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Towards Dynamic Modeling of a Teaching/Learning System Part 2: A New Theory on Types of Learners*

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Before an attempt is made to construct a simulation model for the teaching/learning process, three crucial questions are answered: What are the types of minds that learners possess? What are the types of incoming information (from the information-issuing source) relating to the minds of learners? How is each type of information treated with each type of mind? To answer the above questions, in this part of the study, through a system analysis, 'learning style' is taken as the main basis for the investigation. Four major models of learning styles in Engineering Education are discussed and two of them are chosen for this purpose. A short lecture in the Introduction to Industrial Engineering course is worked out as an example case in this study. The short lecture is divided into different stages, each of which includes a piece of information. The original knowledge of a Form and a Function learner as it is arranged in learners' minds, is defined. The lecture is presented, and the way students tackle different types of information in the lecture is described. Their final knowledge, as 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 study to a new idea about the pattern of knowledge in different minds. This results in recognizing eight types of information and identifying seven types of learning abilities for each type of learner.

INTRODUCTION

RESEARCHERS and theorists in the field of Education and Education Psychology have developed various models to describe the different ways that students learn. These models are mainly based on learning styles, learning strategies and learning abilities. According to the literature search, the distinction between learning abilities, learning styles and learning strategies are difficult to specify. Most experts in the field emphasize that learning styles are generalized and unconsciously acquired by the learner while learning abilities and learning strategies are deliberately acquired and adopted respectively. Some experts view 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. On the other hand, 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 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 advantages of such information are 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.

However, It may be argued that among them (learning styles, learning strategies and abilities), the models that are based on learning styles are more promising. Referring to the literature [1–6], one at least can find five reasons for such a claim:

- Learning styles are more relevant to the learners' perception of learning and their personality rather than what they do for the learning itself.
- Learning styles represent characteristics that exist somewhere midway between learning abilities and learning strategies.
- Learning styles do not measure ability or intelligence, but they are the ways learners perceive situations, understand, process, and learn information.
- Learning styles are the consistent and stable manner in which learners do the operations of 'organizing' and 'processing' of information.
- Learning styles refer to the preferred way learners learn, process information, make decisions, and solve problems.

Considering the above statements, therefore, learning styles may provide appropriate clues for any investigation into the individuals' learning characteristics. It is worthwhile to note that

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they by themselves only represent the necessary conditions for the process. The sufficient conditions may be satisfied if one tries to incorporate the other dimensions based on learning strategies and abilities into his or her process of investigation.

Thus, for the purpose of this study, the four most popular models of learning styles that have been used effectively in engineering education research are considered and reviewed [11]. Then, through a facts finding process, two of them are selected for a further analysis. The findings from these two models are compared with the findings from a learning model which is based on learning strategies and abilities. Finally, the results are compared with some other findings from the literature and a possible global definition for different types of learners is sought.

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 three striking approaches in the literature (e.g., Myers-Briggs type indicators, Kolb's learning cycle, and Marton's surface and deep learning approach);
- judging the practical soundness of the proposed two types of learners based on the researcher's own personal experience;
- defining Type I learner as Form-oriented Learner and Type II learner as Function-oriented learner;
- 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.

THE FOUR MAJOR MODELS OF LEARNING STYLES

The Myers-Briggs Type Indicator (MBTI)

The Myers-Briggs Type Indicator (MBTI), shows the different ways learners prefer to receive information (perception functions) and reach conclusions or make decisions (judgment functions). Within each of these functional areas are two preferences. In receiving information (perception function), one may prefer Sensing (S), using the five senses, or alternatively, one may prefer Intuition (N), involving insight and unconscious associations. In reaching conclusions (judgment functions), a learner may prefer either Thinking (T), or Feeling (F), as a basis for choosing or making decisions [7].

