4	a production process can be demonstrated	***uses the relationship:***
rel/real	as:	inputs ----> production process ----> outputs (goods)
	inputs -------> transformation process	***expand the relationship linearly:***
	-------->outputs	inputs ----> production process: like a car assembly line ---> cars
info 5	inputs are resources like labor, capital,	***attempts to find a procedure:***
rel/real	and management.	***generates a relationship***
		inputs: labor, capital, management ---->
		car assembly ----> outputs: cars
info 6	outputs are goods and services, including	***finds a procedure:*** ***use relationship:***
rel/real	such diverse items as guns, butter,	outputs of a production process ---> physical products
	home appliances, education, improved	guns, butter, home appliances: output of a service process
	judicial systems, and ski resorts.	----> non-physical products: education, judicial, ski resorts.
info 7	so, we can write: labor, capital, management ---->	
rel/real	production process ----> goods or services	*already got it.*
info 8	now, we can define productivity.	***attempts to expand the procedure linearly:***
rel/rote	productivity is the ratio of the output	***generates new relationship:***
	generated by a production or service over	productivity = output / input =
	the input provided to create this output,	any physical product/ (labr+capt+mangmt) ? Or
	that is: productivity = output / input	any service / (labr + capt + managmt) ?
		attempts to expand procedure nonlinearly:
info 9	now let's see how we measure	productivity is a tool ---> a comparative tool ---> used in a
proced	productivity and how we can use it.	production process --> relates its outputs to inputs
		---> through a ratio of output/input ---> a comparative ratio? --->
		perhaps compare wo different conditions? ---> perhaps any
		change in productivity is a sign of change in production process.
info 10	what is productivity of a steel plant for 250	***use procedure:***
c.p.s.	labor-hours used to produce 1000 tons of	output = 1000 tons of steel, input = 250 labor-hours
	steel?	productivity = output / input = 1000 / 250
		productivity = 4.0 tons steel / labor-hour
info 11	since: productivity = output / input	
proced	first we have to identify output and input,.	
	then substitute their relevant values in the	*idle*
	the above relation; value of output in the nominator	
	and value of input in the dominator.	
	finally solve to find productivity.	
info 12	what is productivity of the above steel	***use procedure:***
c.p.s.	plant for the same labor-hours used	increase in output = 10% ----> 10% increase in productivity
	to produce 1100 tons of steel?	----> productivity = 4.40
info 13	now compare the values we got for	***attempts to expand procedure nonlinearly:***
o.p.s.	productivity in both above problems	productivity is a comparative tool for IEs --> comparing these two
	(4.0 and 4.40), what is your comment?	values --> production is more efficient --> increase in performance
info 14	productivity measurement is a way to	
rel/rote	evaluate performance of a firm or an industry.	*already got it*
info 15	for instance, in the above plant, since productivity	
	has increased, so performance has improved.	
	the higher productivity the better its performance is.	*already got it*
info 16	the effective use of three variables of productivity:	***use procedure:***
rel/rote	i.e., labor, capital, and management by production/	it's obvious
	operations managers improve productivity.	
info 17	productivity can be measured in a variety of ways,	***linear expansion of the proc:***
rel/rote	such as labor, capital, energy, material, and so on.	no. of cars / unit of labor OR no. of cars / unit of capital

Fig.5.7b: An Example Short Lecture Experiment to Show How a Function Mind Treats Incoming Information

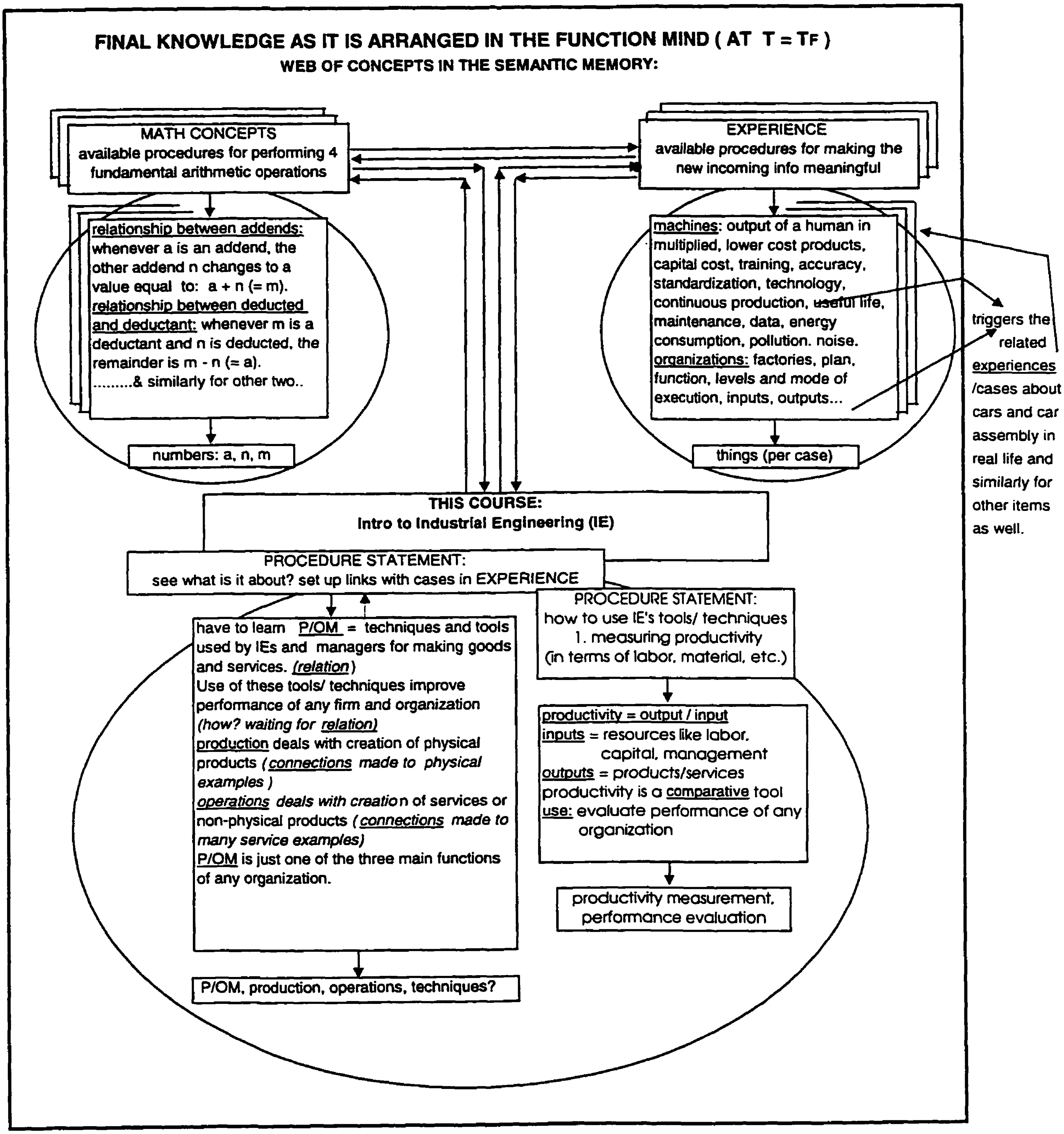


Fig. 5.7c: The final Knowledge as it is Arranged in the Function-oriented Mind

5.4 Summary and Conclusion

In this chapter, by employing the soft OR and systems thinking techniques (to support the system dynamics approach), three fundamental questions were answered:

(1) What are the types of the minds that learners possess?

The research combined the results of the previous synthesis and those from the four major studies in the literature (the Myers-Briggs Type Indicators, Kolb's theory, Gothenburg Studies by Marton and his colleagues, and Bloom's Taxonomy). A theory was conceptualized, introduced, and solidified. This theory (Form-Function Theory of Types) states that, learners possess two distinctive types of minds: form-oriented and function-oriented. The characteristics of these two minds were defined and discussed in detail. It is suggested that these two types of learners represent the two extreme types of learners on a learning continuum. In fact, countless learners, each with their own specific intensity in form-function orientation can be seen between the two ends of the continuum.

Moreover, different learning abilities of the form type and the function type students, regardless of their motivation related to having to work or wanting to work, were investigated. The findings were checked for validity with two renowned theories on student learning (absorption and cognitive approach - 2.2.4) and found to fit very well. Interestingly, form type fit exactly the absorption approach (See Table 2.2) while function type fit very well the cognitive approach (See Table 2.3).

However, to be more strict in the validation of the proposed theory, another effort can be made to compare the three basic learning abilities related to elements, relationships and procedures for each type of learners (developed by this study and discussed earlier in this chapter) with those proposed by absorption and cognitive theories. This can be done by contrasting Table 2.2 and Table 2.3 with Fig.5.5. The results are summarized and reported in Table 5.8.

Fig. 5.8: Validating the Proposed Form-Function Theory of Types

Form Type (See Table 2.2)	**Function Type** (See Table 2.3)
MEMORIZE ELEMENTS Learning by repetition	USE RELATIONSHIPS Learning by relationship
MEMORIZE RELATIONSHIPS Learning by association	USE LINEAR PROCEDURE Learning by assimilation Learning by integration
MEMORIZE PROCEDURES Learning by accumulation	USE NON-LINEAR PROCEDURE Learning by changes in thinking pattern

(2) *What are the types of incoming information?*

This research, through a long investigation and experimentation was able to recognize the different types of information in a typical teaching lecture. Nine types of information were identified and described in two sets: main types of information and question types of information. While the first set includes the main constituents of a statement, the second set includes the auxiliary constituents of the statement and is used for testing purposes. These nine types of information are demonstrated in Fig. 5.9.

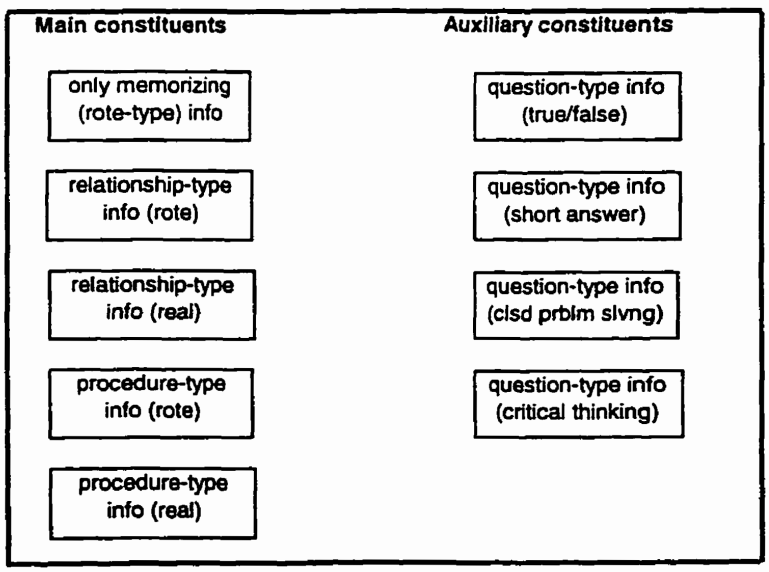


Fig. 5.9: Nine Types of Information (The constituents of a lecture)

The proposed theory of form-function prepared the ground for a better understanding of the types of incoming information (originated from the teaching system) to the minds of learners. Conversely, the knowledge of the dominant types of information given by teachers, could lead to better understanding of their types. That is, whether they are form or function type individuals.

(3) How is each type of information is accommodated by each type of mind?

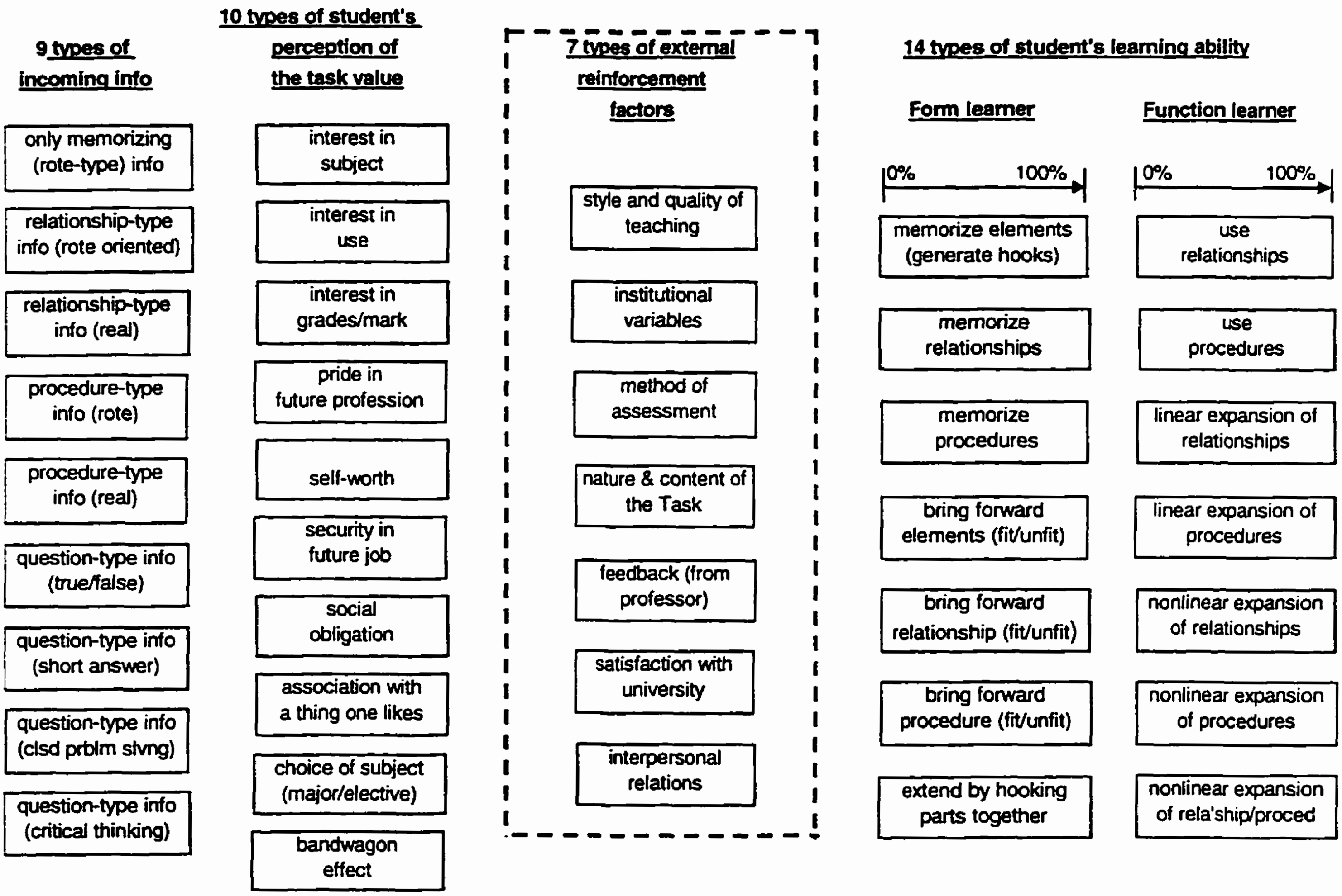
In fact, finding an answer to this question cost this research in a great deal of time and energy. Many theoretical trials (different types of students posed to different types of information), in different disciplines, were examined. Again, it was the conceptualization of the Form-Function Theory of Types that produced a momentum in this adventure. The original knowledge as it was arranged in the students' minds were defined schematically. Then, form and function minds were subjected to a set of the same pieces of information, in order. The way each mind deals with (takes in, processes, and stores) each type of information was guessed based on the best judgement of the researcher and was noted. Finally, their final knowledge as it was arranged in their minds, was developed (based on the findings) schematically. The totally different pattern of the build-up of knowledge in the form and function minds clearly demonstrated the mechanism of the learning process. Needless to say, the impact of motivational factors on the process of knowledge acquisition was the major missing part in these trials.

Fig. 5.10 is an effort to demonstrate all the important findings by this study so far. This figure, has brought together all the major components of a teaching/learning process in a single diagram as below:

- The nine types of information are in the left column.
- The ten types of the student's perception of task value (as proposed and discussed in Chapter 4) are in the next column to the right.
- Seven types of the external reinforcement factors are in the middle of the diagram. (They represents the characteristics of the teaching system and the learning environment, as proposed and described in Chapter 4).
- The two columns in the right of the diagram include fourteen types of the student's learning abilities (seven for the form type and seven for the function

type). Each of these abilities can vary from 0 to 100%. They represent the different stable and distinctive traits of learners. They were proposed and described earlier in this chapter.

Fig. 5.10: Proposed Major Components for a Teaching/Learning Process



By placing the new proposed components in Fig. 4.5 (A proposed Model for a Teaching/Learning Process), a more comprehensive flow diagram would be generated. Fig. 5.11 is an example demonstration of one way that some of these components could be connected to each other in the same flow diagram for a form-oriented learner. A similar diagram can be constructed for a function-oriented learner as well.

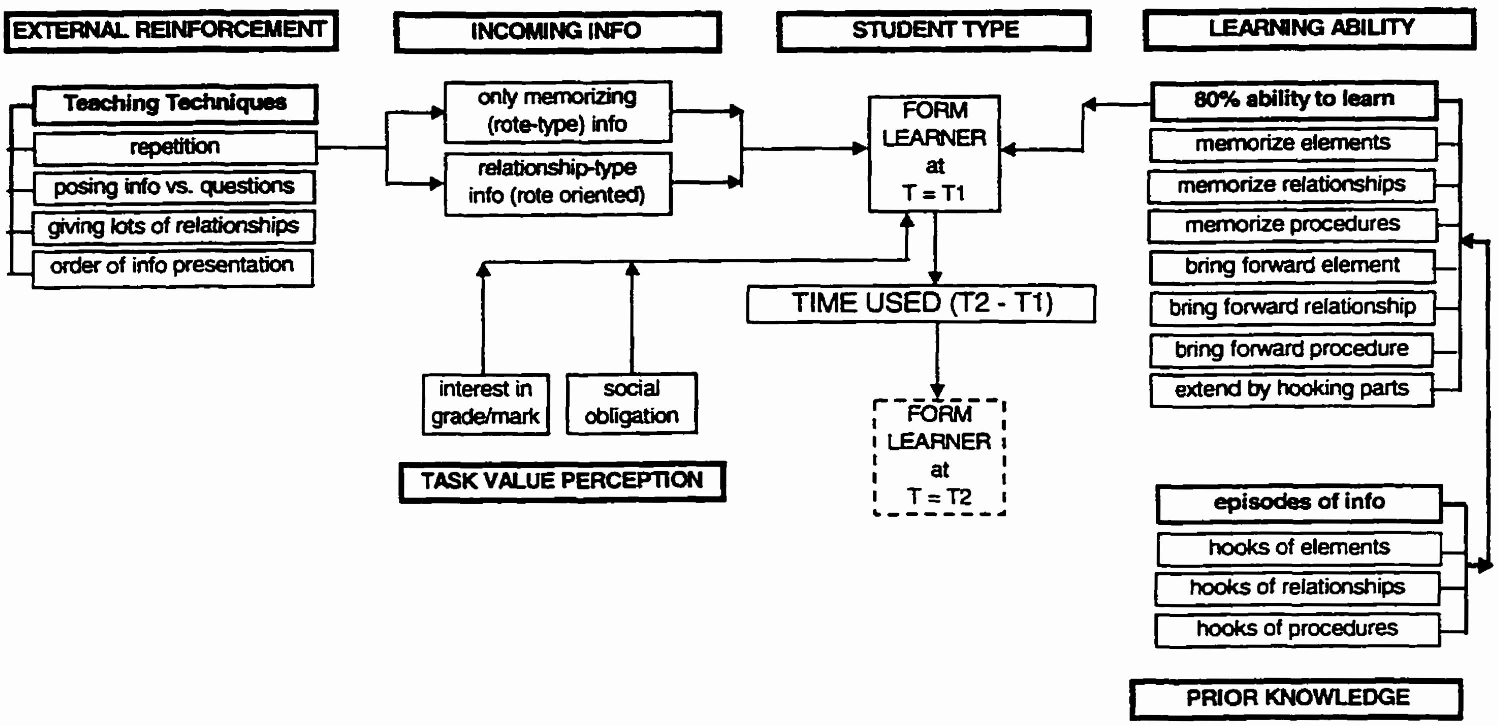


Fig. 5.11: An Example Flow diagram for a Form Learner: Connecting the Major Blocks

Now, the stage is ready to translate the above findings into a STELLA level and rate diagram. Formulating and simulating of the model will be next. This work will be done in Chapter 6 and in line with the other steps of the system dynamic method.

Chapter 6

The Model of a Teaching/Learning Process

In the previous chapters, in line with step 1 and step 2 of the system dynamics method, a system for the teaching/learning process was defined. The building blocks of the system, their constituent parts, and their relationships were theorized and described. Then, the main parts of the system were converted into a unified diagrammatic representation. Further analysis of the literature search in Chapter 5, uncovered new knowledge about student learning and resulted in the introduction of two different types of learners with two distinctive approaches to learning: *form* learners and *function* learners. The new findings, accordingly, have led to the development of a separate model of the teaching/learning process for each type of learner.

In this chapter, first, the STELLA language software, as an operational manifestation of the system dynamics approach, is introduced and discussed in detail. Then, the general model of the teaching/learning process will be translated into the STELLA stock and flow equation of a system dynamics model. Although the gist of the teaching/learning model is common for *form* and *function* learners, because of their totally different approaches to learning, two separate base models are built and run concurrently. The rest of the chapter deals with the description, analysis and results of the base models and the implementation of the different policies to improve the behavior of these two systems.

6.1 STELLA Language Software

The STELLA software's language is built around a progression of structures. *Stocks* and *flows* are at the lowest level and are the fundamental building blocks of the structure.

Infrastructures, which vary in size and complexity, are the next step in progression. They are built up from various combinations of stocks and flows. *Feedback loops* are the final step in the progression and are the relationships that link stocks to flows in various ways. In so doing, they enable infrastructures to exhibit interesting dynamic behaviors.

This section provides an overview of each step in the progression of the fore-mentioned structures. In fact, this overview will prepare the ground for understanding what the "structure" looks like at each level, how each structure behaves, and overall, how a STELLA model works. To be more efficient, in discussing each step, this research uses examples from the non-physical variables that, one way or another, are parts of a teaching/learning process in real life.

6.1.1 The Building Blocks

Components, or the building blocks, of the system are the first progression of the structure in the STELLA software language. There are four basic building blocks in the system: the stocks, the flows, the converters, and the connectors. A short and concise description of each of these components follows: (For detailed information see references 5, 114 and 116.)

Stocks

Stocks are basically accumulations. They collect whatever flows into and out of them. The default stock type in STELLA is the "reservoir." A reservoir passively accumulates its inflow, minus its outflows. Any units, which flow into a reservoir, will lose their individual identity. Reservoirs mix together all units into an undifferentiated mass as they accumulate. In a teaching/learning process, for instance, the student knowledge is an accumulation that varies as the process of teaching/learning proceeds.

Three other stock types are available in the STELLA software, but only two of them; "conveyors" and "ovens" are used in this study. A conveyor can be thought of as a moving sidewalk or a conveyor belt. Stuff gets on the conveyor, rides for a period of time, and then gets off. The transit time for a conveyor can be either constant or variable. Both capacity and inflow limit can constrain entry to a conveyor. On the other hand, an oven may be thought as a processor of discrete batches of stuff. The oven opens its doors; fills either to capacity or until it is time to close the door, bakes its contents for a time (as defined by its outflow logic); then unloads them in an instant. By contrast, stuff that enters these two stock types (conveyor and oven) does retain both its magnitude and time-of-arrival identity.

Stocks, in general, can be referred to as system state variables Fig. 6.1a, 6.1b, and 6.1c show a reservoir, a conveyor, and an oven type of stocks respectively.

Fig. 6.1a: A Reservoir

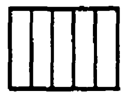


Fig. 6.1b: A Conveyor

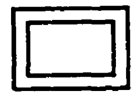


Fig. 6.1c: An Oven

Flows

The job of flows is to fill and drain accumulations. Mathematically, they are the instantaneous rates of flows that represent the means by which the system is controlled and represent activity points in the system. In fact, without flows, no change in the magnitude of stocks could occur. So, stocks and flows are inseparable components. They form the minimum set of structural elements needed to describe the dynamics of a system. Fig. 6.2 exhibits two types of flows that are used in the STELLA program; uniflows and biflows. In Fig. 6.2a, the unfilled arrow head on the flow pipe indicates the direction of the uni-directional flow. Clouds represent infinite sources or sinks for flows as illustrated in the diagram. Also, Fig. 6.2b shows a bi-directional flow (biflow), which is used to transport things both into and out of an accumulation. The second, shaded arrow head on this flow points the direction of outflow. Uniflows will assume only non-negative (i.e., inflow) values, but biflows can take on any value.

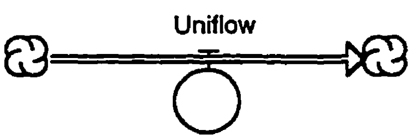


Fig. 6.2a: A Flow (uniflow)

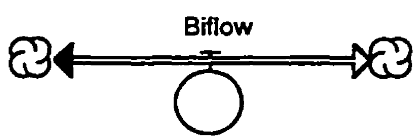


Fig. 6.2b: A Biflow

Converters

Converters are auxiliary functions and serve a utilitarian role in the software. They hold values for constants, define external inputs to the model, calculate algebraic relationships, and serve as the repository for graphical functions. In general, they represent the decision processes in the system. They are called "converters" since they convert system states to system activities (or inputs to outputs). Figure 6.3 shows the symbol that represents converters in the STELLA mapping.

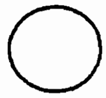


Fig. 6.3: A Converter

Connectors

As their names suggest, the job of connectors is to connect model elements. In fact, connectors are links that connect all of the components to each other. In so doing, they eventually form arcs that influence the flows (which regulate the system). The only restriction of connectors is that one cannot drag it into a stock. The only way to change the magnitude of a stock is through a flow. Figure 6.4 shows how a connector looks in STELLA software

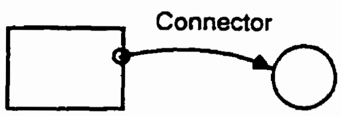


Fig. 6.4: A Connector

6.1.2 Infrastructures

As stated earlier, stocks and flows are the principal building blocks of the STELLA software language. However, irrespective of how many flows are attached to it, a single stock system can self-generate only a very limited set of dynamic behaviors. To produce a more complex dynamic pattern, it is essential to assemble sets of stock/flow combinations. These sets of combinations are called *infrastructures.* They exist in an essentially infinite variety. For the purpose of this study's modeling, it is important to recognize that infrastructures will generally define the range of characteristic behavior patterns that a model of teaching/learning will be capable of exhibiting.

However, in practice, infrastructures typically appear in a limited number of generic forms. Each generic form has certain dynamic behavior. Five main generic forms are recognized in STELLA software as follows [5, 116]:

- First-order linear infrastructure: It is a simple combination of a compounding and a draining process (Fig. 6.5). Note that in a compounding process, the stock serves as the basis for producing its own inflow while in a draining process, the stock serves as the basis for generating its own outflow.
- S-shaped: It is a self-reinforcing growth process that eventually is under control by some growth constraint.
- Overshoot and collapse: In this form, accumulations do not make a smooth transition from growth to steady-state. Instead, they grow rapidly, reach their maximum, and then decline to a new steady-state value.
- Oscillation: It is an oscillatory behavior produced by a minimum of two stocks while each serves as a catalyst for producing the other stock's flow.
- Main chain: This form represents a sequence of stages through which stuff flows while the specific nature of the flows varies, depending on the specific situations being modeled.

Taken as a whole, these generic processes will help this study to operationally specify the teaching/learning processes that it seeks to represent with the software. A model of a teaching/learning process will generally employ a combination of all of the above types. An example of the generic structure of the first-order linear infrastructure is shown in Fig 6.5. The system is called "first-order" since only one stock is involved. Also, it is "linear" since the constant proportionality between the stock and its flows gives rise to the term linear – which refers to the algebraic form of the flow equation.

As the diagram shows, the stock is fed by a compounding process (as defined and formulated in the figure). It is depleted by a draining process. Both the compounding fraction and the loss fraction are constant, which means that both compounding and draining flows are proportional to the amount of the stock.

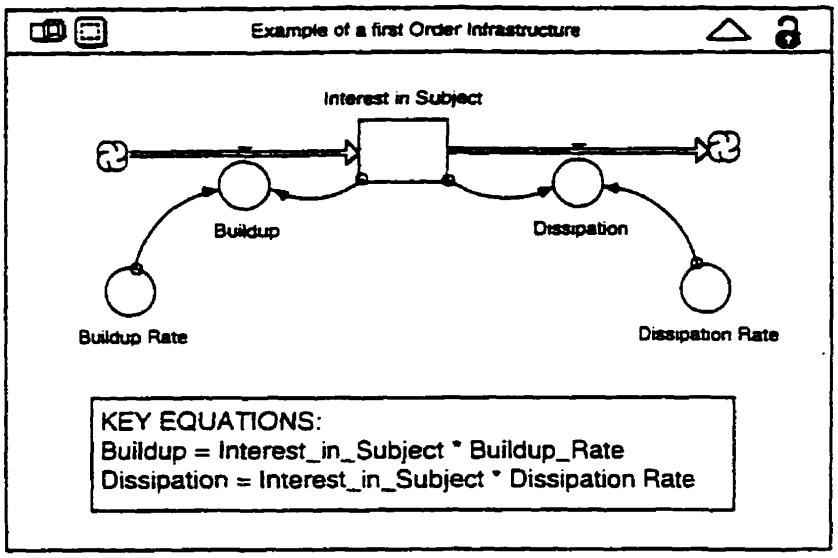


Fig. 6.5: Example of First-Order Linear Infrastructure
Adopted and Modified from Richmond [5]

A first-order linear infrastructure can exhibit three distinct behavior patterns, depending upon the relationship between the compounding and loss fractions. When the two fractions are constant, and the compounding fraction is greater than the loss fraction, the infrastructure exhibits exponential growth – the compounding process will dominate the behavior. In each cycle of the process, more will be added to the stock than will be taken away. As the stock builds, both inflow and outflow will grow larger. In relative terms, however, the inflow will always be greater than the outflow. The net rate of growth in the stock is simply the difference between the compounding and the loss fractions. On the other hand, when the compounding fraction is less than the loss fraction in this infrastructure and both are constant, the net rate of decline is the difference between the loss and the compounding fractions. Finally, when the two fractions are equal, the stock will remain constant. The draining flow is equal to the compounding flow, so no change will occur in the stock.

6.1.3 Feedback Loops

While infrastructures define the range of dynamic behavior patterns that a model is capable of exhibiting, the particular kind of feedback relationships that exist within the infrastructure will determine which of these patterns is realized. A feedback relationship is a closed-loop circle of cause-and-effect. Feedback loop cause-and-effect always includes at least one stock and one flow. This is because stocks are conditions that give rise to actions (or flows of activity) that in turn change conditions. However, it is really the current state of conditions, relative to some target level for the condition, that inspires conditions to change. Thus, feedback loops could be viewed as relationships that generate goal-seeking behavior. Goal seeking is a fundamental activity in which all dynamic systems engage. In fact, goal seeking is what enables conditions within a system to remain on course. When deviation occurs, feedback relationships inspire and direct corrective actions to bring conditions back in line.

There are two types of feedback relationships: negative (counteracting) and positive (reinforcing) feedback loops. When any variable in a negative loop is changed, then the loop causes that variable to readjust in the opposite direction. The negative loop produces self-regulating change (controlling and restorative behavior). Fig. 6.6 illustrates a common counteracting feedback process. In the loop, the Level_of_Effort is being used to regulate the Level_of_Performance. If performance falls below the level that the student has set as his or her target, then effort should go up. A higher Level_of_Effort leads to an increased Level_of_Performance. So, an initial decrease in performance

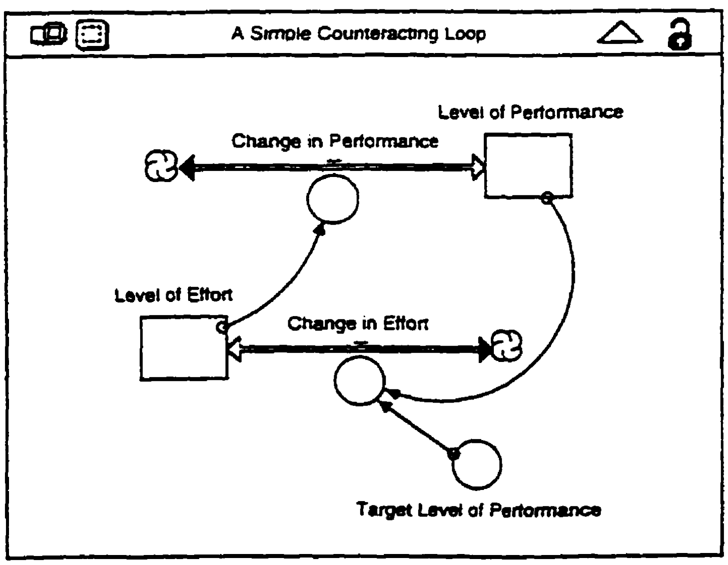


Fig. 6.6: A Simple Counteracting Loop
Adopted and Modified from Richmond [5]

propagates a signal around the loop, which leads to an increase in performance. The loop thus acts to counteract the initial change.

It should be noted that the loop also could counteract change in the other direction. That is, if performance rises above target levels, effort will be scaled back so as to return performance target levels.

By contrast, positive (reinforcing) feedback processes compound change rather than counteract it. When any variable in a positive loop changes, the resulting interactions cause that variable to change further in the same direction. The positive loop, in other words, characteristically produces self-reinforcing change (unrestrained growth).

Fig. 6.7 is an illustration of how a typical reinforcing feedback process works. The better a student performs, the more confident s/he feels. Subsequently, the more confident s/he feels, the better s/he performs. However as mentioned in the counteracting feedback relationship, the loop also may change conversely. That is, the less confident one feels, the worse s/he performs and subsequently, the worse s/he performs, the less confident s/he feels.

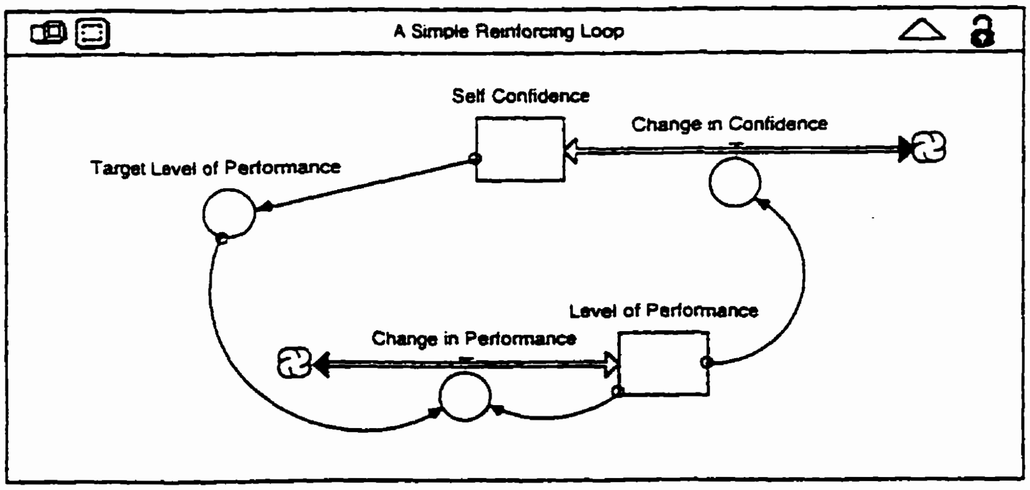


Fig. 6.7: A Simple Reinforcing Loop
Adopted and Modified from Richmond [5]

As the diagram indicates, in the case of reinforcing feedback loop, the goal (or target level of) performance is linked to the level of Self_Confidence. The link means that when Self_Confidence rises, the target for Level_of_Performance follows suit and vice versa. Then, as performance adjusts to the new target level, self-confidence responds accordingly.

Combining Counteracting and Reinforcing Feedback Loops

In fact, it is the interaction and shifting dominance between the two types of feedback relationships that generates the dynamic character of a system. Fig. 6.8 is an effort to combine the two previous examples and to show the way that the resulting system behaves. As the diagram indicates, now it is Self_Confidence that sets Target_Level_of_Performance and Target_Level_of_Effort. That is, how confident a student feels, determines both how well s/he thinks s/he should be able to perform as well as how much effort s/he puts out to achieve that level of performance. Level_of_Performance feeds back to determine Self_Confidence, and Level_of Effort feeds back to determine Level_of_Performance.

Now, if this set of relationships is allowed to operate with the STELLA software, the behavior of the system will depend on the initial levels of confidence, performance and effort as well as the strength of the relationships between Self_Confidence and the

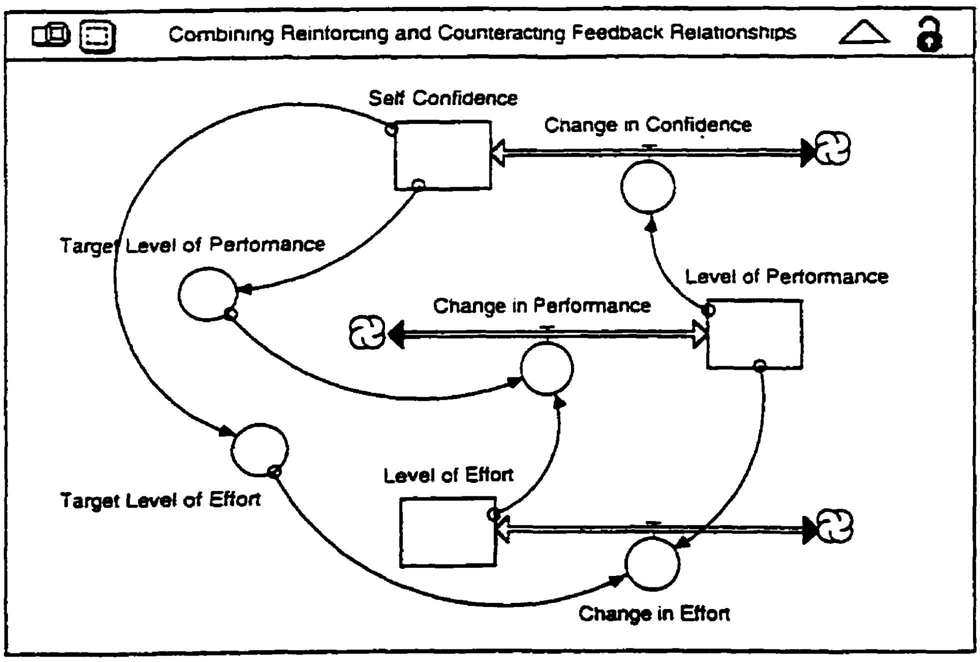


Fig. 6.8: Combining Reinforcing and Counteracting Feedback Relationships
Adopted and Modified from Richmond [5]

two targets. For example, if a decline in Self_Confidence causes a larger decline in the target for effort than it does for performance, then the system accelerates downward.

However a decrease in Self_Confidence has only a minimal effect on the Target_Level_of_Effort, the counteracting feedback loop which ties Level_of_Performance back to Change_in_Effort will have a chance to operate. This loop will act to boost the Level_of_Effort which, in turn, will increase the Level_of_Performance. An increase in performance, then will inspire a rise in the level of Self_Confidence accordingly.

Worth mentioning is that there are a lot of "ifs" in these scenarios. The "ifs" depend on the relative strengths of the feedback relationships that are involved. This simple example emphasizes the fact that it is difficult to make accurate predictions about the performance of systems involving extensive webs of feedback relationships.

6.2 Modeling Soft Variables in a Teaching/Learning System

Modeling of a teaching/learning system requires total involvement of a modeler with variables that are internal to both learners and teachers. Variables like student's abilities and motivation or quality of teaching are not entities that can be measured or computed. In fact, since they are non-physical (soft) variables, they could not get numeric or precise values. Despite this reality, however technically there is a mechanism for tackling such a problem. The mechanism may be found in the fundamental distinction that exists between *measurement* and *quantification* [128].

Measurement, by definition, means "assessing the magnitude of". The result of the assessment is often expressed numerically. All physical quantities or "hard" variables like height, volume and weight have pre-defined units-of-measures. On the other hand, *quantification* means, "assigning a numerical index to". While assigning a quantitative index is usually a pre-condition to measuring something, the two activities are not the same. The interesting point is that one can quantify almost anything.

Fortunately, in the case of a teaching/learning process, it is not necessary to measure all of the soft variables to be able to use them in the simulation model. That is, the research will assign a numerical index to each of the non-physical entities that are involved in the system. For instance, to quantify student motivation, the research will assume that 0 represents the complete lack of motivation and 100 represents as much motivation as it is possible for a student to have. A similar quantitative index would work equally well for the effort that students put into a learning task or the interest they have in the subject matter. Likewise, to quantify the rate of knowledge acquisition, the research will assume 0 represents the complete absence of effort to learn and 100 represents as much knowledge as is possible for a student to acquire for a given period.

Doing this will cause this study to act in a rigorous manner about the relationship each variable bears to other variables in the teaching/learning system. Hence, the more this research tries to quantify, the better the desired model resembles the real one. In addition, this will enable the study to solidify all the soft variables and simulate them to examine their role in the dynamics of a teaching/learning process.

This study, based on the discussions and findings in Chapter 4 and Chapter 5, has proposed two separate models for the components involved in a teaching/learning process. That is, a system for a form-oriented learner and a separate system for a function-oriented learner. It is noteworthy that the gist of the main structure for both models is the same and only the main chain within each model is different.

Table 6.1 shows the list of soft variables that have been defined and considered within the two models. Each soft variable is represented by one of the main building blocks of the STELLA software (stock, flow, or converter). As the table depicts, each model is comprises of exactly fifty soft variables with most of them being common in both models. Note that this is a good number for a STELLA model. In fact, a model with this number of variables is neither too complicated to be unmanageable nor too simple to be unacceptable as the representation of the reality.

Each model uses eight stocks and nine flow rates. The remaining variables have been defined by the converters. All of the stocks except two, hooks_for_repetition and structures_to_form, are reservoir types. On the other hand, four flow rates out of a total of nine flows are biflow types. These flows represent variables that can "change" values in either direction, e.g., change_in_quantity_of_info and change_in_expectancy.

Table 6.1: Defined Variables for the Proposed Models of Teaching/Learning Process

Proposed Teaching/Learning Model	Stocks	Flows	Converters
Form-oriented Learners	hooks_under_development hooks_for_repetition hooks_in_memory quantity_of_information interest_in_subject expectancy_ level_of_effort level_of_performance	taking_ (information) completing_ (the hooks) repeating_ (hooks of information) lecturing_ change_in_quantity_of_info change_in_expectancy change_in_effort change_in_performance waste_	type_of_info: memory_info, relrote_info, relreal_info, procedure_real, procedure_rote learning reinforcers: testing_ (rote_type, clsd_prbm_slvg, opn_prbm_slvg), quality_of_teaching, other_reinforcers interest_in_use, interest_in_grade, impact_of_other_values availability_, student's_perceived_availability, forecast_ adjustment prior_knowledge, amount_learned, productivity_, coding_ waste_fraction, learning_style_compatibility, constraints_ willingness_, mark_of_desire, perceived_assessment target_info, adjustment_fraction allocated_time-factor
Function-oriented Learners	relationships_under_study structures_to_form structures_in_memory quantity-of-information interest_in_subject expectancy_ level_of_effort level_of_performance	taking_ (information) evaluating_ (the information) finishing_ (the structures) lecturing_ change_in_quantity_of_info change_in-expectancy change-in_effort change_in_performance waste_	Same as above

6.3 Learning Model of a Form-oriented Learner

In this section, the STELLA model of a teaching/learning system for a form-oriented learner during a short period, such as a class lecture, is presented. The role of each variable in the model is highlighted, the nature of the interactions between different variables within the entire system (feedback loops) is described, and finally, the behavior of the system is discussed.

6.3.1 Description of the Base Model for a Form-oriented Learner

The system flow diagram for the learning process of a form-oriented learner is as shown in Fig 6.9. The diagram has been constructed by STELLA simulation language software and represents all the variables presented earlier in Table 6.1. Basically, the variables within the system can be recognized in three sets of components: components of the teaching system, components of the learning side (the form-oriented learner) and components of the subject matter. Note that the components of both the teaching system and subject matter are at the top and the right end of the diagram. The remainder of the diagram includes the components that represent the characteristics of the learner which include learning, motives and performance. The definition and description of each variable have been given in the List of Equations (Appendix I). Worth mentioning is that the STELLA equations created from Fig. 6.9 in the List of Equations are two types. The first types are stock level equations, which are generated by the software directly from the diagram, and their associated initial conditions. The remainder are the flow and converter equations that are generated by the modeler.

Referring to Fig. 6.9, the main chain infrastructure at the center of the diagram represents a sequence of stages through which the information flows in the learning side of the system. Apparently, the specific nature of flows vary, depending on the specific situation of each type of information. The chain is fed by a single flow (taking_). The cloud on the left-hand side of the flow of taking_ depicts the boundary of the model. It represents an infinite source for the taking_ flow, as shown. For the purpose of this model, it does not matter what is in the cloud. The flow of lecturing_ (teaching system) is governed by two main variables: type_of_info and change_in_quantity_of_info. Type_of_info comprises five different types of incoming information, as introduced and discussed in Chapter 5. In fact, the composition of the type_of_info determines the type of the teaching system or the teacher. If more weight is given to the memory_info or relrote_info (relationship rote-oriented information), the teacher is most likely a form-oriented teacher. Other potential possibilities can be created and used in the model by changing the composition of type_of_info. The governing effect of type_of info on the flow of lecturing_ has a subsequent impact on the learning_style_incompatibility (which has its relevant impact on the learning side as will be discussed later).