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, MBTI includes two additional dimensions, called attitudes or orientations. 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. The second attitude, Judgment (J) or Perception (P), reflects the learner's preferences for interacting with the environment. Knowledge of a learner's preferences within each of the two functions (perception and judgment), 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 [3]. For instance, research based on application of MBTI has indicated that engineering students (and engineering professors) are usually INTJ (Introverts/Intuitors/Thinkers/Judgers) oriented [8].

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.

Kolb's learning style model

The core of 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). 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 [9, 10] (Fig. 1).

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. Kolb's

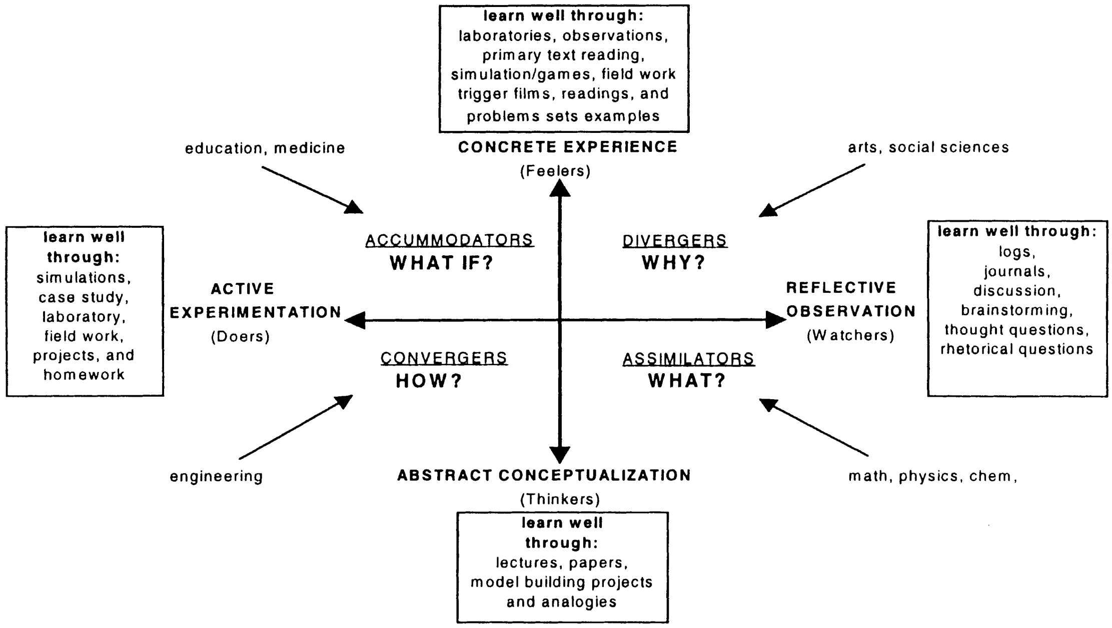

Fig. 1. Kolb's learning cycle.

learning cycle has been largely used for research purposes and also in the design of academic programs. For instance, research based on the application of this method on testing of undergraduate engineering students at several universities in the United States has shown that about 75% of engineering students prefer What and How-oriented learning styles [11].

Figure 1 demonstrates the four different Kolb learning orientations that were discussed above. 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.

Felder-Silverman learning style model

This model divides learners into five categories, four of them are more or less very similar to the types mentioned in MBTI. According to this model, learners are:

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

Research based on the application of this model suggests that, most engineering teaching has been heavily biased toward intuitive, verbal, deductive, reflective, and sequential learners [11]. 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)

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. The same population has been reported for those with strong preferences for right-brain (cerebral) thinking [11].