In the present base model, the flow of taking_ is capturing each piece of issuing information from the teaching system (flow of lecturing_) and placing it into the mind of

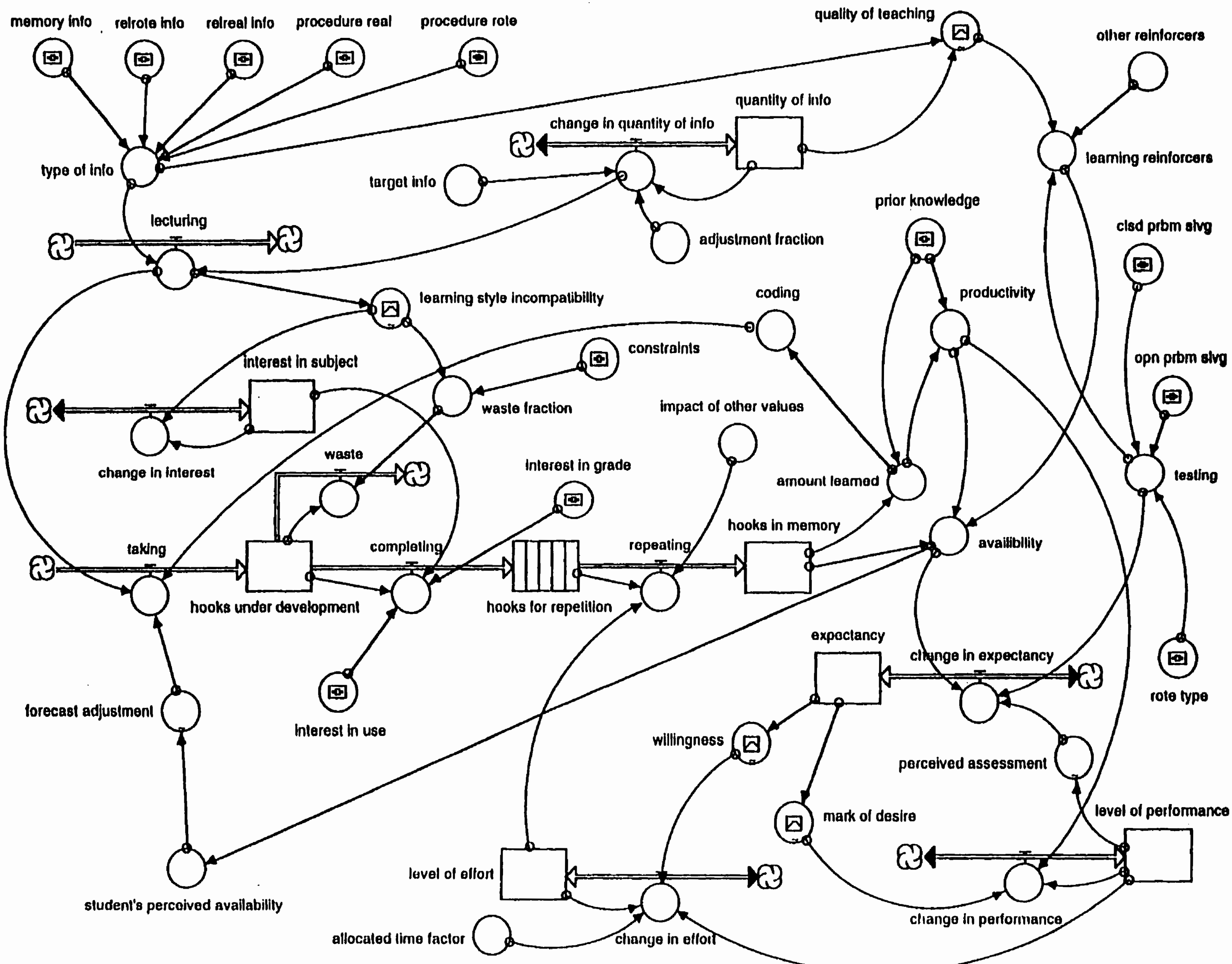


Fig.6.9: System Flow Diagram for a Form Learner

learner (stock of hooks_under_development). Therefore, the flow of taking_ depends upon the flow of lecturing_ from one side, and coding_ (suitability to be categorized and connected to the hooks already stored in the amount_learned), and the learner's own forecast_adjustment from the other side. The flow of waste_ drains the stock of hooks_under_development at a rate that is determined by the level of the stock itself and the waste_fraction. Waste_fraction is the product of constraints_ (that include all impeding factors, whether internal or external to the student, that lead to waste in the process of the knowledge acquisition – Refer to Chapter 3.1.3) and learning_style_incompatibility.

Flow of completing_ takes the hook of information from the stock of hooks_under_development and places them in the stock of hooks_for_repetition. This flow is under the influence of four variables: the level of the direct upstream stock, the learner's interest_in_subject, interest_in_grade, and interest_in_use (Chapter 4.4). The learner's interest_in_subject is represented by a stock and flow combination while the other two types of interest are shown by converters. It is assumed that the magnitude of the learner's interest_in_subject may vary during a lecture period while this is not so for the other two.

As shown in the diagram (Fig. 6.9), a conveyor type stock represents the state of the hooks_for_repetition in the mind of a form-oriented learner. Interestingly, by assigning different inflow limits and capacities to the conveyor, different types of form-oriented minds can be detailed and modeled. Subsequently, the flow of repeating_ gets the repeated hooks off the conveyor and stores them in the stock of hooks_in_memory. The flow rate of repeating_ is adjusted by the level_of_effort that the learner puts into the task. The impact_of_other_values (all the remaining task values – Chapter 4.3) reinforces the flow of repeating_. Finally, the sum of total number of hooks_in_memory and prior_knowledge are represented by the amount_learned (Chapter 4.4).

The other five stocks (shown as boxes in the diagram) are quantity_of_info (given by the teaching system), interest_in_subject, level_of_effort, expectancy_, and level_of_performance. Each of these stocks allows these parts of the system to have initial values. These stocks change in value according to the amount they receive or lose since their bi-directional flows can get both positive and negative values.

To simplify the model, only the two most important learning_reinforcers namely quality_of_teaching (shown on the top right of Fig. 6.9) and testing_ (shown on the left end of Fig. 6.9) have been defined in the model. Learning_reinforcers is modeled by a graphical function of type_of_info and quantity_of_info. On the other hand, testing_ comprises rote_type, clsd_prbm_slvg, and opn_prbm_slvg components, as discussed in Chapter 5. In fact, the other less important types of external reinforcers have been represented by a single converter as other_reinforcers (Chapter 4.4).

Also, to have a more solid model, two new components, productivity_ and availability_, have been conceptualized and introduced in the model. Note that the learner's productivity indicates the level of his or her learning effectiveness in the acquisition of new information. It is defined as the ratio of amount_learned to prior_knowledge (output to input) and, as pointed out, influences the learner's performance during the learning process. Availability_, on the other hand, has an important inter-relational role between the learner's *available* knowledge and his or her productivity_ from one side, and the impact of learning_reinforcers on the availability_ of the current knowledge from the other side. This parameter has been created to demonstrate the relevant concept discussed in Chapter 4.4. Availability_ connects the main chain of the student learning abilities to three important dimensions of expectancy_, level_of_effort, and level_of_performance.

The remaining components; willingness_, mark_of_desire, perceived_assessment, student's_perceived_availability, forecast_adjustment, allocated_time_factor, target_info, and adjustment_fraction, represent the other important characteristics within a teaching/learning system and are defined and detailed in the List of Equations (Appendix I) based on the previous discussions in chapter 4 and 5.

6.3.2 Feedback Mechanisms

Several feedback mechanisms are included in the model (Fig. 6.9). Four of these loops have a determining effect on the resulting behavior of the system. Two loops are acting merely in the learner's ability (to learn) side. One loop is acting in the student's performance side which demonstrates the impact of subject matter. And the last loop, which is the largest loop, is acting in the teaching system side. These four loops are described here in detail.

1. The Learner's Ability (to Learn) Mechanisms

The first mechanism acts along the main chain running from the stock of hooks_under_development to the stock of hooks_in_memory, and from there to the amount_learned and to the coding_ and finally back to the flow of taking_. This linkage closes a feedback loop in which as the amount of incoming information (lecturing_) increases, the form-oriented learner will take more and make more hooks_under_development. This leads to a higher rate of completing_ (the hooks and strings of information) and subsequently, more hooks_for_repetition. A higher number of hooks_for_repetition, inevitably increases the rate of repeating_ and the amount of hooks_in_memory respectively. The amount_learned will increase and, accordingly, causes an increase in the categorizing and coding_ ability of the form learner. This, in return, will facilitate the flow rate of taking_. The reinforcement of taking_ is one of the feedback mechanisms included in the model for responding to changes in the amount of incoming information. Thus, the feedback loop starts with an increase in the amount of hooks_under_development and feedback to taking_ makes it increase more. This phenomenon is the characteristic of a positive feedback loop that tries to reinforce the process. As stated in the previous sections, when any variable in a positive loop changes, the resulting interactions cause that variable to change further in the same direction. The positive loop, in other words, characteristically produces self-reinforcing change (unrestrained growth).

The second mechanism acts in parallel to the first one, keeping the same track but diverts from hooks_in_memory to availability_. Thus, an increase in hooks_under_development, ultimately, increases the hooks_in_memory. The result is an increase in the availability_ of the information that gives rise to a higher student's_perceived_availability. A higher perceived_availability, subsequently, decreases the student's forecast_adjustment. This, in return, leads to a negative impact on the flow of taking_ and a subsequent decrease in the hooks_under_development.

Summing up, the loop starts with an increase in the hooks_under_development and the feedback to hooks_under_development makes it decrease. This phenomenon is typical behavior for a negative feedback loop. As mentioned in the previous sections, when any variable in a negative loop is changed, then the loop causes that variable to readjust in the opposite direction. The negative loop produces self-regulating change (controlling and restorative behavior). And so, an initial increase in the number of hooks_under_development propagates a signal around the loop, which leads to an eventual decrease in the level of this stock. The loop thus acts to counteract the initial change.

In summary, it is obvious that the overall behavior of the learning ability of the learner is almost the result of the interaction between these two feedback loops. a positive feedback loop that acts in the "coding_" side, and a negative feedback loop that acts in the "availability_" side.

2. The Student's Performance Mechanism

The other feedback loop that has a major effect on the behavior of the overall learning system acts along the student's "performance" side (down to the right of the diagram). This loop may either act as a negative or a positive feedback loop. The way it works depends upon the direction or the resulting direction of changes in the involving biflow rates.

This loop starts with the stock of hooks_in_memory. Note that an increase in hooks_in_memory, concurrently, increases the amount_learned by the student. This, in turn, increases the student learning productivity_ and availability_ of the knowledge respectively. The result is reinforcement in the positive direction of change_in_expectancy which subsequently leads to an increase in student's expectancy_ for a higher achievement. The increase in expectancy_ has a direct impact on the student's expected mark_of_desire, and at the same time, on the willingness_, as discussed in Chapter 4.3. However, if change_in_performance and change_in_effort biflows tend to be in positive directions, then they result in subsequent increases in level_of_performance and level_of_effort respectively.

On the other hand, mark_of_desire and willingness_ are the target levels for the level_of_performance and level_of_effort respectively. Therefore, the rate of change in each biflow depends directly on the difference between the value of each reservoir and the value of the corresponding target level. Even though an increase in the level_of_performance reinforces the positive direction of the change_in_effort which subsequently increases the level_of_effort. The increase in level_of_effort, strengthens the rate of repeating_ and generates more hooks_in_memory. Needless to say, the resulting effect is a typical behavior of a positive feedback loop. As mentioned earlier, when any variable in a positive loop changes, the resulting interactions cause that variable to change further in the same direction.

Two points are worth mentioning. First, the biflow of change_in_effort is under the influence of allocated_time_factor. This converter represents the time dimension of the effort that a student puts into different learning tasks. Second, the biflow of change_in_expectancy is under the influence of testing_. Note that testing_, as discussed in Chapter 5.3, comprises three major types of questions: (1) rote_type (true/false, multiple choice and short/long answer questions), (2) clsd_prbm_slvg (closed problem solving type questions) and (3) opn_prbm_slvg (open problem solving type questions). The value of testing_ in the model is defined by the following relation:

$$Value\ of\ testing\_ = \frac{w_r \times r + w_{cps} \times cps + w_{ops} \times ops}{w_r + w_{cps} + w_{ops}}$$

where

w_r = weight percent of rote-type questions

w_{cps} = weight percent of close problem solving type questions

w_{ops} = weight percent of open problem solving type questions

r = value of the rote-type questions in the teacher's view

cps = value of closed problem solving questions in the teacher's view

ops = value of open problem solving questions in the teacher's view

In the base case of the model, it is assumed that a form-oriented teacher represents the teaching system. It is obvious that form-oriented teachers normally intend to ask questions or create tests with higher weight percentages of the types of questions that they prefer the most (i.e., more rote-type and less closed problem-solving type). Conversely, function-oriented teachers normally intend to ask questions and create tests while they give more weight to the open problem-solving and closed problem-solving type questions.

In the meantime, each of these types has its value in the teacher's view. Form-oriented teachers assign higher values to rote-type questions while function-oriented teachers assign higher values to the problem solving types questions. By assumption, the following values (out of 5) have been considered for each type of question in a form and function's view respectively and may be used in the base model:

	Rote-type questions	Closed-problem solving	Open-problem solving
Form-oriented teacher	5	3	0
Function-oriented teacher	0.5	3	5

Since both the form teacher and the form learner prefer the first two types of questions, the better a testing_ represents these two types of question, the higher the expectancy_ of a form-oriented student, and the higher s/he sets his or her mark_of_desire. Subsequently, the higher s/he sets his or her mark_of_desire, the better s/he performs. But, as mentioned in the counteracting feedback relationship, the loop also may change conversely. That is, the less testing_ represents the form student's preferred question types (if say, for instance, the teacher is a function-oriented individual), the lower his or her expectancy_ for a better achievement and subsequently, the less his or her mark_of_desire and the worse s/he would perform.

3. The Teaching Side Mechanism

The largest feedback loop mechanism acts along the "teaching_" side (top left) of the model. This loop, again, may either act as a negative or a positive feedback loop. The way it works depends upon the direction (or the resulting direction) of changes in the involving biflows. This feedback loop could be tracked as mentioned below.

The "teaching_" loop starts with the stock of quantity_of_info. The level of this stock (the total accumulation of information presented at any time) is controlled by rate of change_in_quantity_of_info. The biflow of change_in_quantity_of_info may change direction in either positive or negative side to regulate the level of the stock, based on the amount of target_info (as is preset by the teaching system for each lecture, here for instance, in the base model, say it is set as 200 pieces of information) and adjustment_fraction (as is adjusted by the teaching system based on the feedback received from the student's level_of_performance).

As the level of quantity_of_info increases, provided that the type_of_info is at its appropriate value for a form learner, the quality_of_teaching increases. The increase in quality_of_teaching has its reinforcing effect on the student's learning_reinforcers and subsequently on the student's availability_ of knowledge. The more the availability_ of knowledge, the greater the expectancy_, the higher the mark_of_desire, the better the performance, and finally, the larger the adjustment_fraction. This means a higher flow rate of information to the stock of quantity_of_info. Note that for the sake of having a neat diagram, the connector that links level_of_performance to the adjustment_fraction is not shown in Fig. 6.9.

It is worthwhile to notice the role of type_of_info in the teaching_ side of the model. In fact, it represents *what* is flowing, via lecturing_, from the teaching system to the learning side (learner). The different types of information within a lecture were recognized and classified in two sets; "main set" and "testing (auxiliary) set," as discussed in the previous chapter. On this side, the model shows the types of information that are included in the "main set" namely memory_info (memorizing type – rote info), relrote_info (relationship-type info – rote oriented), relreal_info (relationship-type info – real), procedure_real (procedure-type info - real) and procedure_rote (procedure-type info – rote oriented). The four types of the "testing set" have been reduced to three types and are shown as constituents of testing_ in the right end of the diagram (Fig. 6.9). They are part of learning_reinforcers like the quality_of_teaching_ and other_reinforcers that were dealt with earlier. The value of type_of_info is determined by the following fomula:

$$\text{Value of type\_of\_info} = \frac{a \times w_a + b \times w_b + c \times w_c + d \times w_d + e \times w_e}{w_a + w_b + w_c + w_d + w_e}$$

where

w = weight % of each type of information in the lecture presented by the teaching system

a = memorizing type information

$b =$ relationship-type info – rote oriented

$c =$ relationship-type info – real

$d =$ procedure-type info – real

$e =$ procedure-type info – rote

In the base case of the model, it is assumed that a form-oriented teacher represents the teaching system. It is obvious that, form-oriented teachers normally are giving lectures with higher weight percentages of the types of information they prefer the most (i.e., memory type, relrote, and procedure-rote). Conversely, function-oriented teachers prefer these three types of information less and present lectures with higher weight percentages of relreal and procedure-real. In the meantime, each of these types has its value in a teacher's view. Form-oriented teachers assign higher values to a, b and e while function-oriented teachers assign higher values to c and d.

By assumption, the following values (out of 5) could be considered for each type of information in a form and function's view respectively and may be used in the base model:

	memory type	relrote	relreal	procedure real	procedure rote
Form -oriented teacher	5	4	1	1	5
Function-oriented teacher	1	2	5	5	1

In general, the last two feedback loops described above act on two sides of the model (teaching and learning) and due to the bi-directional effect of their biflow rates, seek eventually either goal-maintaining or a growing pattern. At the same time, some smaller loops exist in the model that behave locally and generate their limited effect on the system. Consequently, the overall behavior of the teaching/learning process is the resulting behavior produced by all of the mentioned loops.

6.3.3 Behavior of the System

Referring to Fig.6.9, and List of Equations (Appendix I), it can be seen that the simulation starts with an initial stock of the hooks_under_development of 0 hooks, a prior-knowledge of 10 hooks about the subject matter, an initial interest_in_subject of 0.01 (1%) and an initial quanity_of_info of 0 hooks. The other initialization values are as defined and assumed in the List of Equations (Appendix I). The time horizon for the model is assumed to be 45 normal minutes, namely the length of a regular lecture.

As the lecture starts, the flow of lecturing_ sends the desired quantity_of_info to the mind of the learner. The form learner begins to receive the information at the rate of taking_. At this stage, as each piece of information moves to the stock of hooks_under_development, it will be classified, coded, and adjusted as well. The stock of hooks_under_development represents the learner's Short-Term Memory (STM) in real life. To be consistent with the reality, the model assumes that some information is leaked from the stock and has gotten lost during the information-taking process at the flow rate of waste_. As discussed earlier, the rate of waste_ is controlled by waste_fraction. Again, as mentioned earlier, the value of waste_fraction is determined by two factors: learning_style_incompatibility and the amount of constraints_. Note that the lower the learning_style_incompatibility (say, for instance, both teacher and learner are form-oriented individuals), the smaller the waste_fraction, the lower the rate of waste_ and the higher the level of hooks_under_development.

Therefore, as lecturing_ proceeds, the flow of taking_ sends more hooks to the stock of hooks_under_development. The flow of completing_ takes the information from the upstream stock and places them as the completed hooks in the stock of hooks_for_repetition. The rate of completing_ is reinforced by three factors: the level of student's interest_in_subject (shown as a stock), and the amount of both interest_in_grade, and interest_in_use (shown as converters). If the type of information received by the form-oriented learner is compatible with his or her preferences (almost rote-types), then learning_style_incompatibility between the teaching system and the learner would be at its minimum. Again, the lower the value of learning_style_incompatibility, the lower the waste_fraction, and the less is the variation in the level of student's interest_in_subject.

The stock of hook_for_repetition is represented by a conveyor type stock. The time that it takes that each piece of information finds its location in the episodic memory of the learner's Long-Term Memory (LTM) has been considered as a variable. The inflow capacity and transit time for the conveyor vary for different form-oriented learners. The maximum inflow capacity for the hooks_for_repetition in the base model is assumed to be at most 20 hooks of information. Also, the transit time (the time it takes for each piece of information to get off the conveyor) for the conveyor is assumed to vary. (Refer to the List of Equations in Appendix I)

The flow of repeating_ takes each hook of information from its upstream stock and after required repetition implants it into the student's LTM (hooks_in_memory) as a permanent trace. The rate of repeating_ is regulated by the stock of student's level_of_effort and is reinforced by the impact_of_other_values. Note that three of the student's perception of task value (interest_in_subject, interest_in_grade, and interest_in_use) have been already defined and modeled in the diagram (Fig. 6.9). The impact of the remaining six values (pride in future profession, self-worth, security in future job, social obligation, bandwagon effect and association with something one likes – as discussed in Chapter 4.3), are represented by a single converter for the sake of simplicity.

Maximum level of both hooks_under_development and hooks_for_repetition happen between minute 8 and 9. This can be found from the Table of Base Run in Appendix II or Fig. 6. 10 (Graph of Base Run for a form-oriented learner). This fits the reality quite well, especially when one notices the large amount of new information that is usually presented by the teacher right at the beginning of each lecture. Normally, as the lecture proceeds, the rate of the presentation of new information decreases and the content of the lecture, more or less, is focused around the expansion of the topics that are presented in the beginning of the lecture.

The maximum level of hooks_in_memory happen at the end of the simulation period and is approximately about 15 hooks. The maximum interest_in_subject is about 0.7 (out of 1.0) and again happens at the end of the lecture. Also, the level_of_performance reaches its maximum; 60 out of 100, at the end of the period. Again, this value can be read either from the Table of Base Run in Appendix II or from Fig. 6.10.

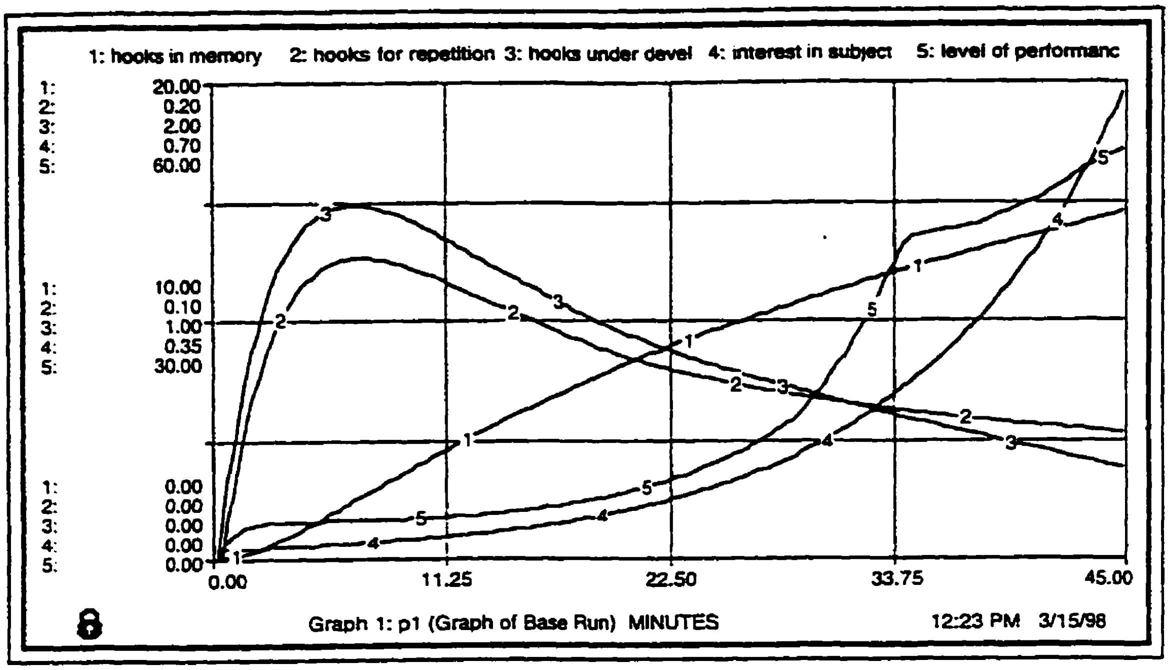


Fig. 6.10: Graph of Base Run for Form-oriented Learner (Part I)

The simulation may be run for the analysis of other variables as well. Note that Fig. 6.11 demonstrates a second graph of Base Run for the other five major variables. As shown in the graph, the flow rate of waste_ reaches its maximum at minute 7 and then keeps descending at an almost uniform rate as the lecture proceeds to the end. The reason why the rate of waste_ is at its maximum at minute 7 may be found in the large amount of new information that is normally delivered by the teaching system at the beginning of the lecture. The sharp ascending pattern of the graph for the first 7 minutes fits nicely with what is happening in the reality. Interestingly, as the teacher gives more explanation about the topics (learning objectives), which usually happens after the first 5-7 minutes, the rate of waste_ then decreases.

Two variables, amount_learned and productivity_, follow a common track. Both variables show a continuous increasing trend. These two variables have been defined, simply by using the cognitive algebra concept, as discussed in Chapter 3, as shown below:

amount_learned = prior_knowledge + hooks_in_memory

and productivity = (amount_learned) / prior_knowledge

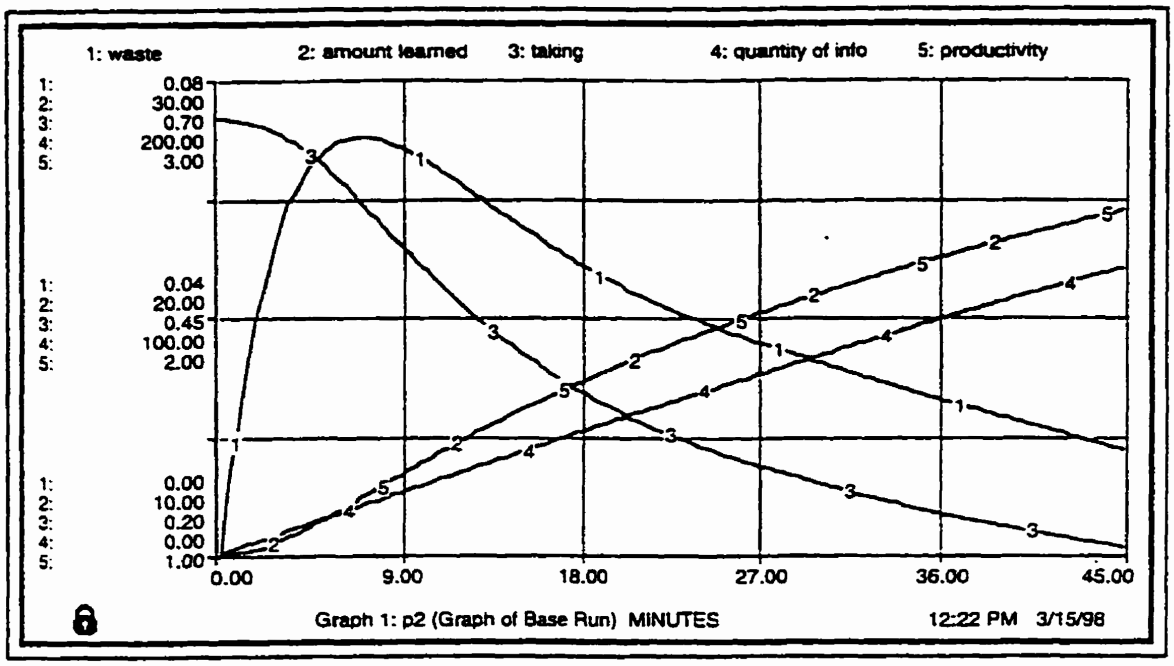


Fig. 6.11: Graph of Base Run for Form-oriented Learner (Part II)

Note that the simulation begins with a prior_knowledge of 10 and the hooks_in_memory of 0 hooks. This means that the initial productivity_ is equal to one. At the end of lecture, the form-oriented learner acquires 14.5 more hooks and consequently the productivity_ ratio increase to 2.45.

Also, the flow of taking_ starts at an initial rate of 0.7 hooks per minute and ends at a rate of 0.2 hooks per minute. In the mean time, the quantity_of_info delivered by the teaching system starts at 0 and is accumulated at the final level of 200 pieces of information by the end of the lecture. The patterns of behavior of these two variables over time seem very promising. As the lecture proceeds, the learner gets more detailed information about the topics at hand, becomes more familiar with the subject matter, and consequently adjusts (reduces) his or her rate of taking_ accordingly.

As mentioned earlier, the behavior of any other variable can be simulated and tracked on the similar graphs (or tables). The Table of Base Run in Appendix II shows the behavior of all of the variables involved in the simulation model over 45 minutes of a typical lecture period. The interested reader can refer to this table and observe how each variable within the base model changes value minute after minute.

6.3.4 Experimental Runs

A number of experiments (8 – 10) were carried out with the simulation model in line with step 4 and 5 of system dynamics method (Chapter 4.1). The intention was to examine different policy alternatives and to determine which policies show the greatest promise. The alternatives were chosen mainly from the experience of the analyst and also from intuitive insights generated during the first three stages of the system dynamics. Although, in a complex system like teaching/learning, there would be many competing criteria for defining failure or success, nevertheless different scenarios of favorable performance might be identified. In addition, the better alternative behaviors would often come from changing the system base structure.

To keep concise, only four experiments are discussed in this section. These simulation experiments were carried out to gauge the effects of prior-knowledge, memory_info, and rote_type (questions) as policy variables on the learning behavior of the form-oriented learner. All of these variables have been chosen intentionally. Prior knowledge represents one of the student's trait variables in the model, while memory_info and rote_type represent the characteristics of subject matter and teaching system respectively.

<u>Experiment # 1</u>:

A sensitivity analysis was made of the student prior-knowledge for 10, 20 and 30 hooks of information to gauge its effect on the rate of completing_ (Fig.6.12a).

<u>Experiment # 2</u>:

A sensitivity analysis was made of the memory_info for the weight factor of 5, 10, and 15 to gauge its effect on the productivity_ of the form-oriented learner (Fig.6. 12b).

<u>Experiment # 3:</u>

A sensitivity analysis was made of the memory_info for the weight factor of 0, 5, and 10 to gauge its effect on the level_of_perormance of the form-oriented learner (Fig. 6.12c).

<u>Experiment # 4:</u>

A sensitivity analysis was made of the rote_type (questions) for the weight factor of 0, 5, and 10 to gauge its effect on the student's expectancy_ for a mark_of_desire (Fig. 6.12d).

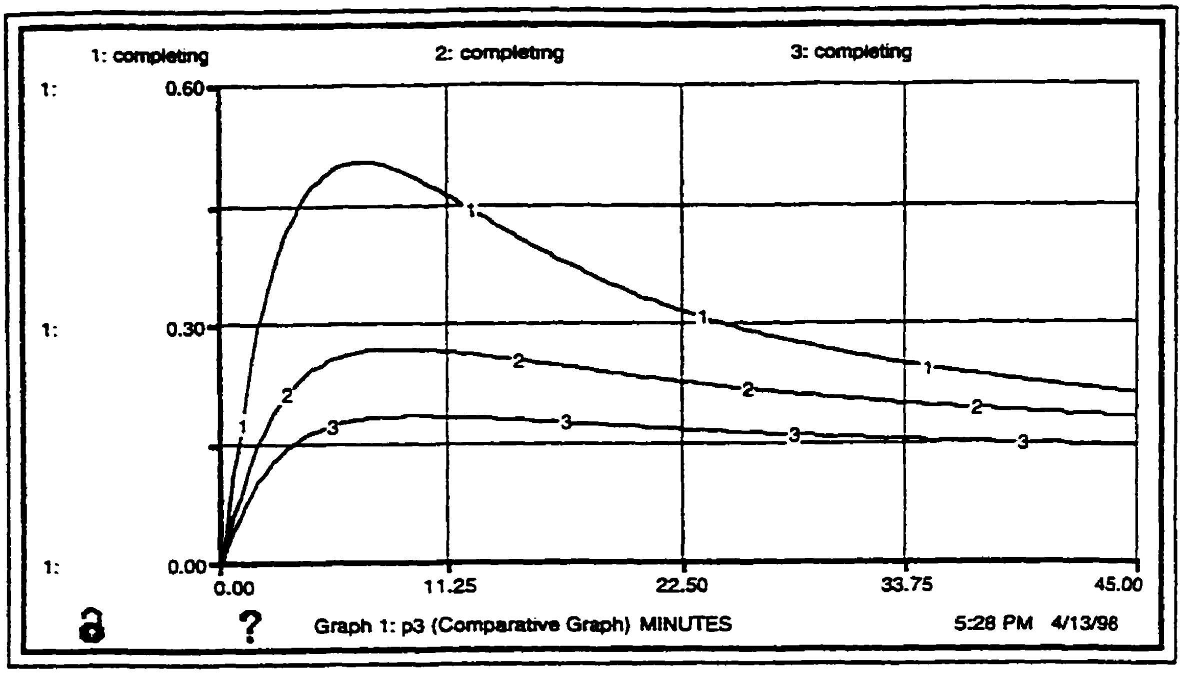


Fig. 6.12a: Comparative Graph for Experiment 1

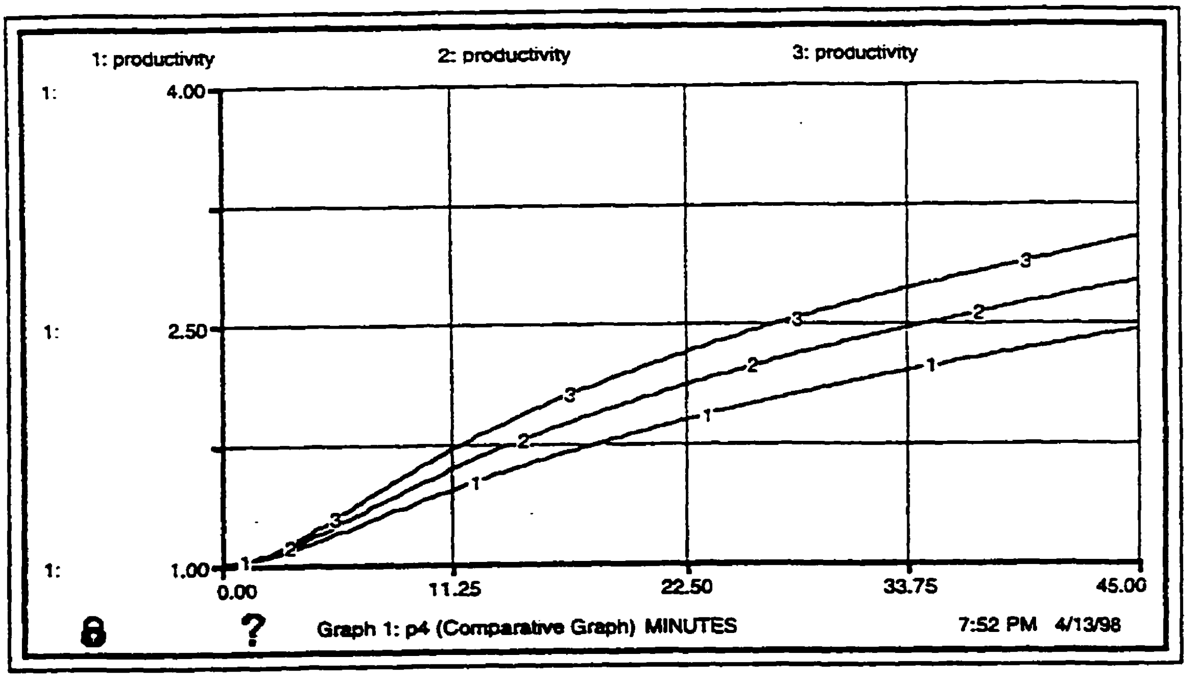


Fig. 6.12b: Comparative Graph for Experiment 2

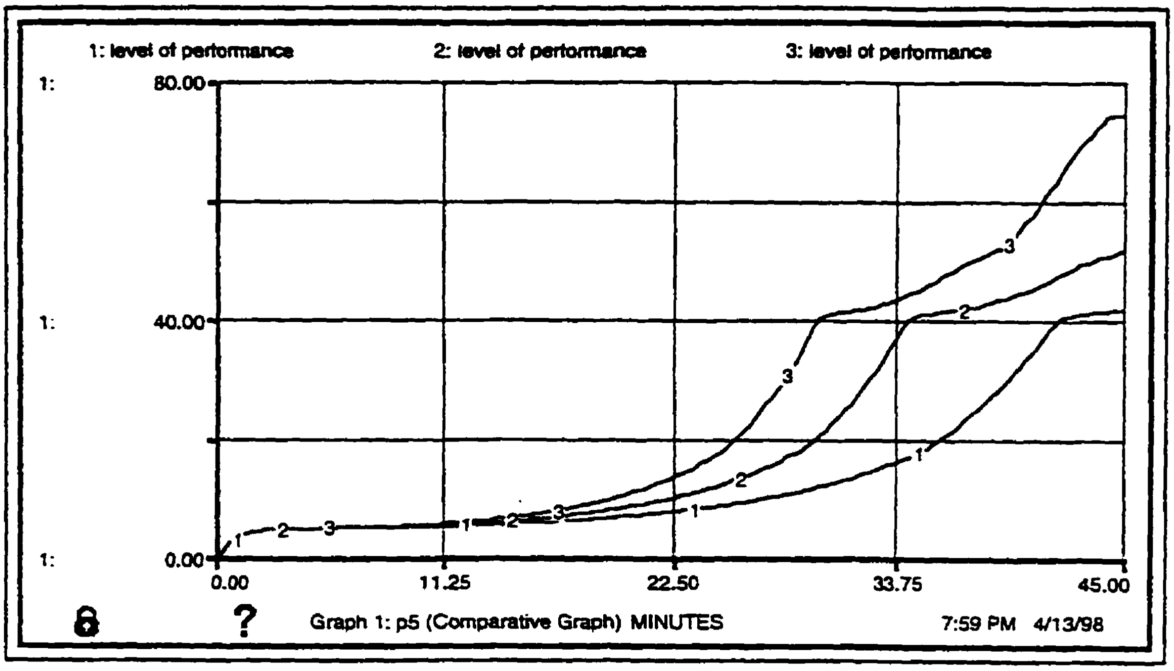


Fig. 6.12c: Comparative Graph for Experiment 3

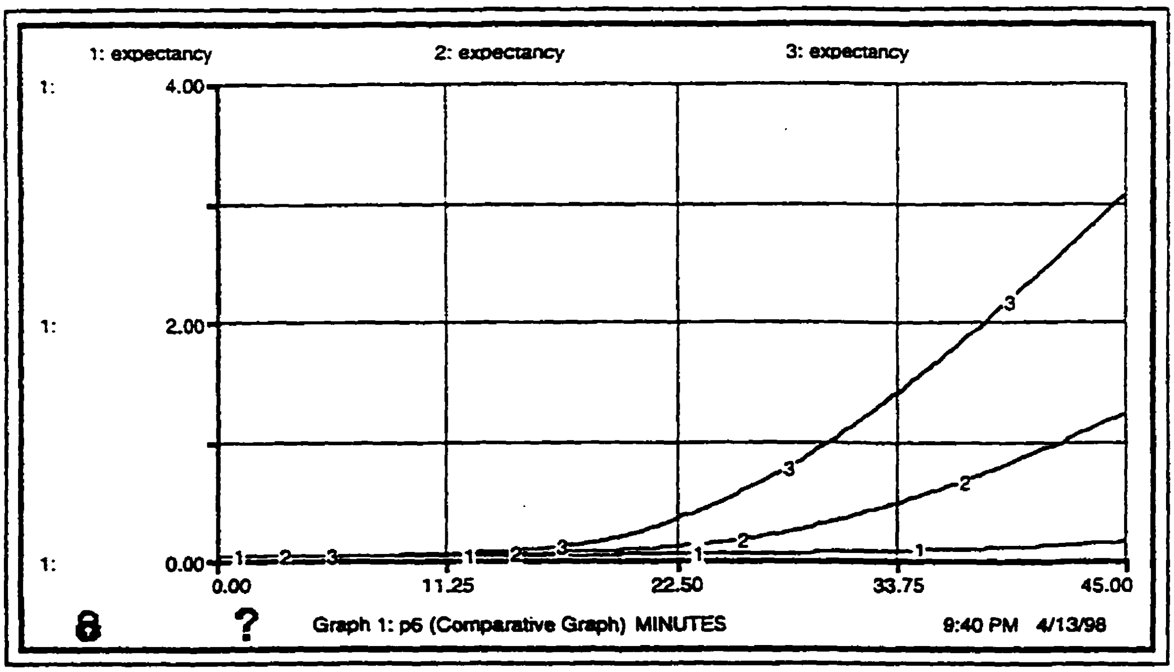


Fig. 6.12d: Comparative Graph for Experiment 4

Effects of other policy variables like interest_in_subject, learning_style incompatibility, quality_of_teaching, level_of_effort, and other_reinforcers have been investigated as well. However, the discussion of results of the above four experiments would suffice and serve the purpose of this study.

6.3.5 Results of Experiments

To examine the results of the above experiments, the data at four points of interest (minutes 11.25, 22.5, 33.75 and 45.0) were extracted from Fig. 6.12a, 6.12b, 6.12c and 6.12d respectively, and tabulated as shown in Table 6.2. The similar results of the Base Run are also included, so then the changes in the learning "behavior" of the form-oriented learner would be more obvious. Note that the data of Base Run for minutes 11.25, 22.50, 33.75 and 45.00 have been extracted from the Table of Base Run in Appendix II.

Rate of completing_, productivity_, level_of_performance, and expectancy_ are taken as the measures of change in the behavior of the system. These choices look reasonable as everything runs on the rate of acquisition of knowledge (here, in this case, on the rate of completing_ new hooks of information in the memory). Besides, the level of the acquisition of knowledge could be evaluated based on the productivity_, level_of_performance, and the expectancy_ of the form-oriented learner, for his or her mark_of_desire.

The results of Experiment #1 indicate that the higher the initial level of prior-knowledge about the subject, the lower the student's rate of completing_ would be. This means that a form-oriented learner with more prior_knowledge about the subject at the beginning of the lecture, is more "efficient" in absorbing the new incoming pieces of information and hence, more relaxed in processing the information (here, read it as: slower in the rate of completing_ hooks of information in his or her memory).

The difference in the rate of completing_ is more evident at the beginning of the lecture. As shown in Fig 12a, for all of three runs, the rate of completing_ reaches its maximum in the first ten minutes of the lecture and then keeps decreasing for the rest of the lecture. Note that this pattern of behavior is quite consistent with what happens in

Table 6.2: Results of Sensitivity Analysis

Measure of Behavior		Minute 11.25	Minute 22.5	Minute 33.75	Minute 45
Base Run (prior_knowledge = 10.0)					
	completing_	0.46	0.31	0.24	0.21
	productivity_	1.45	1.885	2.19	2.45
	level_of_performance	4.97	9.60	38.38	51.44
	expectancy_	0.01	0.05	0.23	0.66
Experiment # 1 completing_					
prior_knowledge:	Run 1 = 10.00	0.46	0.31	0.24	0.21
	Run 2 = 20.00	0.26	0.23	0.21	0.18
	Run 3 = 30.00	0.18	0.17	0.16	0.15
Experiment # 2 productivity_					
memory_info:	Run 1 = 5.00	1.46	1.90	2.20	2.45
	Run 2 = 10.00	1.65	2.12	2.48	2.75
	Run 3 = 15.00	1.73	2.32	2.73	2.98
Experiment # 3					
level_of_peformance					
memory_info	Run 1 = 0.00	4.90	7.70	16.0	42.0
	Run 2 = 5.00	4.97	9.60	37.33	51.44
	Run 3 = 10.0	5.05	14.0	44.0	75.0
Experiment # 4 expectancy_					
type_of_info	Run 1 : 0.00	0.08	0.10	0.15	0.022
	Run 2 : 5.00	.09	0.15	0.50	1.30
	Run 3 : 10.00	0.10	0.38	1.40	3.12

reality in the teaching/learning environments. Upon beginning a lecture, the teacher usually starts with the presentation of the topics and introduction of the learning objectives. Then, s/he uses the rest of the time of the class, to expand around each topic and go into the details. The student, on the other side, knows well that s/he must build more hooks of information in the beginning to hang the other information incoming later onto them. (Refer to Chapter 5 - Fig. 5.6a and 5.6b and see the example short lecture experiment that shows how a form-oriented learner treats incoming information in the beginning of the lecture.)

Comparing the values of completing_ at minutes 11.25, 22.5, 37.75, and 45 implies another finding. With a prior_knowledge of 10 hooks (Base Run), a student has a harder job to do in contrast with a student with a prior_knowledge of 20 or 30 hooks. In fact, as the prior_knowledge about the subject increases, the rate of completing_ shows a more promising pattern of behavior. For instance, the rate of completing_ for a student with prior knowledge of 10 (Run 1 in Experiment # 1) varies in a larger span than of the student with a prior_knowledge of 20 (Run 2 in Experiment # 1) or 30 (Run 3 in Experiment # 3). This can be seen in the diagram of Fig. 6.12a. The rate of completing_ for Run 1, starts at 0 in the beginning, reaches its maximum (0.50) at minute 7, and ends up to 0.21 hooks per minute at minute 45. Compare these values with the values of completing in Run 3. Here, the rate of completing_ starts at 0 in the beginning, reaches its maximum (0.18) at minute 8, and ends up to 0.15 hooks per minute at minute 45. What are the differences? Obviously, the form-oriented learner in Run 3 has an average completing_ rate of about 0.15 – 0.18 hooks per minute over the whole period of the lecture except for the first few minutes, which is normally expected. This, of course, may be interpreted as less pressure on the student's mind and more stable behavior in the process of knowledge acquisition. Run 2 shows a similar pattern as Run 3.