TOWARDS DEFINING TWO TYPES OF LEARNERS

The short review of the four major learning styles in the previous section, prepares the stage for this study to conceptualize a new model for the types of learners. Table 1 is a starting point for this purpose. It is an effort by this study to summarize and contrast the main characteristics of the forementioned models in a single diagram. Needless to say that all of these models have a common

The Myers-Briggs Type Indicator	Kolb's Learning Style Model	Felder-Silverman Learning Style	Herrmann Brain Dominance Instrument (HBDI)
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)	**Type 1: divergers** (concrete, reflective - characteristic Why? 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) or **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) or **Intuitors (N)** (imaginative, concept-oriented, focus on meanings and possibilities)	**Type 2: assimilators** (abstract, reflective - characteristic What? 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) or **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) or **Feelers (F)** (appreciative, tend to make decisions based on personal and humanistic considerations)	**Type 3: convergers** (abstract, active-characteristic How? 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) or **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) or **Perceivers (P)** (adapt to changing circumstances, resist closure to obtain more data)	**Type 4: accommodators** (concrete, active - characteristic What if? type learners) like applying course material in new situations to solve real problems.	**Active Learners** (learn by trying things out, working with others) or **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) or **Global Learners** (holistic, systems thinkers, learn in large leaps).	

Table 1. Four major models of learning styles

orientation to the learner and as stated earlier, they emphasize 'distinctive' and 'stable' differences among learners. Typically, they are a good way towards understanding differences among learners and in illuminating 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 of 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 classifies the different types of learners. And finally, HBDI focuses on a higher level of knowledge acquisition and, in fact, 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 seem most promising. Especially, when taking into consideration the specific approach of each model (MBTI in personality and Kolb in learning style), if this study can accommodate 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 study from the types of learners 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 learners, this study employs the similarities that exist in the types of learners in both MBTI and Kolb's model. Moreover, to be on the safe side, a student approach which is based on learning strategies and learning abilities is incorporated in the process of analysis as well. This approach is one of the most striking studies in the literature at the University of Gothenburg (in Sweden) by Marton [12] and Saljo [13]. These Swedish researchers used a phenomenological-like approach and described two different ways that students approach their textbook assignments: surface processing and deep processing. Surface processors read the assignment straight and hardly attempt to think about the purpose and relationship between the assigned reading and their own previous knowledge. They memorize the parts of the information they consider to be important, guided by the type of questions they anticipate being asked subsequently. 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. Obviously, this distinction between surface and deep approaches to learning appears to be a powerful form of categorization for differences in learning strategies.

Table 2 illustrates how two different types of students (Type I learner and Type II learner) could be conceptualized and developed by comparing the identical learner's characteristics found in both MBTI and Kolb's models on one side and from the studies made by Marton and Saljo on the other side. As shown in Table 2, 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 Observation and Concrete Experience respectively) in Kolb's model, and/or Surface type students in Marton's view. 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 Abstract Conceptualization and Active Experimentation respectively) in Kolb's model, and/or deep type students in Marton's view.

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

Table 2. Introducing two types of learners

	Type I learner	Type II learner	Remarks
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 less successful
Kolb's theory	CE/RO 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 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/doers and watchers/feelers; • three-fourth of engineering students are, more or less, thinkers/doers
Marton's view	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 the studies at Gothenburg University on student approach to learning by Marton and Saljo [12, 13]
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 1 and Type II students have been graduated and now are working as design engineers in XYZ company.

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 in new methods and procedures.

The different characteristics of the learners have been further examined in a practical point of view based on the authors' own industrial experience. The personal judgment (last row in Table 2) indicates the authors' 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 learners.

TYPES OF MIND: A PROPOSED THEORY

Before discussing different types of mind within the context of types of learners, 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. The collected information showed a 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 type of learner fitted well with one of the proposed Type I and Type II learners. This information has been refined down to the following characteristics for the Type I and Type II learners respectively.

Characteristics of type I learners

- 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 memory depends 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 study 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 gives 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 supposed as individuals that had dominant associative memory. They associated new information with previous knowledge and developed new relationships.

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

Finally, the latest work on the characteristics of the different minds, has led this study to a new stage. In other words, examining various cases has given 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 word, 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 Form/Function Theory of Types

The above definitions for the Form type and Function type learners (or minds) could be solidified and expressed in a general theory:

> The Form/Function Theory of Types suggests that individuals, in general, possess two different types of mind. They either posses a Form-oriented mind or a Function-oriented mind. Form-oriented minds *view* the incoming information as related to its outside appearance (form), while Function-oriented minds *interpret* incoming information as related to its inside organization (function).