On the other hand, according to the results of Experiment # 2, as the teacher puts more value on the memory_info and delivers a lecture with a higher content of memory-type information, the form-oriented learner's productivity_ would be higher. As shown in Fig. 6.12b, doubling the memory_info content from 5.00 to 10.00 would result in, more or less, about a 10% increase in the student's productivity_. Even another increase, this time 50%, would give a better productivity_ (Run 3 in Table 6.2). Again, this fits very well with the reality if one notes that a form-oriented learner is highly productive when s/he receives information in his or her type of preference. Worth mentioning is that if the teacher uses other rote-type information like relrote_info and procedure_rote in his or her lecture, the pattern of the behavior would be similar to that shown in Fig. 6.12b.

Conversely, if the teacher gives a lecture with more stress on relreal and procedure_real, the form-learner definitely will be in trouble and his or her productivity_ will decrease. Experiment # 3 is to gauge the effect of the same input variable (memory_info) on the student's level_of_performance. As shown in Fig. 6.12c, if the teacher uses no memory_type_info in his or her lecture, the form-learner's achievement falls below the "passing zone" and is about 42%. In such cases, the teacher most likely is a function-oriented individual and the form-oriented student will be at risk. In contrast, as the teacher uses memory_type info with 5 or 10 weight factors, the student's level_of_performance increases to 51.44% and 75% respectively. Interestingly, the doubling of memory_info content from 5 in Run 2 to 10 in Run 3 results in about 50% increase in the student's level_of_performance. The model assumes that the continuous assessment of the student's achievement during a lecture is feasible and practical.

Experiment # 4 is complementary to Experiment # 3 and demonstrates the effect of different types of testing_ on the student's expectancy_. Testing_ could be occasional short oral questions during the lecture or a written short quiz. The important issue is the type (or orientation) of testing_. If the teacher asks no rote_type questions (memory oriented yes-no, true/false, short/long answers questions) in his or her testing_, the form-oriented learner presumes a lower level of expectancy_ for success, in obtaining a passing grade. In this case, the teacher most likely is a function-oriented individual and hence, the form-oriented student would be definitely at risk. Apparently, as the teacher uses rote_type questions in his testing_ , say, for instance, at a weight factor of 5 (Run 2 of Fig. 6.12d), then the student's expectancy_ rises considerably and results in a higher mark_of_desire accordingly. Furthermore, if the teacher doubles the amount of rote_type questions (Run 3 of Fig. 6.12d), the student's expectancy_, more or less, increases by 150% (Table 6.2). Once more one can observe the role of different types of issuing information by a teacher, whether they are part of "main set" or "auxiliary set," as defined in Chapter 5.3, on the student's achievement.

6.4 Learning Model of a Function-Oriented Learner

6.4.1 Description of the Base Model for a Function-Oriented Learner

As mentioned in section 6.2, the system flow diagram for the learning process of a function oriented learner is the same as Fig. 6.9 except for the main chain of the model. (Refer to Table 6.1: Defined Variables for the Proposed Models of Teaching/Learning Process.) To be brief and to prevent mentioning repetitive material, in this section, only the main differences are discussed.

The main chain of the system flow diagram for the learning process of a function-oriented learner is shown in Fig. 6.13. The definition of each variable except for the main chain is the same as described in the List of Equations (Appendix II). The definition of each variable in the main chain is given as the following.

Referring to Fig. 6.13, the main chain infrastructure represents a sequence of stages through which the information flows in the mind of a function-oriented learner. Note that the specific nature of flows varies, depending on the specific situation of each stock. The chain is fed by a single flow (taking_). A non-conserved system is demonstrated by the stock of relationships_under_study. The cloud on the left hand side

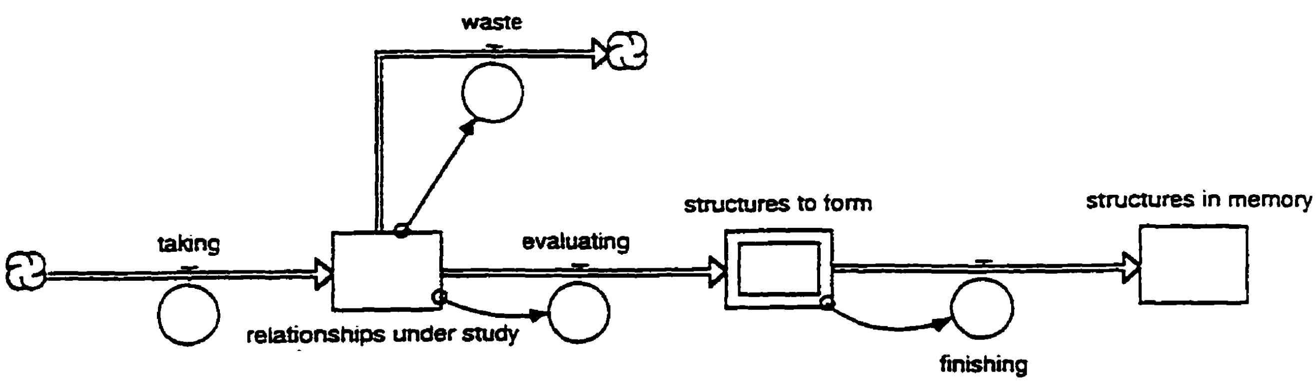


Fig.6.13: Main Chain of the System Flow Diagram for a Functrion-oriented Learner

of the flow of taking_ depicts the boundary of the model. It represents an infinite source for the taking flow, as shown. Again, for the purpose of this model, it does not matter what is in the cloud.

In this model, flow or taking_ is receiving each piece of the incoming information from the teaching system and placing it into the mind of the function-oriented learner (stock of relationships_under_study). The flow of waste_ drains the stock of relationships_under_study at a rate that is controlled by the level of the stock itself and the waste_fraction (not shown in the diagram).

Flow of evaluating_ takes the relationships from the stock of relationships_under_study and places them in the stock of structures_to_form. In fact, each incoming information to the mind of the function learner is seen as for a relationship that has to be evaluated in view of its significance.

As shown in the diagram, an oven-type stock represents the state of structures_to_form in the mind of a function-oriented learner. Two interesting points are worth mentioning. First, by assigning different capacities and fill time to the oven, different types of function-oriented minds can be detailed and modeled. Capacity tells how much information the oven can hold. The oven will close its doors and begin processing its contents when capacity is reached, or fill time is expired - whichever comes first. Note that both capacity and fill time may be assigned small or large values, and so, make the analyst's job easy or difficult. Second, oven cook time (processing time) can be set to a constant or it can be made variable. In so doing, different situations can be defined for a function-oriented learner. For example, if the teacher is a form-oriented individual and delivers memory type information rather than relationship-type information, which is the student's more preferred type information, the oven can be set to use long fill times and small capacity to represent capacity-constrained situations.

Finally, the flow of finishing_ completes the learning task by taking each would-be-structure from the stock of structures_to_form and placing it into the stock of structures_in_memory. The flow of finishing_ is under the direct influence of the amount of the structures_to_form and level_of_effort (not shown in the diagram). In other words, acquisition of knowledge is viewed as student effort-based activity as well. Knowledge is acquired by the function-oriented type student when s/he puts effort into the learning task over a certain period of time as defined.

6.4.2 Feedback Mechanisms

The same number of feedback mechanisms as discussed for the model of form-oriented learner are included in the model. Similarly, two of these loops have a major effect on the resulting behavior of the learner. As discussed in 6.3.2, both of these loops act in parallel along the main chain, running from the stock of relationships_under_study to the stock of structure_in_memory, and from there each diverts in a different direction. For the sake of brevity, the material will not be repeated here.

6.4.3 Behavior of the System

The behavior of the system is the same as discussed in section 6.3.3 (for the form-oriented) learner. By assigning initial values to each of the stocks and converters, the simulation model may be run. The initialization values could be defined and assumed in the same way as described in the List of Equations for the form-oriented learner (Appendix I). The time horizon for the model is assumed to be as 45 minutes, that is; the length of a regular class lecture.

The only main difference between the two models is the nature of the pieces of information that are flowing through the main chain. In the case of a form-oriented learner, the nature of knowledge was based on the hooks of information. In contrast, in the case of a function-oriented learner, the nature is based on the structures of information. The model has properly taken care for this difference. The use of a conveyor type stock in the form-oriented case and an oven type stock in the function-oriented account for this major difference.

6.5 Assumptions and Simplifications

The proposed form-function model of teaching/learning in this chapter is the first attempt in a chain of models that will evolve from this study. The structure of the present model provides a principal backbone for future models that necessarily will have more complicated components and linkages. However, while the present model includes all the major variables of a teaching/learning process, it is founded on a few assumptions to maintain its simplicity at this stage. These assumptions as well as simplifications are as follows:

1. Because of the imprecise non-physical nature of a teaching/learning process, any attempt to model this process in a quantitative manner must be influenced by the subjective experiences, backgrounds, and beliefs of the modeler. Therefore, in the system dynamics model presented here, one must expect a degree of subjectiveness in the selection of variable values used in the equations. The values are based on the "best judgement" of the researcher. Clearly, any other researcher might end up with a different set of values. This in no way invalidates this work.
2. Since modeling is an emerging process, any "model" represents only one of a sequence of models, that provide insight to the situation and form a basis for continued evolution. The model worked on in this study is presented in this spirit. This model is to be viewed as a vehicle that can be used to identify the important dimension of form-function orientation for implementing policies and tracing the resulting behavior of a teaching/learning process.
3. The focus in the proposed model is mainly on the learner or learning side of the system. The reason can be seen in the fact that the two other sides of the system, teaching system and subject matter, have complementary roles in a teaching/learning system and serve the learning side. Hence, the characteristics of the teacher system and the subject matter are not defined and detailed like the learning side in the proposed model. Each of these sides should be detailed and worked out in a sub-model with its characteristics' constituents.
4. The obtained results are valid only for the particular student under the conditions and limitations defined in the boundary of the system. Each individual student, whether form-oriented or function-oriented, has his or her particular traits that in similar situations may give or not give rise to an identical pattern of behavior.
5. The only student's task value that is represented by a stock-flow combination in the proposed model is interest_in_subject. The two other major student task values

namely, interest_in_use and interest_in_grade have been introduced by simple converters. While, it is assumed that these two values remain constant during the time of study (i.e., during a 45 minutes normal lecture), nevertheless, this assumption is not so far from reality. Considering their negligible change in short-term, these values cannot vary much to any extent during a limited lecture period.

6. Also, all of the other values (pride in future profession, self-worth, security in future job, social obligation, association of the task with something one likes, choice of subject, and bandwagon effect) are presented with a single converter (other_values). Each of these values is a complex variable that demands to be defined separately and be assigned an appropriate weight factor. Needless to say, some of these variables have reciprocatory inter-relationships with each other.
7. Willingness_, despite its complexity, also has been represented by a single entity. This major learning driver should be demonstrated in its own stock-flow combination. To reduce the weight of this inadequacy in the present model, willingness_ is defined as a graphical function and is represented by a graph that is a function of changes in the student's expectancy_.
8. Only two external reinforcement factors, quality_of_teaching and testing_ (method of assessment), have been defined in the model. The other five factors (institutional factors, nature and content of the task, feedback from the teacher, satisfaction with the university, and interpersonal relations) are represented by a single converter (other_reinforcers). In a more complete model of teaching/learning, these factors should be represented by separate entities. Also, the interactions between the reinforcement factors themselves have not been shown (i.e., effect of quality_of_teaching on testing_ and vice versa). However, the effect of these interactions in a short term (during a lecture period) is minor and may be neglected.
9. "Knowledge" is the sole content of all of the flows and stocks that are located on the main chain of the model. It is assumed that the unit of knowledge taking, knowledge processing, and knowledge storing for a form-oriented learner is well represented by "hooks of information." On the other hand, the unit of knowledge-taking, knowledge-processing, and knowledge-storing for a function-oriented learner is assumed to be well represented by "structures."

10. Other miscellaneous assumptions and simplifications that have been made but are not limited to absence of some environmental variables in the model, continuity of testing_, introducing productivity_ (that seems somehow in conflict with the basic concept of productivity), availability_ (that does not seem to be a perfect term for the concept it represents), simple approach to the definition amount_learned and some other minor items.

6.6 Summary and Conclusion

The modeling effort made on the learning process in this study is a unique combination of educational metrics and engineering simulation programs. On one side, the work consists largely of inferences drawn from available educational experience and viewpoints with an absence of a defensible, universal mechanism. On the other side, it relies heavily on a series of activities drawn from a methodology of system dynamics to build a solid engineering framework for the reinforcement and improvement of the process.

The four sensitivity analyses discussed earlier in this chapter demonstrate that the behavior of the proposed model seems quite persuasive and promising. At the same time, the four example experiments attest to the strength of the system dynamics approach in predicting changes in behavior of a learner when using different policy actions. The important characteristic of the methodology used here is its power to show the insight of the system or the understanding of what is happening in the system. As one can observe, unlike methodologies that focus only on an ideal future condition for a system, system dynamics reveals the way one arrives at the present and then, in a later step, the path that leads to improvement.

The simulation tests described in this chapter, determine which policies show the greatest promise and how the study can work toward a consensus for implementation of the policies. Influence of a combination of two or more policies on the behavior of the system can be examined as well. For instance, in the model of a form-oriented student, a learner at prior-knowledge of 20 interacting with a type_of_info of 10 (issued from the teaching system) can be taken as an alternative option. In general, by comparing the resulting behavior of the learning system under different options, the most appropriate policy or course of action can be identified. This step, would eventually, direct the study to the last step of system dynamics (Chapter 4.1). In fact, this study is now at a position that can make a conclusive statement related to the results of the experiments. The conclusive statement will clarify the standpoint of this study on how one can implement changes in the policies and structure of a teaching/learning system for the purpose of its improvement.

One can thus concludes that: The Base Model for a teaching/learning system, and all of the experiments performed by the study on the Base Model, were strongly under the influence of the *form-function dimension* of the learners and the teachers. This dimension is so powerful that has a primary role in analyzing any teaching/learning process. The literature search in this study (Chapter 2 and 3) bears witness to many dimensions and aspects that exist in the field of teaching and learning. However, what this study has done is to highlight a dimension that by itself takes into account all of the other dimensions (i.e., lecturing, discussion, demonstration, etc.).

Chapter 7
Conclusion

The proposed form-function theory for the types of learner, provides a new ground for analyzing, understanding, and re-engineering of the teaching/learning processes. This theory is based on a "systems as cause" thinking approach and, hence, looks at the systems or processes as the cause of their performance as opposed to their performance being merely determined by outside forces. By conceptualizing how form-oriented and function-oriented learners and teachers really work and interact with each other (their "physics"), the theory provides a better likelihood for understanding how to make a teaching/learning system work better. The proposed theory is a powerful vehicle for measuring intangible variables that are involved in teaching/learning systems. In this chapter, a summary of the research and directions for further work is provided.

7.1 Synopsis

This study opens a new frontier in the field of engineering education and cognitive ergonomics by combining education metrics and industrial engineering techniques. The main intent is to determine how to model a teaching/learning system for a subject taught to engineering students, and how to use the model to help predict consequences of changes to the inputs, the process, and the outputs of the system. The model is based on the interaction between three major sets of components in the system:

- The learner's learning abilities and motivation,
- The teaching system's characteristics
- The nature and quality of the subject matter

The answers to two fundamental questions raised from the interaction of the above forces, namely: (a) *what* should be taught to *whom*, and (b) *how* should *it* be taught are dealt with in an engineering perspective. The study employs a combination of three soft approaches; system thinking, system dynamics and soft operation research (soft OR), to investigate the different components of the above forces and to find answers to the above questions. This research also attempts to help answer the two questions of *how what* should be taught should be taught by teaching systems, and similarly *how what* should be learned would be learned by different types of learners.

Through investigation for a dynamic model of a teaching-learning system, the research conceptualizes, solidifies, and validates a new theory about the different types of minds that learners possess. The new proposed theory is called the *Form-Function Theory of Types* since it deals with two distinctive types of learner defined as Form-oriented and Function-oriented.

The proposed theory suggests that learners, in general, possess either *form* or *function* minds. Form-oriented learners are interested in the way things look and intend to find answers to *what* and *how many* type questions. On the other hand, function-oriented learners are interested in the way that things function and like to know *why* and *how* things work. Depending on the intensity of their *form* or *function* orientations, the learners' acquisition of knowledge are totally different. The proposed theory in this study provides a new challenge in defining the mechanism of *learning* and what is going on in a learner's mind.

The study, in the light of the new theory, subsequently, identifies seven types of learning abilities for each of the *form* and *function* learners as follows:

Form-oriented Learner	Function-oriented Learner
Memorize elements (generate hooks)	Use relationships
Memorize relationships	Use procedures
Memorize procedures	Expand relationships linearly
Bring forward elements (fit/unfit)	Expand procedures linearly
Bring forward relationship (fit/unfit)	Expand relationships nonlinearly
Bring forward procedure (fit/unfit	Expand procedures nonlinearly
Extend by hooking parts together	Expand rel'ships/proc's nonlinearly

The ways of how *form* and *function* learners use their different abilities to take-in information, process it and retrieve new knowledge are analyzed and detailed.

At the same time, in a separate systematic endeavor, this research intends to recognize the different types of information and the way that each type of information is treated with each type of mind. The typical *form* and *function* students, in a number of theoretical trials, were subjected to some example short lectures. Information supplied by the teaching system is categorized to nine different types as follows:

- Only memorizing (rote-type) information
- Relationship-type information (quasi or rote oriented – non-verifiable)
- Relationship-type information (real – cause and effect relationship)
- Procedure-type information (quasi or rote oriented – follow method type)
- Procedure-type information (real – cause and effect oriented)
- Question-type information (true/false, multiple choice or yes/no)
- Question-type information (short answer required)
- Question-type information (closed problem solving oriented)
- Question-type information (open problem solving oriented – most likely needs critical thinking ability)

The lectures are divided into different stages, each of which includes a piece of information with one of the above characteristics. The findings of this research result in creating a preliminary, but solid and logical, shape of how each type of elemental information gets processed in the mind of learners, i.e., what the arrangement of knowledge is in the beginning and at the end of each lecture. Contrasting the original knowledge and the final knowledge as it is arranged in the *form* and *function* minds leads this research to a new edge related to the pattern of knowledge in different minds.

To gain a better insight into the dynamic behavior of the situation, a dynamic model for a teaching/learning system reflects the above findings. This is achieved by using a system dynamics approach and employing a computer simulation program (STELLA Research software). Two different basic structures for a *form* and *function* learner are constructed. The base models are run and the results are compared with observed realities to validate the models. The learning process may be enhanced by the careful choice of the learning material (subjective, objective, and procedural) that the teaching system presents. Other policy variables may be used to show significant performance improvement particularly among students at risk.

The results of this experimentation indicate the power and effectiveness of using industrial engineering modeling techniques in the field of non-physical (non-rigorous) variables of education. Moreover, and more importantly, the proposed Form-Function Theory of Types introduced in this study, facilitates a better understanding of the mechanism of *learning* from one side and *teaching* from the other side. The application of this theory, consequently, would allow educators and education administrators to make necessary changes to the system, with greater knowledge of the ramifications than is presently available.

7.2 Results

Three crucial questions were challenged for appropriate answers on an engineering standard:

1. *What are the types of the minds that learners possess?*
2. *What are the types of incoming information?*
3. *How is each type of information accommodated by each type of mind?*

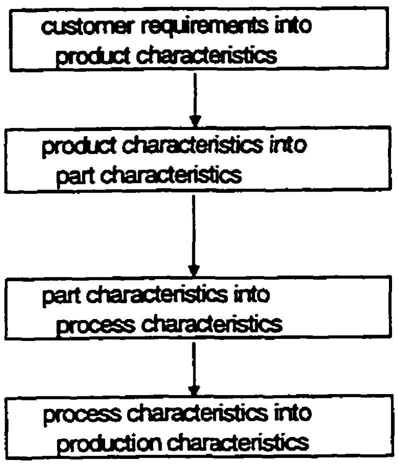
As stated earlier, the Form-Function Theory of Types, discovered by this research, opens a new window to the uncharted area of the teaching/learning processes. It is a powerful scale to measure the uncharted area of minds of learners in a new light and with a better understanding of the dimensions that one is dealing with.

The application of this theory enabled the research to demonstrate the totally different pattern of the build-up of knowledge in the form and function minds. It is an important step forward.

Two dynamic models of teaching/learning worked out by this study are based on continuous phase-type movement of information from the issuing origins (different types of teaching systems) to the receiving destinations (different types of learners). The main result from the models reveals that the advance knowledge about the types of teachers and learners (form-function orientations) warrants an efficient re-engineering of the teaching/learning system.

The results from the simulations provide considerable insight into the operation of any educational system. The types of learners and teachers, whether they are form-oriented or function-oriented, has a major impact on their performance.

Fig. 7.1 is an effort to find the hidden physical-like linkages among the different components of a non-physical system. As shown, the results obtained form the four major findings in this study have been summarized from an industrial engineering perspective:



customer:	different types of student (form, function, in-between)
customer requirements:	refer to 14 defined types of student's abilities plus 10 types of student's perception of the task value
product:	any lecture
product characteristics:	focus is on any technical (engineering oriented) material
part:	each individual information
part characteristics:	refer to 8 defined types of information
process:	teaching system (and teaching environment)
process characteristics:	refer to 7 defined external reinforcement factors
production:	learning process (quantitative increase in knowledge)
production characteristics:	knowledge construction: hooks of info (*form*) and structures (*function*)

Fig. 7.1: Summary of Results

7.3 Implications

The literature survey revealed in this study in Chapter 2 and Chapter 3 demonstrates that there are many dimensions related to teaching/learning processes. However, what this research has accomplished in this direction is the introduction of a new dimension that takes into account all of the other dimensions that are involved in a teaching/learning system.

This research can help decision-makers select a performance parameter that will optimize a given policy variable in a teaching/learning process. The effect of system configuration (form-function orientation of individuals) on the performance of the system can be used to influence the design of the system before the planning stage is implemented. This information is critical in developing an efficient system in both academia and industry.

For technical learning it is extremely important that the learning structure emphasizes function-learning orientation. The required degree or intensity of the function-learning orientation for each technical discipline may be considered as an interesting area of research. Obviously, the field of engineering education has the necessary and sufficient capacity for further investigation in this area. Conversely, in other fields, analysts and researchers have to find a similar measure (or measures) regarding to what extent the learning structure should emphasize on form-orientation.

As stated earlier, with the discovery that this research has made, it is predictable that the education and industry sectors, in general, may have a more cost-effective human resources strategy on one side, and a higher-quality products [2] on the other side. The challenge is that organizations start from their employees and investigate whether each employee's form-function orientation fits with the nature and requirements of their assigned jobs or not.

7.4 Further Research

7.4.1 Approach

The learner's mind should be taken as the central component of the focus in a further study. The traditional motto; "If the learner hasn't learned, the teacher hasn't taught" may be reasonably restated as follows and be taken as a motto for a further study: "If the learner hasn't learned to his or to her learning capacity, the teacher hasn't taught to his or her teaching capacity." Understanding the individuals' minds, their structures, the mechanism of information processing, and the roles of different controllable and non-controllable parameters in a teaching/learning process are the essence of a new study.

Fig.7.2 is an effort to demonstrate the major components in the system. The focus is the box of the "learner's mind" and the direction is to trace and chase each piece of

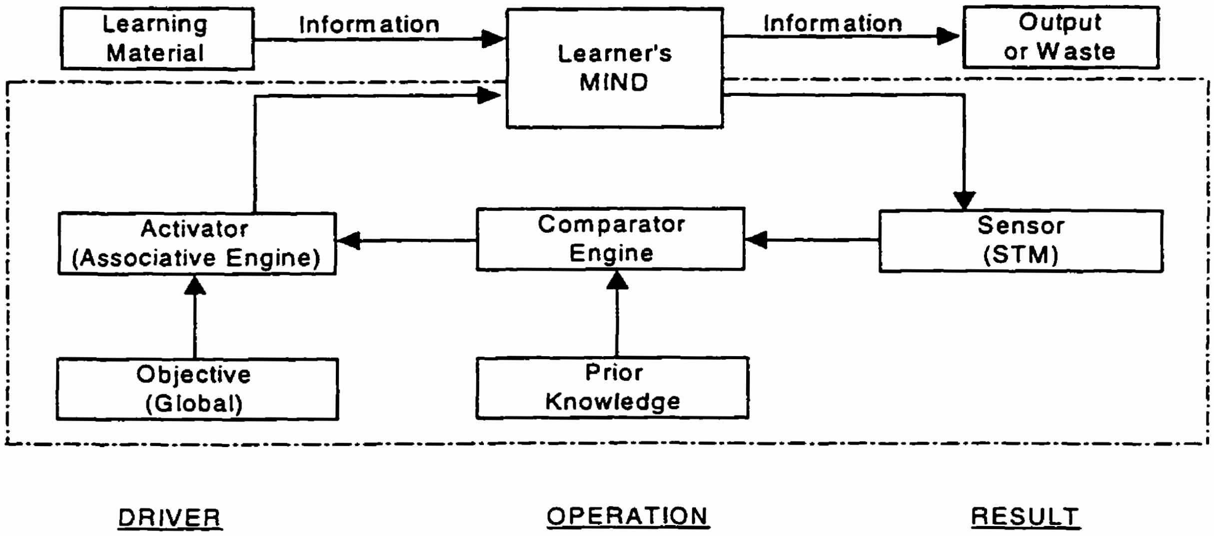


Fig. 7.2: An Engineering Model for Acquisition of Knowledge

information that goes into his or her mind.

Generally speaking, further research should determine the type of incoming information, how it gets into the mind of the learner, how it gets processed, how it gets implanted in the memory, how it becomes a trace of knowledge in the mind, how it is brought forward when it is recalled later and so on.

4.4.2 The Tool

Simulation has much to offer in any research, whether it deals with physical or non-physical systems. The role of simulation to analyze and to evaluate different behaviors of a teaching/learning system were examined in this study. As this research demonstrates, simulation programs could provide the researcher with a greater breadth and depth of information on which to base decisions. In addition, the simulation approach could support sensitivity analysis by allowing rapid changes to a model's logic and data.

Based on the survey made by this study, the most promising simulation program that fits well with the direction for further research in this field, is WITNESS, although it is mainly a manufacturing-oriented software. Considering the fact that flow of information is discrete rather than continuous, this program is the most appropriate tool for future study.

The benefits of the WITNESS approach are that:

- Models can be built and tested in small incremental stages. This greatly simplifies model building, provides the ability to identify errors in the logic and makes the model more reliable.
- The model can be changed at any time during its run. Changes are incorporated immediately, leading to faster model building.
- The simulation program fits well with the direction of this study; that is, the intent to trace and chase each piece of information that moves into the mind of a learner.

References

1. Eftekhar, N., and Strong, D. Dynamic Modeling of a Learning System. Accepted paper for publication in *the International Journal of Engineering Education* (1996). Available on the WWW URL: http://www.ijee.dit.ie/articles/999995/article.htm.

2. Eftekhar, N., Hawaleshka, O., and Strong, D. Activity-Based Costing (ABC): A Response to Budgetary Shortfalls in Higher Education. In B. Schmeiser, and R. Uzsoy (Eds.) *IERC Proceedings of the 4th Industrial Engineering Research Conference*, Nashville, TN, Institute of Industrial Engineers (1995), pp. 622-627.

3. Heizer, J., and Render, B. *Production and Operation Management*. 4th Ed., Prentice-Hall, USA (1996), pp. 4-25.

4. Heizer, J., and Render, B. *Study Guide with Examples & Selected Detail Solutions for Production and Operation Management.* 4th Ed., Prentice-Hall, USA (1996), pp. 3-8.

5. Richmond B., et al. *An Introduction to System Thinking: STELLA Research*. High Performance Systems, Inc., Hanover, NH (1996).

6. Forrester, J.W. System Dynamics, System Thinking, and Soft OR. *System Dynamics Review*, Vol. 10, No. 2-3 (1994), pp. 245-255.

7. Lanner Group, *Introduction to WITNESS*. Redditch, Worcestershire, UK (1996).

8. Eftekhar, N., Strong D., and Hawaleshka, O. Dynamic Modeling of a Learning System to Aid System Re-engineering. In D. Harris (Ed.) *Engineering Psychology and Cognitive Ergonomics*, Vol.2, Ashgate Pub. Co., USA (1997), pp. 105-114.

9. Eftekhar, N., Strong D., and Hawaleshka, O. Toward Dynamic Modeling of a Teaching-Learning System: 1- The Unified Theory. *The International Journal of Engineering Education*, Volume 12, No. 6 (1997), pp. 355-365.

10. Schneider Fuhrmann, B., and Grasha, A.F. The Past, Present, and Future in College Teaching: Where Does Your Teaching Fit? In *Teaching and Learning in the College Classroom* by K. Feldman, and M. Paulsen (Eds.), ASHE Reader Series, Ginn Press, MA (1994), pp. 5-19.

11. Rudolf, F. *The American College and University: A History*. New York, Vintage Books (1965).

12. Bower, G.H., and Hilgard, E.R. *Theories of Learning*. 5^{th} ed., Englewood Cliffs, N.J., Prentice-Hall (1981).

13. Skinner, B.F. *The Technology of Teaching*. New York, Appleton-Century-Crofts (1968).

14. Messick, S., and Associates. *Individuality in learning: Implications of Cognitive Styles and Creativity for Human Development.* San Francisco, Jossey-Bass (1976).

15. Konz, S., *Work Design: Industrial Ergonomics*. 4^{th} ed., Publishing Horizons Inc., Scottsdale, AZ (1995), pp. 2-7.

16. McKeachie, W.J. Research on College Teaching: The Historical Background. *Journal of Educational Psychology,* Vol. 82, No. 2 (1990), pp. 189-200.

17. Feldman, K., and Paulsen, M. (Eds.) *Teaching and Learning in the College Classroom.* ASHE Reader Series, Ginn Press, MA (1994).

18. Mann, R.D. et al., *The College Classroom.* Wiley, New York (1970).

19. Goldschmid, M. L. The Learning Cell: An Instructional Innovation. *Learning and Development,* No. 2 (1971), pp. 1-6.

20. Annis, L.F. The Process and Effects of Peer Tutoring. *Human Learning,* Vol. 2, No. X (1983), pp. 39-47.

21. Marsh, H.W. Student's Evaluations of Teaching: Dimensionality, Reliability, Validity, Potential Biases, and Utility. *Journal of Educational Psychology,* No. 76 (1984), pp. 707-754.

22. Sullivan, A.M., et al. The Relative Effectiveness of Instructional Television. *Interchange,* Vol. 7, No. 1 (1976), pp. 46-51.

23. Keller, F.S. Good-bye, Teacher... *Journal of Applied Behavior Analysis,* No. 1 (1968), pp. 79-89.

24. Cross, K.P. *Accent on Learning: Improving Instruction and Reshaping the Curriculum.* Jossey-Bass, San Francisco (1976).

25. Kulik, J.A., Bangert, R.L. and Williams, G.W. Effects of Computer-Based Teaching on Secondary-School Students. *Journal of Educational Psychology,* No. 75 (1983), pp. 19-26

26. Kulik, J.A., Kulik, C.C., and Cohen, P.A. Effectiveness of Computer-Based College Teaching: A Meta-Analysis of Findings. *Review of Educational Research,* No. 50 (1980), pp. 525-544.

27. Clark, R.E. Reconsidering Research on Learning from Media. *Review of Educational Research,* No. 4 (1983), pp. 445-459.

28. Farrington, G. Bringing Technology to Education. *ASEE PRISM*, Oct. 1996, p. 56.

29. Alexander, S. Teaching and Learning on the World Wide Web. *AusWeb 95: The 1st Australian WorldWideWeb Conference.* Available on the WWW URL: http://www.scu.edu.au/ausweb95/papers/education2/alexander/

30. Marton, F. On non-verbatim learning II – The erosion effect of a task-induced learning algorithm. *Reports from the Institute of Education,* University of Gothenburg, No. 40 (1975).

31. Marton, F. and Saljo, R. On Quantitative Differences in Learning II - Outcome as a Function of the Learner's Conception of the Task. *British Journal of Educational Psychology,* Vol. 46 (1976), pp. 115-127.

32. Svensson, L. *Study Skills and Learning.* Gothenburg, Sweden, Acta Universitates, Gothenburgensis (1976).

33. McKeachie, W.J., Pintrich, P.R., and Lin, Y.G. Learning to Learn in G. d'Ydewalle (Ed.), *Cognition, Information Processing and Motivation,* Elsevier Science Publishers, North Holland (1985), 601-618.

34. Weinstein, C.W., and Mayer, R.E. The Teaching of Learning Strategies in M. Wittrock (Ed.), *Handbook of Research on Teaching,* 3rd ed., New York (1986), pp. 315-327.

35. Hilgard, E.R. (Ed.) *Theories of Learning and Instruction: Sixty-Third Yearbook of the National Society for the Study of Education.* University of Chicago Press, Chicago (1964).

36. Fincher, C. What is Learning? *Engineering Education,* No. 68 (1978), pp. 420-423.

37. Ramsden, P. *Learning to Teach in Higher Education,* Routledge, London, UK (1992).

38. Fincher, C. Learning Theory and Research. *Higher Education: Handbook of Theory and Research,* Vol. 1, J. C. Smart (Ed.), Agathon Press, New York (1985), pp. 63-96.

39. Gagne, R.M. Learning Outcomes and Their Effects: Useful Categories of Human Performance. *American Psychologist,* No. 39 (1984), pp. 377-383.

40. Cooley, W.E., and Lohnes, P.R. *Evaluation Research in Education: Theory, Principles, and Practice.* Irvington, New York (1976).

41. Svinicki, M.D. Practical Implications of Cognitive Theories. *New Directions for Teaching and Learning,* No. 45, Jossey-Bass Publishers Inc. (1991), pp. 27-38.

42. Anderson, L. and Sosniak, L. (Eds.) *Bloom's Taxonomy: A Forty-year Retrospective - Part II.* The University of Chicago Press, Chicago, IL (1994), pp. 15-25.

43. Bruner, J. Models of the Learner. *Educational Researcher,* June/July 1985, pp. 5-8.

44. Baroody, A.J. *Children's Mathematical Thinking: A Developmental Framework for Preschool, Primary, and Special Education Teachers.* Teachers College Press, New York (1987), pp. 7-15.

45. McKeachie, W.J. et al. *Teaching and Learning in the College Classroom: A Review of the Research Literature.* National Center for Research to Improve Post-Secondary Teaching and Learning, Ann Arbor, Michigan (1990).

46. Laurillard, D. *Rethinking University Teaching: A Framework for the Effective Use of Educational Technology.* Routledge, London (1993).

47. Block, H.J. (Ed.) *Mastery Learning: Theory and Practice.* Holt, Rinehart and Winston Inc., New York (1971), pp. 5-7.

48. Carroll, J.B. Model of School Learning. *Teachers College Record,* No. 64 (1963), pp. 723-733.

49. Sjogren, D.D. Achievement as a Function of Study Time. *American Educational Research Journal,* No. 4 (1967), pp. 337-343.

50. Bloom, B.S. Learning for Mastery. *UCLA– CSEIP Evaluation Comment,* Vol. 1, No. 2 (1968).

51. Carroll, J.B. Problems of Measurement Related to the Concept of Learning for Mastery. *Educational Horizons,* Vol. 48, No. 3 (1970), pp. 71-80.

52. McMillan, J.H., and Forsyth, D.R. What Theories of Motivation Say About Why Learners Learn. In R.J. Menges and M.D. Svinick (Eds.) *College Teaching: From Theory to Practice for Teaching and Learning,* No. 45, Jossy-Bass, San Francisco, (1991), pp. 39-52.

53. Weiner, B. *Theories of Motivation: From Mechanism to Cognition.* Rand-McNally College Publishing Co., Chicago (1972).

54. Skinner, B.F. *Science and Human Behavior.* Macmillan, New York (1953).

55. Hull, C.L. *Principles of Behavior.* Appleton-Century-Crofts, New York (1943).

56. Spence, K.W. *Behavior Theory and Conditioning.* Yale University Press, New Haven, Conn. (1956).

57. Atkinson, J.W. *An Introduction to Motivation.* Van Nostrand, Princeton, N.J. (1964).

58. Lewin, K. *Principles of Topological Psychology.* McGraw-Hill, New York (1936).

59. Tolman, E.C. Principles of Performance. *Psychological Review,* No. 62 (1955), pp. 315-326.

60. Weiner, B. *Human Motivation: Metaphors, Theories, and Research,* Sage Publications Inc., USA (1992).

61. Rotter, J.B. Generalized Expectancies for Internal Versus External Control of Reinforcement. *Psychological Monographs,* No. 80 (1966).

62. Ames, C.A. Motivation: What Teachers Need to Know. *Teachers College Record,* No. 91 (1990), pp. 409-421.

63. Brophy, J. Conceptualizing Student Motivation. *Educational Psychologist,* No. 18 (1983), pp. 200-215.

64. Maslow, A. *Motivation and Learning,* Harper & Row, New York (1954).

65. Atkinson, J.W., and Feather, N.T. *A Theory of Achievement Motivation.* New York Wiley (1966).

66. Chickering, A.W. *Education and Identity.* Jossey-Bass, San Francisco (1969).

67. Covington, M.V. The Motive for Self-Worth. In R. Ames and C. Ames (Eds.) *Research on Motivation in Education - Vol. 1: Student Motivation,* Academic Press, Orlando, Florida (1984), pp. 77-113.

68. Pascarella, E.T. and Terenzini, P.T. *How College Affects Students: Findings and Insights From Twenty Years of Research.* Jossey-Bass Publishers, San Francisco (1991), pp. 17-61.

69. Perry, W.G., *Jr. Forms of Intellectual and Ethical Development in the College Years.* Holt, Rinehart and Winston, New York (1970), p. 1.

70. Schunk, D.H. Perceptions of Efficacy and Classroom Motivation. Paper presented at the annual meeting of the American Educational Research Association, Boston (1990).

71. Deci, E. L. *Intrinsic Motivation,* Plenum Press, New York (1975).

72. Weiner, B. Principles for a Theory of Student Motivation and Their Application Within and Attributional Framework. In R. Ames and C. Ames (Eds.) *Research on Motivation in Education - Vol. 1: Student Motivation,* Academic Press, Orlando, Fla. (1984), pp. 15-38.

73. Weiner, B. History of Motivational Research in Education. *Journal of Educational Psychology,* No. 12 (1990), pp. 616-622.

74. Eccles, J., and Wigfield, A. Teacher Expectations and Student Motivation. In J.B. Dusek (Ed.), *Teacher Expectancies.* Erlbaum, Hillsdale, N.J. (1985), pp. 185-226.

75. Bailey, R.W. *Human Performance Engineering: A Guide for System Designers.* Prentice Hall, New Jersey (1982), pp. 148-160.

76. Kroemer, K., et al. *Ergonomics: How to Design for Ease and Efficiency.* Prentice Hall, New Jersey (1994), pp. 132-133.

77. Anderson, N.H. (Ed.) *Contributions to Information Integration Theory, Vol. I: Cognition.* Lawrence Erlbaum Associates Publishers, New Jersey (1991), pp. 48-63.

78. Entwistle, N.J., and Ramsden, P. *Understanding Student Learning.* Croom Helm Ltd., UK (1983).

79. de Bono, E. *Lateral Thinking.* Penguin Books, London, England (1970).

80. Wilson, J.D. *Student Learning in Higher Education.* Croom Helm Ltd. London, UK (1981), pp. 151-165.

81. Biggs, J.B. Dimensions of Study Behaviour: Another Look at ATI. *British Journal of Educational Psychology,* No. 46 (1976), pp. 68-80.

82. Biggs, J.B. What Do Inventories of Students' Learning Processes Really Measure? *British Journal of Educational Psychology,* No. 63 (1993), pp. 3-19.

83. Entwistle, N., Hanley, M., and Hounsell, D. Identifying Distinctive Approaches to Studying. *Higher Education,* No. 8 (1979), pp. 3655-3680.

84. Laurillard, D. *A Study of the Relationship Between Some of the Cognitive and Contextual Factors in Study Learning.* Unpublished Ph.D. Thesis, University of Surrey (1978).

85. Milton, O., Polio, H. R., and Eison, J.A., *Making Sense of College Grades.* Jossey-Bass Publishers, San Francisco (1986), pp. 124-149.

86. Felder, R.M., and Silverman, L.K. Learning and Teaching Styles in Engineering Education. *Engineering Education,* Vol. 78, No.7 (1988), pp. 674-681.

87. Dunn, R., et al. Learning Style Researchers Define Differences Differently. *Educational Leadership,* February 1981.

88. Myers, I. and McCaulley, M. *Manual: A Guide to the Development and Use of the Myers-Briggs Type Indicator*. Consulting Psychologists Press, CA (1985), p. 2.

89. Felder, R.M. Matters of Style. *ASEE Prism,* December 1996, pp. 18-22.

90. Yokomoto, C.F., Buchanan, W.W., and Ware, R. Assessing Students Attitudes Toward Design and Innovations. *Proceedings of Frontiers in Education Conference* (1991).

91. McCaulley, M., et al. Applications of Psychological Type in Engineering Education. *Engineering Education,* Vol. 73, No. 5, February 1983, pp. 394-400.

92. Rosati, P.S. Text Style and Student Learning Style. *Proceedings of ASEE Annual Conference – Reno* (1987), pp. 862-867.

93. Kolb, D.A. *Experiential Learning: Experience as the Source of Learning and Development,* Prentice-Hall, Englewood Cliffs, N.J. (1984).

94. McCarthy, B. *The 4MAT System: Teaching to Learning Styles with Right-Left Mode Techniques.* EXCEL Inc., Barrington, IL (1986).

95. Kolb, D.A. *Self-Scoring Inventory and Interpretation Booklet.* McBer and Co., Boston (1985).

96. Sharp, J.E., Harb, J.N, and Terry, R.E. Combining Kolb Learning Styles and Writing to Learn in Engineering Classes. *Journal of Engineering Education,* Vol. 86, No. 2, (1997), pp.93-101.

97. Sharp, J.E., and Giorgio, T.D. Combined Instruction: Chemical Engineering and Technical Communication – Eleven years Later. *American Society for Engineering Education 1992 Annual Conference Proceedings,* Vol.2 (1992), pp. 1273-1276.

98. Harb, J.N., Durrant, S.O., and Terry, R.E. Use of the Kolb Learning Cycle and the 4MAT System in Engineering Education. *Journal of Engineering Education,* Vol. 82, No. 2 (1993), pp. 70-77.

99. Woods, W.A. and Tindal, M.J. Aspects of Teaching and Learning with Particular Reference to Internal Combustion Engines and Heat Engine. *International Journal of Engineering Education,* Vol. 10, No. (1994), pp. 355-360.

100. Felder, R. and Soloman, B. Index of Learning Styles (ILS). Available on the WWW URL: http://www2.ncsu.edu/unity/locers/users/f/felder/public/ILSpage.html.

101.Rosati, P.S. Learning Preferences Reported by Engineering Students. *Int. Journal of Engineering Education,* Vol. 9. No. 3 (1993), pp. 218-222.

102.Herrmann, N. *The Creative Brain.* Brain Books, Lake Lure, NC (1990).

103.Lumsdaine, M. and Lumsdaine, E. Thinking Preferences of Engineering Students: Implications for Curriculum Re-structuring. *Journal of Engineering Education,* Vol. 84, No. 2 (1995), pp. 193-204.

104.Flammer, G. H. Effective Teaching: A Model of Learning and Learning Efficiency. *Journal of Engineering Education,* February 1987 (Effective Teaching Issue), pp. 268-273.

105.Fuhrmann, B.S., and Grasha, A.F. Toward a Definition of Effective Teaching. In K. Feldman, and M. Paulsen (Eds.) *Teaching and Learning in the College Classroom,* ASHE Reader Series, Ginn Press, MA (1994), pp. 241-252.

106.Feldman, K.A. Effective College Teaching from the Students' and Faculty's View: Matched or Mis-mathced Priorities? *Research in Higher Education,* Vol.28, No. 4 (1988), pp. 291-344.

107.Feldman, K.A. The Association Between Student Ratings of Specific Instructional Dimensions and Student Achievement: Refining and Extending the Synthesis of Data from Multisection Validity Studies. *Research in Higher Education,* Vol.30, No. 6 (1989), pp. 136-194.

108.Kulik, J.A., and Kulik, C.C. Student Rating of Instruction. *Teaching of Psychology,* No. 1 (1974), pp. 51-57.

109.Cashin, W.E. Student Ratings of Teaching: A Summary of the Research. From *Idea Paper # 20.* Published by the Center for Faculty Evaluation and Development at Kansas State University (1988).

110.Norman, D.A. What Goes on in the Mind of the Learner. In W.J. McKeachie (Ed.) *New Directions for Teaching and Learning: Learning, Cognition, and College Teaching,* No. 2, Jossey-Bass Inc. (1980), pp. 37-49.

111.Marton, F. What Does it Take to Learn? Some Implications of an Alternative View of Learning. In N.J. Entwistle (Ed.) *Strategies for Research and Development in Higher Education,* Swets and Zeitlinger, Amsterdam (1976), pp. 32-43.

112.Fransson, A. On Qualitiative Differences in learning. IV: Effects of Motivation and Test Anxiety on Process and Outcome. *British Journal of Education Psychology,* No. 47 (1977), pp. 244-257.

113.Anderson, R.C. Some Reflections on the Acquisition of Knowledge. *Educational Researcher,* Vol. 13, No. 9 (1984), pp. 5-10.

114.Wolstenholme, E.F. *System Enquiry: A System Dynamics Approach.* John Wiley & Sons Ltd., West Sussex, England (1990), pp. 3-9.

115.Forrester, J.W. *Industrial Dynamics.* MIT Press, Cambridge, MA. (1961).

116.Peterson, S., and Richmond, B. *STELLA Technical Documentation.* High Performance Systems Inc., Hanover, NH (1996).

117.Forrester, J.W. *World Dynamics.* MIT Press, Cambridge, MA (1969).

118.Richardson, G.P. and Pugh, A.L. *Introduction to System Dynamics Modeling with DYNAMO.* MIT Press, Cambridge, MA (1981).