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 connection is the two extreme types of learners. In fact, the Form and Function learners represent vertical and horizontal sides of a learning matrix. Each side of such an imaginary matrix can be scaled from 0 to 100% in terms of the intensity of Form/Function orientation. Obviously, on this matrix there are as many combinations as there are learners fitting to define it.

Table 3 is an effort to demonstrate the internal structure of a Form-type versus a Function-type mind. Each structure speaks for itself. The difference between the 'way' that the Form type and the Function type minds treat each piece of incoming information is quite evident. A detailed pictorial form of this table will be demonstrated later when an example short lecture is presented to each type of mind.

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.

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 known approaches of knowledge acquisition in the literature. Generally speaking, there are two basic theories of knowledge acquisition, absorption theory and cognitive theory. Each reflects a different belief about the nature of knowledge and how knowledge is acquired [14].

Absorption theory suggests that knowledge is impressed upon the mind from without. Basically,

Table 3. Form-type mind vs. Function-type mind

Form type	Function type
Internal structure: • memorize forms easily; • compare forms; • perform procedures. (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.)	Internal structure: • from forms, work to find background functions; • memorize most found functions; • memorize most forms around found functions; • perform procedures.

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. In fact, absorption theory views knowledge as a collection of facts (associations) that are learned by means of memorization. Also, this theory suggests that the knowledge expansion is an accumulation process that basically increases the number of associations.

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 where elements of information are 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, one 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.

In fact, 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 authors, 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 judgment by the reader on this comprehensive conclusion, gives no doubt to the validation of this proposed theory.

INVESTIGATING THE MECHANISM OF A LEARNING PROCESS

In the previous section, this 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 an engineering perspective, what is the mechanism of a learning system and what does one mean when one says something has been *learned?*

Actually, these two questions have challenged this study from the beginning. 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 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.

The earlier approach

At the beginning stage, 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 deposited 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 short lecture cases from different courses in engineering. Each short lecture had to have at least one predefined 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 produce 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:

1. Rote memory type information.
2. Closed-problem solving.
3. Open problem solving.

Then with 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 determined 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:

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

Moreover, at this stage, the information processing was assumed to be based on the traditional approach. That is, learners after obtaining each piece of information, 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 learners was in the way in which their string memory and associative memory functioned respectively. Obviously, this approach had its own weak points but enabled this research to start digging in the uncharted area.

The interim approach

Further investigations, generated a better idea about the types of learner. At this stage, the two different types of learners were known as Memorizers and Relators (as defined earlier). 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 timewise 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 about the mechanism in a learning process.

Based on the available knowledge at this stage about Memorizers' and Relators' 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:

1. Rote-type information: a sort of information that is memory oriented with no link to one's real life experience
2. Relationship-type information: a kind of information that recalls past pieces of knowledge, idea, concept, or experience, and can be directly or indirectly connected to it.
3. 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 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 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 a 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.

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/Long Answers, and Problems) and the possible way that they tackle questions were worked out. The most likely answers were determined (based on the authors' past teaching/ learning experience) and marked accordingly. Analyzing the way that each type of mind handles the test questions led this study to the new findings. For instance the different types of information were further modified to the following:

1. Only memorizing (rote) type information.
2. Relationship-type information (quasi or rote oriented—non-verifiable).
3. Relationship-type information (real—verifiable, cause and effect type).
4. Procedure-type information (quasi or rote oriented methods—follow rules type).
5. Procedure-type information (real—interrelational cause and effect type).