119.Roberts, N., et al. *Introduction to Computer Simulation: The System Dynamics Approach.* Addison-Wesley, Reading, MA (1983).

120.Morecroft, J.D.W. System Dynamics and Microworlds for Policy Makers. *European Journal of Operational Research,* Vol. 35 (1988), pp. 301-320.

121.Saeed, K. Slicing a Complex Problem for System Dynamics Modeling. *System Dynamics Review,* Vol. 8, No. 3 (1992), pp. 251-261.

122.Cronbach, L.J., and Snow, R.E. *Aptitude and Instructional Methods: A Handbook for Research on Interactions.* Irvington, New York (1977).

123.Canfield, A.A. *Learning Styles Inventory Manual.* Humanics Media, Ann Arbor, Michigan (1980).

124.Cameron, B.J. (Ed.) *Teaching at the University of Manitoba: A Handbook.* University of Manitoba Teaching Services (UTS), Winnipeg, Manitoba, Canada (1993), pp. 62-78.

125.Rosati, P. Students'Psychological Type and Success in Different Engineering Programs. *ASEE/IEEE Frontiers in Education 97 Proceedings.* Available on the WWW URL: http://fairway.ecn.purdue.edu:80/~fie/fie97/papers

126.Lane, D.C. With a Little Help from Our Friends: How Third-Generation System Dynamics and Issue-Structuring Techniques of "Soft" OR can learn from Each Other? In E. Zepeda, and J. Machuca (Eds.) *System Dynamics*. System Dynamics Society, Lincoln MA (1993), pp. 235-244.

127.Jackson, M.C. *Systems Methodology for the Management Sciences.* Plenum, New York (1992).

Appendices

Appendix I

List of Equations

☐ expectancy(t) = expectancy(t - dt) + (change_in_expectancy) * dt
INIT expectancy = 0.01

DOCUMENT: [1] Expectancy stems from the learner's self confidence which in fact sets his/her mark_of_desire (target level of performance) and willingness (target level of effort). How confident student feels is determining both how well student thinks he should be able to perform as well as how much effort he will put out in order to achieve the level of performance.

INFLOWS:

change_in_expectancy = availability*testing*perceived_assessment/100
DOCUMENT: [1/min] Rate of change in expectancy (in the well-doing of the task) or the rate of change in self-confidence

hooks_for_repetition(t) = hooks_for_repetition(t - dt) + (completing - repeating) * dt
INIT hooks_for_repetition = 0
TRANSIT TIME = varies
INFLOW LIMIT = 20
CAPACITY = 20

DOCUMENT: [H] stock of hooks ready for repetition at current completing rate

INFLOWS:

completing = hooks_under_development*(interest_in_subject+interest_in_use+interest_in_grade)/3
DOCUMENT: [H/min] assuming it takes 3 seconds or 1/20 minute to finish a total new hook or extend a pre-exited hook.

OUTFLOWS:

repeating = CONVEYOR OUTFLOW
TRANSIT TIME = hooks_for_repetition*level_of_effort*impact_of_other_values
DOCUMENT: [H/min] Assuming rate of repeating the available hooks for implanting in the episodic memory.

☐ hooks_in_memory(t) = hooks_in_memory(t - dt) + (repeating) * dt
INIT hooks_in_memory = 0

DOCUMENT: [H] total number of active hooks in episodic memory at this time

INFLOWS:

repeating = CONVEYOR OUTFLOW
TRANSIT TIME = hooks_for_repetition*level_of_effort*impact_of_other_values
DOCUMENT: [H/min] Assuming rate of repeating the available hooks for implanting in the episodic memory.

☐ hooks_under_development(t) = hooks_under_development(t - dt) + (taking - completing - waste) * dt
INIT hooks_under_development = 0

DOCUMENT: [H] Number of hooks of information under construction or extension in the student's mind.

INFLOWS:

taking = forecast_adjustment*lecturing/coding
DOCUMENT: [H/min] assuming the starting rate of building new hooks of info or extending the existing hooks of info.

OUTFLOWS:

completing = hooks_under_development*(interest_in_subject+interest_in_use+interest_in_grade)/3
DOCUMENT: [H/min] assuming it takes 3 seconds or 1/20 minute to finish a total new hook or extend a pre-exited hook.

waste = hooks_under_development*waste_fraction
DOCUMENT: [H/min] Rate of waste of information due to the impact of waste fraction.
Waste fraction is controlled by the compatibility of learning style

☐ interest_in_subject(t) = interest_in_subject(t - dt) + (change_in_interest) * dt
INIT interest_in_subject = 0.01

DOCUMENT: [1] Assuming the level of interest in subject may vary per incoming info.

INFLOWS:

change_in_interest = interest_in_subject*learning_style_incompatibility
DOCUMENT: [1/min] Assuming rate of change in interest (in subject matter) at any time is directly proportional to the rate of lecturing and the level of student's performance.

☐ level_of_effort(t) = level_of_effort(t - dt) + (change_in_effort) * dt
INIT level_of_effort = 0

DOCUMENT: [1] Level_of_effort feeds back to determine level of hooks_in_memory.

INFLOWS:

change_in_effort = (willingness-level_of_effort)*(level_of_performance)*(allocated_time_factor)
DOCUMENT: [1/min] Rate of change in the amount of effort that the rote learner puts in the task of memorizing.

☐ level_of_performance(t) = level_of_performance(t - dt) + (change_in_performance) * dt
INIT level_of_performance = 0

DOCUMENT: [%] Level_of_performance feeds back to determine the learner's effort .

INFLOWS:

change_in_performance = (mark_of_desire-level_of_performance)*productivity
DOCUMENT: [1/m] Rate of change in performance is a function of the amount of effort and time that the rote learner puts into the task (difference of the mark of desire and current level of performance] at any time.

quantity_of_info(t) = quantity_of_info(t - dt) + (change_in_quantity_of_info) * dt
INIT quantity_of_info = 0

DOCUMENT: [H] Assuming the stock level of quantity of info given by the teaching system

INFLOWS:

change_in_quantity_of_info = (target_info-quantity_of_info)*adjustment_fraction
DOCUMENT: [H/min] Rate of change in the quantity of info (number of hooks) given by the teaching system. Teaching system is a form-oriented source so the flow rate of info is based on the number of hooks issued.

UNATTACHED:

lecturing = type_of_info*change_in_quantity_of_info
DOCUMENT: [H/min] Assuming the rate of hooks given by the teaching system per minute.

adjustment_fraction = 0.005
DOCUMENT: [1/min] Assuming it is the required time fraction for the teaching system to adjust any change in the rate of given info.

allocated_time_factor = 0.05
DOCUMENT: [1/min] Assuming time fraction it takes for the rote learner to change his/her effort rate.

amount_learned = prior_knowledge+hooks_in_memory
DOCUMENT: [H] total number of active and unactive hooks

availability = hooks_in_memory*productivity*learning_reinforcers
DOCUMENT: [H] Assuming the theoretical amount of hooks of knowledge available to the learner. Amount of availability is directly related to the level of hooks in the memory and learning reinforcers and indirectly related to the level of starting knowledge(through productivity).

clsd_prbm_slvg = 3
DOCUMENT: [1] assuming the value of a closed-problem solving question assigned by the teacher.

Form teacher = 3
Function teacher = 3

coding = SMTH1(amount_learned, 3)
DOCUMENT: [1] Assuming the average ability to make decision for either starting new hooks or extending old hooks over the past 3 lecture minutes. This indicates the form learner's ability to find the related hooks compatible to the incoming information as per coding system in his/her memory (fit/unfit].

constraints = 0.5
DOCUMENT: [1] Constraints include all impeding factors, whether internal or external to the studentl, that lead to waste in the acquisition of knowledge.

impact_of_other_values = 0.3
DOCUMENT: [1] Assuming average quantified impact of other values:
pride in future prof'n, self-worth, security in future job, social obligation, bandwagon effect, and association with something one likes.

interest_in_grade = 0.5
DOCUMENT: [1] Assuming the amount of interest in the grade for this course.

interest_in_use = 0.5
DOCUMENT: [1] Assuming the amount of nterest in use of the task

prior_knowledge = 10
DOCUMENT: [H] total number of active hooks of information in the student's memory.

procedure_real = 1
DOCUMENT: [1] assuming the value of the "real procedure type of information" in the teacher's view.
Form teacher = 1
Function teacher = 5

procedure_rote = 5
DOCUMENT: [1] assuming the value of the "rote procedure type information" in the teacher's view.

Form teacher = 5
Function teacher = 1

productivity = amount_learned/prior_knowledge
DOCUMENT: [1] Productivity is the ratio of the output (amount_learned) to the input (prior_knowledge).

relreal_info = 1
DOCUMENT: [1] assuming the value of the "real relationship type information" in a teacher's view.
Form teacher = 1
Function teacher = 5

relrote_info = 4
DOCUMENT: [1] assuming the value of the "rote-oriented relationship type information" in the teacher's view.

Form teacher = 4
Function teacher = 2

○ learning_reinforcers = (testing+other_reinforcers+quality_of_teaching)/3
DOCUMENT: [1] Assuming the quantified average impact of learning reinforcers

○ memory_info = 5
DOCUMENT: [1] assuming the value of "only memorizing (rote) type of information" in the teacher's view. The weight is different and depends on the type of the mind a teacher possesses.
Assume: Form teacher = 5
Function teacher = 1

○ opn_prbm_slvg = 0
DOCUMENT: [1] assuming the valuet of an open problem solving question assigned by a teacher.
Form teacher = 0
Function teacher = 3

○ other_reinforcers = 0.3
DOCUMENT: [1] Assuming the quantified average impact of other learning reinforcers (e.g., institutional variables, interpersonal relations, satisfaction with the university)

○ rote_type = 5
DOCUMENT: [1] assuming the value assigned for a rote-oriented type question (e.g. true/false, multiple choice, and short/long answers) by the teacher.

Form teacher = 5
Function teacher = 0.5

○ student's_perceived_availability = SMTH1(availability,2)
DOCUMENT: [H] Assuming the average perceived availability of hooks of information by the student is 2 minutes.

○ target_info = 600
DOCUMENT: [1] Assuming giving each piece of information takes, in average, 3 seconds or 3/60 = 0.05 minutes. Also assuming two-third of time of each 45 minutes-class is spent by pure lecturing, thus:
30 minutes of pure lecture / 0.05 = 600 could be an average target for the number of total pieces of information which is given by a teaching system during a lecture hour.

○ testing = (rote_type+clsd_prbm_slvg+opn_prbm_slvg)/9
DOCUMENT: [1] testing = [1/(w1+w2+w3] * [a * w1 + b * w2 + c * w3]
where
"w" is the weight of each type of question in the teacher's view.
a= No. of only rote type questions
b= No. of only closed-problem solving
c= No. of only Problem Solving

○ type_of_info = (memory_info+relrote_info+relreal_info+procedure_real+procedure_rote)/25
DOCUMENT: [1] value of type of info =
[1/(Wa+ Wb + Wc + Wd +We)] * [a* Wa + b* Wb + c* Wc + d* Wd + e * We]

a= only memorizing info	d= procedure type -real
b= relationship type - rote	e= procedure type-rote
c= relationship type - real	W = Weight %

○ waste_fraction = learning_style_incompatibility*constraints

⊘ forecast_adjustment = GRAPH(student's_perceived_availability)
(0.00, 3.44), (11.1, 3.34), (22.2, 3.14), (33.3, 2.98), (44.4, 2.66), (55.6, 2.34), (66.7, 2.06), (77.8, 1.86), (88.9, 1.62), (100, 0.72)
DOCUMENT: [1] Impact of the amount of available hooks(in memory) on the rate of taking a new piece of incoming info.

⊘ learning_style_incompatibility = GRAPH(lecturing)
(0.00, 0.31), (0.1, 0.245), (0.2, 0.195), (0.3, 0.185), (0.4, 0.165), (0.5, 0.165), (0.6, 0.165), (0.7, 0.15), (0.8, 0.135), (0.9, 0.125), (1, 0.095)
DOCUMENT: [1] Learning style incompatibility is minimum when the lecture is issued by a teacher whose type of mind is similar to the student's type of mind (e.g., both are either function types or form types). It increases as incompatibility tends to increase.

⊘ mark_of_desire = GRAPH(expectancy)
(0.00, 3.00), (0.111, 18.5), (0.222, 40.5), (0.333, 42.0), (0.444, 45.0), (0.556, 49.5), (0.667, 52.0), (0.778, 59.5), (0.889, 68.5), (1.00, 74.5)
DOCUMENT: [1] Assuming Mark of Desire is the rote learner's target level of performance and it is a function of his/her level of expectancy.

⊘ perceived_assessment = GRAPH(level_of_performance)
(0.00, 0.00), (16.7, 0.185), (33.3, 0.3), (50.0, 0.39), (66.7, 0.415), (83.3, 0.435), (100, 0.445)
DOCUMENT: [1/min] Perceived assessment is the perception of rote learner re his/her level of performance at any time.

⊘ quality_of_teaching = GRAPH(quantity_of_info*type_of_info)
(0.00, 0.275), (0.1, 0.285), (0.2, 0.295), (0.3, 0.335), (0.4, 0.365), (0.5, 0.395), (0.6, 0.4), (0.7, 0.43), (0.8, 0.505), (0.9, 0.565), (1, 0.63)
DOCUMENT: [1] Quality_of_teaching depends on the combination of the type and the quantity of presentation.

⊘ willingness = GRAPH(expectancy)
(0.00, 0.29), (0.1, 0.295), (0.2, 0.305), (0.3, 0.32), (0.4, 0.345), (0.5, 0.37), (0.6, 0.41), (0.7, 0.46), (0.8, 0.545), (0.9, 0.63), (1, 0.69)
DOCUMENT: [1] Assuming willingness is inversely proportional to the level of expectancy and is an indicator of the target that the rote learner sets for his/her level of effort at any time.

Appendix II

Table of Base Run

MINUTES	.00	1.00	2.00	3.00	4.00	5.00	6.00
expectancy	0.01	0.01	0.01	0.01	0.01	0.01	0.01
hooks for repetition	0.00	0.04	0.07	0.10	0.11	0.12	0.12
hooks in memory	0.00	0.04	0.25	0.58	0.99	1.45	1.93
hooks under developme	0.00	0.57	0.95	1.19	1.35	1.43	1.47
interest in subject	0.01	0.01	0.01	0.01	0.01	0.02	0.02
level of effort	0.00	0.02	0.06	0.11	0.14	0.17	0.20
level of performance	0.00	3.01	3.96	4.27	4.37	4.42	4.46
quantity of info	0.00	2.99	5.97	8.94	11.89	14.82	17.74
change in effort	0.02	0.04	0.04	0.04	0.03	0.02	0.02
change in expectancy	0.00	0.00	0.00	0.00	0.00	0.00	0.00
change in interest	0.00	0.00	0.00	0.00	0.00	0.00	0.00
change in performance	3.01	0.96	0.31	0.10	0.05	0.04	0.05
change in quantity of inf	2.99	2.98	2.96	2.95	2.94	2.92	2.91
completing	0.08	0.24	0.35	0.42	0.47	0.49	0.50
lecturing	1.92	1.91	1.90	1.89	1.88	1.87	1.86
repeating	0.04	0.21	0.33	0.41	0.46	0.49	0.50
taking	0.66	0.66	0.65	0.64	0.62	0.60	0.58
waste	0.01	0.03	0.05	0.06	0.07	0.07	0.07
adjustment fraction	0.01	0.01	0.01	0.01	0.01	0.01	0.01
allocated time factor	0.05	0.05	0.05	0.05	0.05	0.05	0.05
amount learned	10.00	10.04	10.25	10.58	10.99	11.45	11.93
availability	0.00	0.02	0.14	0.33	0.58	0.88	1.23
clsd prbm slvg	3.00	3.00	3.00	3.00	3.00	3.00	3.00
coding	10.00	10.00	10.03	10.13	10.31	10.56	10.88
constraints	0.50	0.50	0.50	0.50	0.50	0.50	0.50
impact of other values	0.30	0.30	0.30	0.30	0.30	0.30	0.30
interest in grade	0.50	0.50	0.50	0.50	0.50	0.50	0.50
interest in use	0.50	0.50	0.50	0.50	0.50	0.50	0.50
learning reinforcers	0.41	0.53	0.53	0.53	0.53	0.53	0.53
memory info	5.00	5.00	5.00	5.00	5.00	5.00	5.00
opn prbm slvg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
other reinforcers	0.30	0.30	0.30	0.30	0.30	0.30	0.30
prior knowledge	10.00	10.00	10.00	10.00	10.00	10.00	10.00
procedure real	1.00	1.00	1.00	1.00	1.00	1.00	1.00
procedure rote	5.00	5.00	5.00	5.00	5.00	5.00	5.00
productivity	1.00	1.00	1.02	1.06	1.10	1.14	1.19
relreal info	1.00	1.00	1.00	1.00	1.00	1.00	1.00
relrote info	4.00	4.00	4.00	4.00	4.00	4.00	4.00
rote type	3.00	3.00	3.00	3.00	3.00	3.00	3.00

MINUTES	7.00	8.00	9.00	10.00	11.00	12.00	13.00
expectancy	0.01	0.01	0.01	0.01	0.01	0.02	0.02
hooks for repetition	0.13	0.13	0.12	0.12	0.12	0.11	0.11
hooks in memory	2.44	2.94	3.44	3.92	4.40	4.86	5.30
hooks under developme	1.48	1.47	1.43	1.39	1.35	1.30	1.25
interest in subject	0.02	0.02	0.02	0.03	0.03	0.03	0.03
level of effort	0.22	0.23	0.24	0.25	0.26	0.27	0.27
level of performance	4.51	4.58	4.67	4.79	4.93	5.09	5.29
quantity of info	20.65	23.54	26.42	29.28	32.13	34.96	37.78
change in effort	0.02	0.01	0.01	0.01	0.01	0.01	0.00
change in expectancy	0.00	0.00	0.00	0.00	0.00	0.00	0.00
change in interest	0.00	0.00	0.00	0.00	0.00	0.00	0.00
change in performance	0.07	0.09	0.11	0.14	0.17	0.20	0.23
change in quantity of inf	2.89	2.88	2.86	2.85	2.83	2.82	2.81
completing	0.50	0.50	0.48	0.47	0.46	0.44	0.42
lecturing	1.85	1.84	1.83	1.82	1.81	1.80	1.80
repeating	0.50	0.50	0.49	0.47	0.46	0.44	0.43
taking	0.56	0.53	0.51	0.49	0.47	0.45	0.43
waste	0.07	0.07	0.07	0.07	0.06	0.06	0.06
adjustment fraction	0.01	0.01	0.01	0.01	0.01	0.01	0.01
allocated time factor	0.05	0.05	0.05	0.05	0.05	0.05	0.05
amount learned	12.44	12.94	13.44	13.92	14.40	14.86	15.30
availability	1.61	2.02	2.46	2.91	3.37	3.84	4.32
clsd prbm slvg	3.00	3.00	3.00	3.00	3.00	3.00	3.00
coding	11.25	11.66	12.09	12.55	13.01	13.47	13.93
constraints	0.50	0.50	0.50	0.50	0.50	0.50	0.50
impact of other values	0.30	0.30	0.30	0.30	0.30	0.30	0.30
interest in grade	0.50	0.50	0.50	0.50	0.50	0.50	0.50
interest in use	0.50	0.50	0.50	0.50	0.50	0.50	0.50
learning reinforcers	0.53	0.53	0.53	0.53	0.53	0.53	0.53
memory info	5.00	5.00	5.00	5.00	5.00	5.00	5.00
opn prbm slvg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
other reinforcers	0.30	0.30	0.30	0.30	0.30	0.30	0.30
prior knowledge	10.00	10.00	10.00	10.00	10.00	10.00	10.00
procedure real	1.00	1.00	1.00	1.00	1.00	1.00	1.00
procedure rote	5.00	5.00	5.00	5.00	5.00	5.00	5.00
productivity	1.24	1.29	1.34	1.39	1.44	1.49	1.53
relreal info	1.00	1.00	1.00	1.00	1.00	1.00	1.00
relrote info	4.00	4.00	4.00	4.00	4.00	4.00	4.00
rote type	3.00	3.00	3.00	3.00	3.00	3.00	3.00

MINUTES	14.00	15.00	16.00	17.00	18.00	19.00	20.00
expectancy	0.02	0.02	0.02	0.03	0.03	0.03	0.04
hooks for repetition	0.10	0.10	0.10	0.09	0.09	0.09	0.08
hooks in memory	5.73	6.14	6.54	6.93	7.30	7.65	8.00
hooks under developme	1.20	1.15	1.11	1.06	1.02	0.99	0.95
interest in subject	0.04	0.04	0.04	0.05	0.05	0.06	0.07
level of effort	0.28	0.28	0.28	0.29	0.29	0.29	0.29
level of performance	5.52	5.79	6.10	6.45	6.86	7.33	7.87
quantity of info	40.59	43.38	46.16	48.92	51.67	54.41	57.13
change in effort	0.00	0.00	0.00	0.00	0.00	0.00	0.00
change in expectancy	0.00	0.00	0.00	0.00	0.00	0.00	0.00
change in interest	0.00	0.00	0.00	0.00	0.01	0.01	0.01
change in performance	0.27	0.31	0.36	0.41	0.47	0.54	0.62
change in quantity of inf	2.79	2.78	2.76	2.75	2.74	2.72	2.71
completing	0.41	0.39	0.38	0.37	0.36	0.34	0.33
lecturing	1.79	1.78	1.77	1.76	1.75	1.74	1.73
repeating	0.41	0.40	0.38	0.37	0.36	0.35	0.34
taking	0.42	0.40	0.39	0.38	0.37	0.35	0.34
waste	0.06	0.05	0.05	0.05	0.05	0.05	0.04
adjustment fraction	0.01	0.01	0.01	0.01	0.01	0.01	0.01
allocated time factor	0.05	0.05	0.05	0.05	0.05	0.05	0.05
amount learned	15.73	16.14	16.54	16.93	17.30	17.65	18.00
availability	4.80	5.28	5.76	6.24	6.72	7.19	7.67
clsd prbm slvg	3.00	3.00	3.00	3.00	3.00	3.00	3.00
coding	14.39	14.83	15.26	15.69	16.09	16.49	16.87
constraints	0.50	0.50	0.50	0.50	0.50	0.50	0.50
impact of other values	0.30	0.30	0.30	0.30	0.30	0.30	0.30
interest in grade	0.50	0.50	0.50	0.50	0.50	0.50	0.50
interest in use	0.50	0.50	0.50	0.50	0.50	0.50	0.50
learning reinforcers	0.53	0.53	0.53	0.53	0.53	0.53	0.53
memory info	5.00	5.00	5.00	5.00	5.00	5.00	5.00
opn prbm slvg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
other reinforcers	0.30	0.30	0.30	0.30	0.30	0.30	0.30
prior knowledge	10.00	10.00	10.00	10.00	10.00	10.00	10.00
procedure real	1.00	1.00	1.00	1.00	1.00	1.00	1.00
procedure rote	5.00	5.00	5.00	5.00	5.00	5.00	5.00
productivity	1.57	1.61	1.65	1.69	1.73	1.77	1.80
relreal info	1.00	1.00	1.00	1.00	1.00	1.00	1.00
relrote info	4.00	4.00	4.00	4.00	4.00	4.00	4.00
rote type	3.00	3.00	3.00	3.00	3.00	3.00	3.00