6. Question-type information (true/false or yes/no).
7. Question-type information (short/long answer required).
8. Question-type information (closed problem-solving oriented).
9. 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 frequently as the first five types, more or less, they are included in a well designed quality lecture. However, as 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 study defines the two proposed kinds of Relationship type information. An example for each will clarify their differences. 'James Watt invented the steam engine in 1770', is a typical Relationship-type information that is rote oriented and is not easily memorized by a Relator (since it expresses a non-verifiable relationship). On the other hand, 'a particular ball fits exactly within a particular hoop', is a typical example for a real Relationship-type information that could be memorized easily by the Relator (since it expresses a verifiable—a cause and effect—relationship).

Moreover, in further work on the different learning abilities of Form and Function learners, the previous classification was further modified. According to the new results, each Form-oriented and Function-oriented learner could possess seven different types of learning abilities where each ability could vary from 0 (weak) to 100% (strong). Figure 2 shows the modified types of the

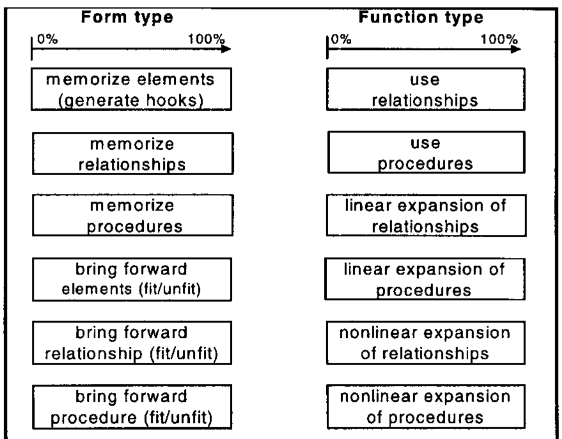

Fig. 2. Different types of learning abilities.

learning abilities for each type of learner. 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.

As mentioned earlier, it should be noted that the focus of this study is on the two extreme types of learners. Apparently, there exist numberless variations of learners 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 one of the authors for two consecutive years. Mastering this course, requires a quantity of mathematics, analysis, memorization, dexterity and other abilities. This study, intentionally, chose a lecture on the 'productivity issue' which covers a part of the first regular lecture in the course. The 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';
- 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.

Figures 3(a), 3(b), and 3(c) demonstrate three important parts of the short lecture trial on 'productivity' for a Form-type learner. Figure 4(a), 4(b), and 4(c) demonstrate similar parts for a Function-type learner. Note that Figs 3(a) and 4(a) 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.

Figures 3(b) and 4(b) depict steps 1–17 of the short lecture and the way that Form and Function minds treat the incoming information respectively.