MINUTES	21.00	22.00	23.00	24.00	25.00	26.00	27.00
expectancy	0.04	0.05	0.05	0.06	0.07	0.08	0.09
hooks for repetition	0.08	0.08	0.08	0.08	0.07	0.07	0.07
hooks in memory	8.34	8.66	8.98	9.29	9.59	9.88	10.17
hooks under developme	0.92	0.88	0.85	0.83	0.80	0.77	0.75
interest in subject	0.07	0.08	0.09	0.10	0.10	0.11	0.13
level of effort	0.29	0.29	0.29	0.29	0.29	0.29	0.29
level of performance	8.49	9.19	10.00	10.92	11.99	13.22	14.63
quantity of info	59.84	62.54	65.22	67.89	70.54	73.19	75.81
change in effort	0.00	0.00	0.00	0.00	0.00	0.00	0.00
change in expectancy	0.01	0.01	0.01	0.01	0.01	0.01	0.01
change in interest	0.01	0.01	0.01	0.01	0.01	0.01	0.01
change in performance	0.70	0.81	0.93	1.06	1.23	1.41	1.63
change in quantity of inf	2.70	2.68	2.67	2.66	2.64	2.63	2.62
completing	0.32	0.31	0.31	0.30	0.29	0.28	0.28
lecturing	1.73	1.72	1.71	1.70	1.69	1.68	1.67
repeating	0.33	0.32	0.31	0.30	0.29	0.29	0.28
taking	0.33	0.33	0.32	0.31	0.30	0.30	0.29
waste	0.04	0.04	0.04	0.04	0.04	0.04	0.04
adjustment fraction	0.01	0.01	0.01	0.01	0.01	0.01	0.01
allocated time factor	0.05	0.05	0.05	0.05	0.05	0.05	0.05
amount learned	18.34	18.66	18.98	19.29	19.59	19.88	20.17
availability	8.14	8.61	9.07	9.54	10.00	10.46	10.92
clsd prbm slvg	3.00	3.00	3.00	3.00	3.00	3.00	3.00
coding	17.25	17.61	17.95	18.29	18.62	18.94	19.25
constraints	0.50	0.50	0.50	0.50	0.50	0.50	0.50
impact of other values	0.30	0.30	0.30	0.30	0.30	0.30	0.30
interest in grade	0.50	0.50	0.50	0.50	0.50	0.50	0.50
interest in use	0.50	0.50	0.50	0.50	0.50	0.50	0.50
learning reinforcers	0.53	0.53	0.53	0.53	0.53	0.53	0.53
memory info	5.00	5.00	5.00	5.00	5.00	5.00	5.00
opn prbm slvg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
other reinforcers	0.30	0.30	0.30	0.30	0.30	0.30	0.30
prior knowledge	10.00	10.00	10.00	10.00	10.00	10.00	10.00
procedure real	1.00	1.00	1.00	1.00	1.00	1.00	1.00
procedure rote	5.00	5.00	5.00	5.00	5.00	5.00	5.00
productivity	1.83	1.87	1.90	1.93	1.96	1.99	2.02
relreal info	1.00	1.00	1.00	1.00	1.00	1.00	1.00
relrote info	4.00	4.00	4.00	4.00	4.00	4.00	4.00
rote type	3.00	3.00	3.00	3.00	3.00	3.00	3.00

4:57 PM 4/13/98 Table 1 (Table of Base Run (Form-oriented Learner))

MINUTES	28.00	29.00	30.00	31.00	32.00	33.00	34.00
expectancy	0.10	0.12	0.13	0.15	0.17	0.20	0.23
hooks for repetition	0.07	0.07	0.07	0.06	0.06	0.06	0.06
hooks in memory	10.45	10.72	10.99	11.25	11.51	11.77	12.01
hooks under developme	0.72	0.70	0.68	0.66	0.63	0.61	0.59
interest in subject	0.14	0.15	0.17	0.18	0.20	0.22	0.24
level of effort	0.29	0.30	0.30	0.30	0.30	0.30	0.31
level of performance	16.26	18.18	21.06	24.52	28.51	33.13	38.46
quantity of info	78.43	81.03	83.62	86.20	88.76	91.32	93.85
change in effort	0.00	0.00	0.00	0.00	0.00	0.00	0.00
change in expectancy	0.01	0.02	0.02	0.02	0.02	0.03	0.03
change in interest	0.01	0.01	0.02	0.02	0.02	0.02	0.02
change in performance	1.92	2.88	3.46	4.00	4.62	5.33	2.24
change in quantity of inf	2.60	2.59	2.58	2.56	2.55	2.54	2.53
completing	0.27	0.27	0.26	0.26	0.25	0.25	0.24
lecturing	1.67	1.66	1.65	1.64	1.63	1.62	1.62
repeating	0.27	0.27	0.26	0.26	0.25	0.25	0.24
taking	0.28	0.28	0.27	0.27	0.26	0.26	0.25
waste	0.03	0.03	0.03	0.03	0.03	0.03	0.03
adjustment fraction	0.01	0.01	0.01	0.01	0.01	0.01	0.01
allocated time factor	0.05	0.05	0.05	0.05	0.05	0.05	0.05
amount learned	20.45	20.72	20.99	21.25	21.51	21.77	22.01
availability	11.37	11.83	12.28	12.73	13.18	13.63	14.08
clsd prbm slvg	3.00	3.00	3.00	3.00	3.00	3.00	3.00
coding	19.55	19.85	20.14	20.42	20.70	20.97	21.23
constraints	0.50	0.50	0.50	0.50	0.50	0.50	0.50
impact of other values	0.30	0.30	0.30	0.30	0.30	0.30	0.30
interest in grade	0.50	0.50	0.50	0.50	0.50	0.50	0.50
interest in use	0.50	0.50	0.50	0.50	0.50	0.50	0.50
learning reinforcers	0.53	0.53	0.53	0.53	0.53	0.53	0.53
memory info	5.00	5.00	5.00	5.00	5.00	5.00	5.00
opn prbm slvg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
other reinforcers	0.30	0.30	0.30	0.30	0.30	0.30	0.30
prior knowledge	10.00	10.00	10.00	10.00	10.00	10.00	10.00
procedure real	1.00	1.00	1.00	1.00	1.00	1.00	1.00
procedure rote	5.00	5.00	5.00	5.00	5.00	5.00	5.00
productivity	2.04	2.07	2.10	2.13	2.15	2.18	2.20
relreal info	1.00	1.00	1.00	1.00	1.00	1.00	1.00
relrote info	4.00	4.00	4.00	4.00	4.00	4.00	4.00
rote type	3.00	3.00	3.00	3.00	3.00	3.00	3.00

Table of Base Run (Form-oriented Learner): (5)

MINUTES	35.00	36.00	37.00	38.00	39.00	40.00	41.00
expectancy	0.26	0.29	0.32	0.36	0.40	0.44	0.48
hooks for repetition	0.06	0.06	0.06	0.06	0.06	0.06	0.06
hooks in memory	12.26	12.50	12.74	12.97	13.20	13.42	13.65
hooks under developme	0.57	0.55	0.53	0.51	0.49	0.47	0.45
interest in subject	0.27	0.29	0.32	0.35	0.39	0.43	0.47
level of effort	0.31	0.32	0.32	0.33	0.34	0.35	0.36
level of performance	40.70	41.21	41.68	42.33	43.31	44.35	45.67
quantity of info	96.38	98.89	101.40	103.88	106.36	108.82	111.27
change in effort	0.00	0.01	0.01	0.01	0.01	0.01	0.01
change in expectancy	0.03	0.03	0.04	0.04	0.04	0.04	0.04
change in interest	0.03	0.03	0.03	0.03	0.04	0.04	0.05
change in performance	0.52	0.47	0.65	0.98	1.04	1.32	1.69
change in quantity of inf	2.51	2.50	2.49	2.48	2.46	2.45	2.44
completing	0.24	0.24	0.23	0.23	0.22	0.22	0.22
lecturing	1.61	1.60	1.59	1.58	1.58	1.57	1.56
repeating	0.24	0.24	0.23	0.23	0.23	0.22	0.22
taking	0.25	0.24	0.24	0.23	0.23	0.22	0.22
waste	0.03	0.03	0.02	0.02	0.02	0.02	0.02
adjustment fraction	0.01	0.01	0.01	0.01	0.01	0.01	0.01
allocated time factor	0.05	0.05	0.05	0.05	0.05	0.05	0.05
amount learned	22.26	22.50	22.74	22.97	23.20	23.42	23.65
availability	14.52	14.97	15.41	15.85	16.29	16.73	17.17
clsd prbm slvg	3.00	3.00	3.00	3.00	3.00	3.00	3.00
coding	21.49	21.74	21.99	22.24	22.48	22.72	22.95
constraints	0.50	0.50	0.50	0.50	0.50	0.50	0.50
impact of other values	0.30	0.30	0.30	0.30	0.30	0.30	0.30
interest in grade	0.50	0.50	0.50	0.50	0.50	0.50	0.50
interest in use	0.50	0.50	0.50	0.50	0.50	0.50	0.50
learning reinforcers	0.53	0.53	0.53	0.53	0.53	0.53	0.53
memory info	5.00	5.00	5.00	5.00	5.00	5.00	5.00
opn prbm slvg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
other reinforcers	0.30	0.30	0.30	0.30	0.30	0.30	0.30
prior knowledge	10.00	10.00	10.00	10.00	10.00	10.00	10.00
procedure real	1.00	1.00	1.00	1.00	1.00	1.00	1.00
procedure rote	5.00	5.00	5.00	5.00	5.00	5.00	5.00
productivity	2.23	2.25	2.27	2.30	2.32	2.34	2.36
relreal info	1.00	1.00	1.00	1.00	1.00	1.00	1.00
relrote info	4.00	4.00	4.00	4.00	4.00	4.00	4.00
rote type	3.00	3.00	3.00	3.00	3.00	3.00	3.00

MINUTES	42.00	43.00	44.00	Final			
expectancy	0.52	0.57	0.61	0.66			
hooks for repetition	0.05	0.05	0.05	0.05			
hooks in memory	13.87	14.08	14.29	14.51			
hooks under developme	0.43	0.41	0.39	0.37			
interest in subject	0.52	0.57	0.62	0.68			
level of effort	0.37	0.39	0.41	0.43			
level of performance	47.36	49.15	50.35	51.44			
quantity of info	113.71	116.14	118.55	120.96			
change in effort	0.02	0.02	0.02				
change in expectancy	0.04	0.05	0.05				
change in interest	0.05	0.06	0.06				
change in performance	1.79	1.19	1.09				
change in quantity of inf	2.43	2.41	2.40				
completing	0.22	0.21	0.21				
lecturing	1.55	1.55	1.54				
repeating	0.22	0.21	0.21				
taking	0.22	0.21	0.21				
waste	0.02	0.02	0.02				
adjustment fraction	0.01	0.01	0.01	0.01			
allocated time factor	0.05	0.05	0.05	0.05			
amount learned	23.87	24.08	24.29	24.51			
availability	17.61	18.05	18.48	18.92			
clsd prbm slvg	3.00	3.00	3.00	3.00			
coding	23.18	23.41	23.63	23.85			
constraints	0.50	0.50	0.50	0.50			
impact of other values	0.30	0.30	0.30	0.30			
interest in grade	0.50	0.50	0.50	0.50			
interest in use	0.50	0.50	0.50	0.50			
learning reinforcers	0.53	0.53	0.53	0.53			
memory info	5.00	5.00	5.00	5.00			
opn prbm slvg	0.00	0.00	0.00	0.00			
other reinforcers	0.30	0.30	0.30	0.30			
prior knowledge	10.00	10.00	10.00	10.00			
procedure real	1.00	1.00	1.00	1.00			
procedure rote	5.00	5.00	5.00	5.00			
productivity	2.39	2.41	2.43	2.45			
relreal info	1.00	1.00	1.00	1.00			
relrote info	4.00	4.00	4.00	4.00			
rote type	3.00	3.00	3.00	3.00			

Table 1 (Table of Base Run (Form-oriented Learner))

MINUTES	.00	1.00	2.00	3.00	4.00	5.00	6.00
student's perceived avai	0.00	0.00	0.03	0.10	0.24	0.43	0.67
target info	600.00	600.00	600.00	600.00	600.00	600.00	600.00
testing	0.67	0.67	0.67	0.67	0.67	0.67	0.67
type of info	0.64	0.64	0.64	0.64	0.64	0.64	0.64
waste fraction	0.05	0.05	0.05	0.05	0.05	0.05	0.05
forecast adjustment	3.44	3.44	3.44	3.44	3.44	3.44	3.43
learning style incompatil	0.10	0.10	0.10	0.10	0.10	0.10	0.10
mark of desire	4.40	4.40	4.40	4.41	4.42	4.46	4.50
perceived assessment	0.00	0.03	0.04	0.05	0.05	0.05	0.05
quality of teaching	0.28	0.63	0.63	0.63	0.63	0.63	0.63
willingness	0.29	0.29	0.29	0.29	0.29	0.29	0.29

Table of Base Run (Form-oriented Learner): (8)

4:57 PM 4/13/98	Table 1 (Table of Base Run (Form-oriented Learner))					
MINUTES	7.00	8.00	9.00	10.00	11.00	12.00	13.00
student's perceived avai	0.97	1.30	1.68	2.08	2.50	2.94	3.40
target info	600.00	600.00	600.00	600.00	600.00	600.00	600.00
testing	0.67	0.67	0.67	0.67	0.67	0.67	0.67
type of info	0.64	0.64	0.64	0.64	0.64	0.64	0.64
waste fraction	0.05	0.05	0.05	0.05	0.05	0.05	0.05
forecast adjustment	3.43	3.43	3.42	3.42	3.42	3.41	3.41
learning style incompatit	0.10	0.10	0.10	0.10	0.10	0.10	0.10
mark of desire	4.57	4.65	4.75	4.88	5.03	5.22	5.43
perceived assessment	0.05	0.05	0.05	0.05	0.05	0.06	0.06
quality of teaching	0.63	0.63	0.63	0.63	0.63	0.63	0.63
willingness	0.29	0.29	0.29	0.29	0.29	0.29	0.29

Table of Base Run (Form-oriented Learner): (9)

4:57 PM 4/13/98 Table 1 (Table of Base Run (Form-oriented Learner))

MINUTES	14.00	15.00	16.00	17.00	18.00	19.00	20.00
student's perceived avai	3.86	4.33	4.81	5.28	5.76	6.24	6.72
target info	600.00	600.00	600.00	600.00	600.00	600.00	600.00
testing	0.67	0.67	0.67	0.67	0.67	0.67	0.67
type of info	0.64	0.64	0.64	0.64	0.64	0.64	0.64
waste fraction	0.05	0.05	0.05	0.05	0.05	0.05	0.05
forecast adjustment	3.41	3.40	3.40	3.39	3.39	3.38	3.38
learning style incompatil	0.10	0.10	0.10	0.10	0.10	0.10	0.10
mark of desire	5.68	5.97	6.30	6.68	7.12	7.62	8.20
perceived assessment	0.06	0.06	0.07	0.07	0.08	0.08	0.09
quality of teaching	0.63	0.63	0.63	0.63	0.63	0.63	0.63
willingness	0.29	0.29	0.29	0.29	0.29	0.29	0.29

Table of Base Run (Form-oriented Learner): (10)

MINUTES	21.00	22.00	23.00	24.00	25.00	26.00	27.00
student's perceived avai	7.19	7.66	8.13	8.60	9.07	9.53	9.99
target info	600.00	600.00	600.00	600.00	600.00	600.00	600.00
testing	0.67	0.67	0.67	0.67	0.67	0.67	0.67
type of info	0.64	0.64	0.64	0.64	0.64	0.64	0.64
waste fraction	0.05	0.05	0.05	0.05	0.05	0.05	0.05
forecast adjustment	3.38	3.37	3.37	3.36	3.36	3.35	3.35
learning style incompatil	0.10	0.10	0.10	0.10	0.10	0.10	0.10
mark of desire	8.85	9.60	10.46	11.45	12.58	13.89	15.40
perceived assessment	0.09	0.10	0.11	0.12	0.13	0.15	0.16
quality of teaching	0.63	0.63	0.63	0.63	0.63	0.63	0.63
willingness	0.29	0.29	0.29	0.29	0.29	0.29	0.29

Table 1 (Table of Base Run (Form-oriented Learner))

MINUTES	28.00	29.00	30.00	31.00	32.00	33.00	34.00
student's perceived avai	10.45	10.91	11.37	11.82	12.28	12.73	13.18
target info	600.00	600.00	600.00	600.00	600.00	600.00	600.00
testing	0.67	0.67	0.67	0.67	0.67	0.67	0.67
type of info	0.64	0.64	0.64	0.64	0.64	0.64	0.64
waste fraction	0.05	0.05	0.05	0.05	0.05	0.05	0.05
forecast adjustment	3.35	3.34	3.34	3.33	3.32	3.31	3.30
learning style incompatil	0.10	0.10	0.10	0.10	0.10	0.10	0.10
mark of desire	17.14	19.41	22.62	26.30	30.54	35.45	40.54
perceived assessment	0.18	0.20	0.22	0.24	0.27	0.30	0.33
quality of teaching	0.63	0.63	0.63	0.63	0.63	0.63	0.63
willingness	0.30	0.30	0.30	0.30	0.30	0.30	0.31

Table of Base Run (Form-oriented Learner): (12)

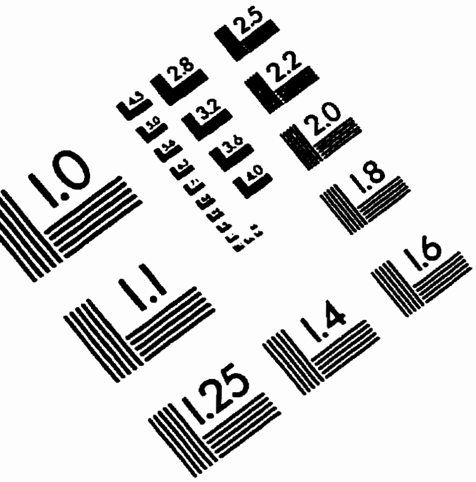
MINUTES	35.00	36.00	37.00	38.00	39.00	40.00	41.00
student's perceived avai	13.63	14.08	14.52	14.97	15.41	15.85	16.29
target info	600.00	600.00	600.00	600.00	600.00	600.00	600.00
testing	0.67	0.67	0.67	0.67	0.67	0.67	0.67
type of info	0.64	0.64	0.64	0.64	0.64	0.64	0.64
waste fraction	0.05	0.05	0.05	0.05	0.05	0.05	0.05
forecast adjustment	3.29	3.29	3.28	3.27	3.26	3.25	3.25
learning style incompatil	0.10	0.10	0.10	0.10	0.10	0.10	0.10
mark of desire	40.97	41.42	41.89	42.74	43.76	44.81	46.37
perceived assessment	0.34	0.34	0.35	0.35	0.35	0.36	0.37
quality of teaching	0.63	0.63	0.63	0.63	0.63	0.63	0.63
willingness	0.31	0.32	0.33	0.34	0.34	0.35	0.36

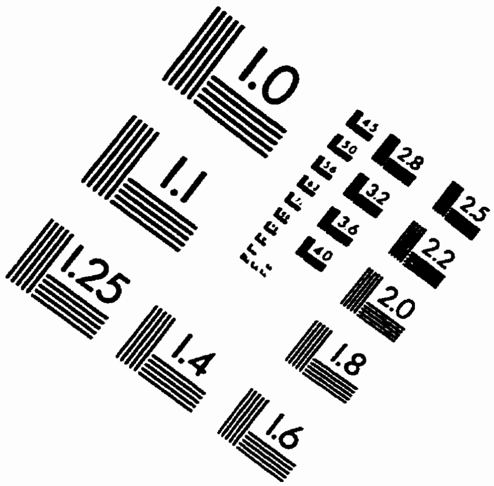
4:57 PM 4/13/98 Table 1 (Table of Base Run (Form-oriented Learner))

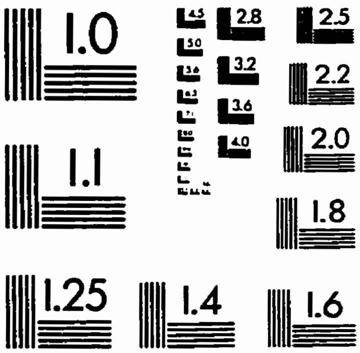
MINUTES	42.00	43.00	44.00	Final
student's perceived avai	16.73	17.17	17.61	18.05
target info	600.00	600.00	600.00	600.00
testing	0.67	0.67	0.67	0.67
type of info	0.64	0.64	0.64	0.64
waste fraction	0.05	0.05	0.05	0.05
forecast adjustment	3.24	3.23	3.22	3.22
learning style incompatit	0.10	0.10	0.10	0.10
mark of desire	48.10	49.73	50.79	51.89
perceived assessment	0.38	0.39	0.39	0.39
quality of teaching	0.63	0.63	0.63	0.63
willingness	0.38	0.40	0.42	0.44

Table of Base Run (Form-oriented Learner): (14)

IMAGE EVALUATION TEST TARGET (QA-3)

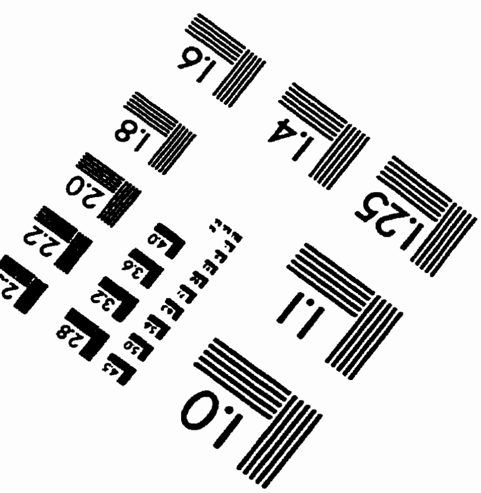


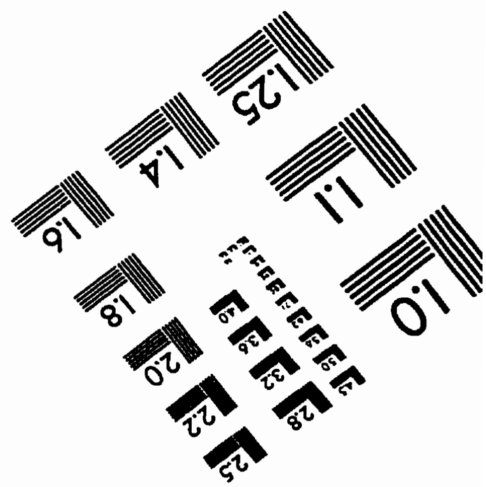




150mm

6″





APPLIED IMAGE . Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989