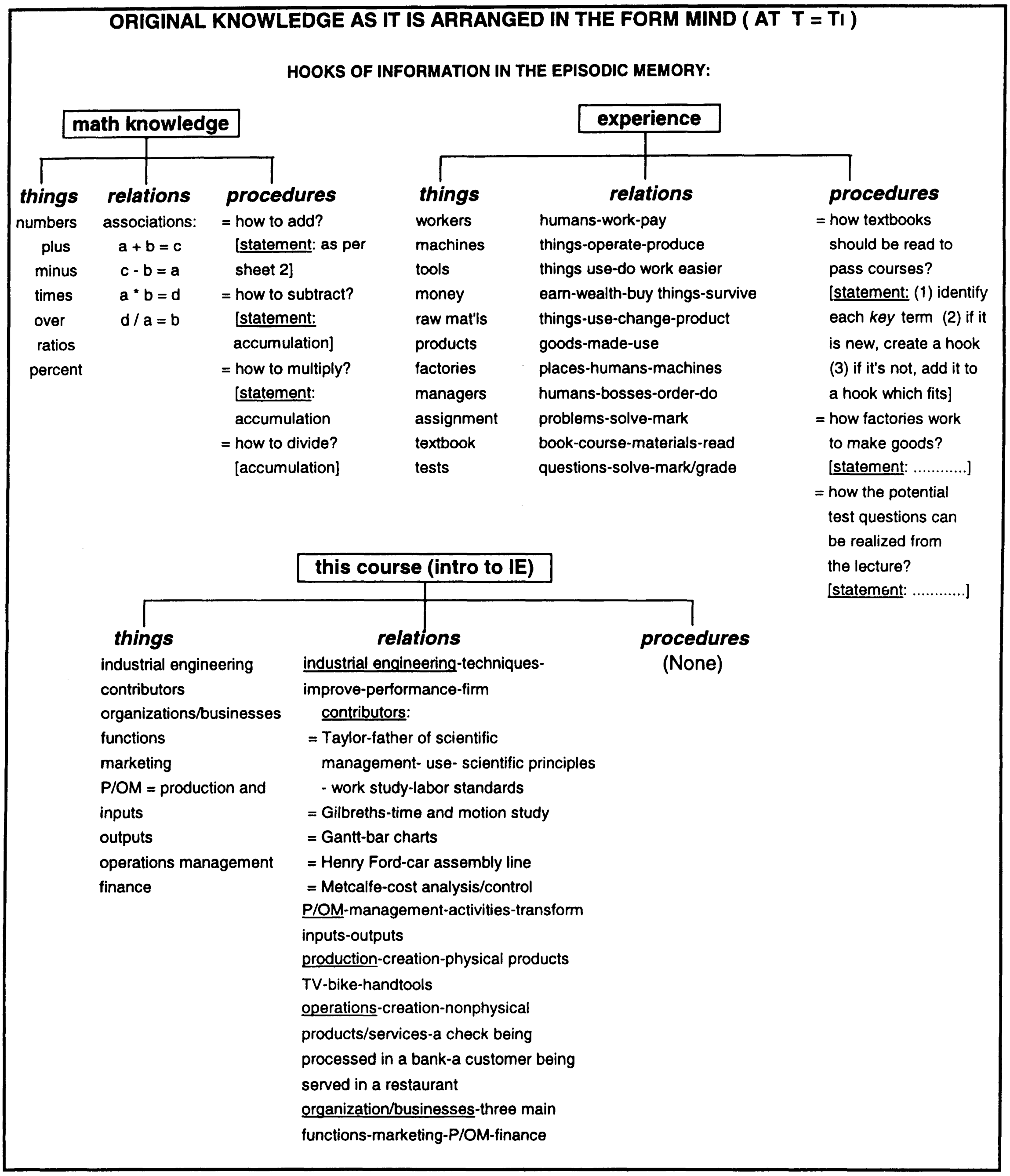

Fig. 3(a). The original knowledge as it is arranged (Form-oriented mind).

Note that the words which are underlined in the left column of the diagrams indicate the keywords within each statement. Also, the words that are shown in bold in the right columns represent the different types of learning abilities that are used by each of the learners for the situation.

Figures 3(c) and 4(c) demonstrate the final arrangement of the knowledge for the Form and Function minds (at the end of the lecture) respectively. A simple comparison of these two diagrams with Figs 3(a) and 4(a) shows the volume of knowledge acquisition by the Form and Function minds respectively. As was mentioned earlier, these two diagrams demonstrate the totally different patterns that Form and Function minds acquire knowledge and store information. In fact, each pattern reveals the distinctive structure of each Form and Function mind.

A few points are worth mentioning:

1. The total information presented by a teacher during a lecture could be analyzed for its types. If the relationships and procedure type information are dominant, then the teacher is most likely a Function-oriented individual and vice versa. This is really exciting! The Form/Function Theory of Types is at work!
2. The total information presented by a teacher

•		
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. 3(b). An example short lecture experiment to show how a Form learner treats incoming information.

during a lecture also could be analyzed for the prediction of the learners' performance beforehand. If the stress is on the memory (rote) 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 Figs 3(b) and Figure 4(b)) could be changed. Depending on the type of the information, a change in the performance of the Function or Form

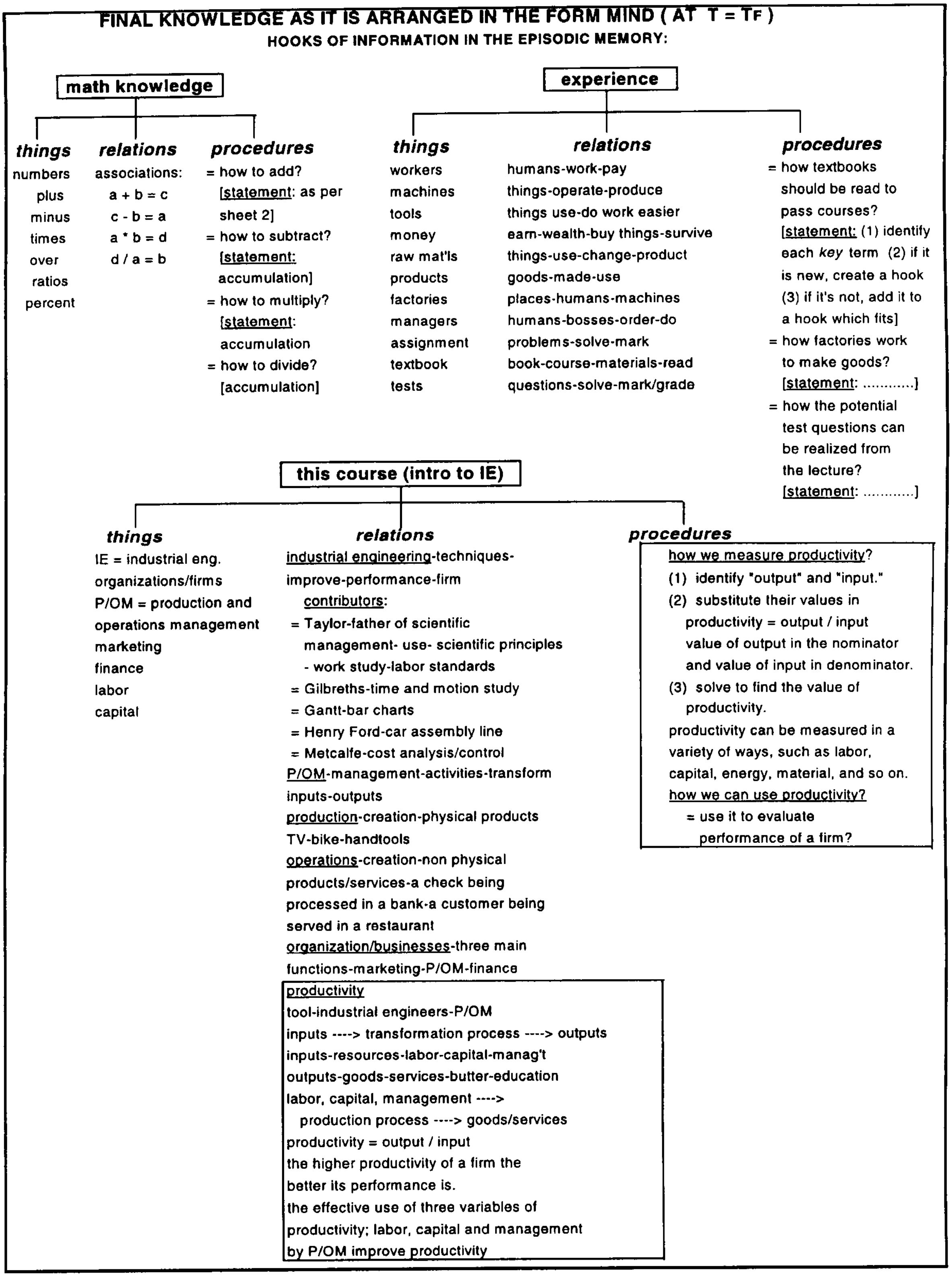

Fig. 3(c). The final knowledge as it is arranged (Form-oriented mind).

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 learners can be identified in advance, by using a well-designed questionnaire, provided that the questions are Form and Function oriented and subject students complete them carefully. Needless to

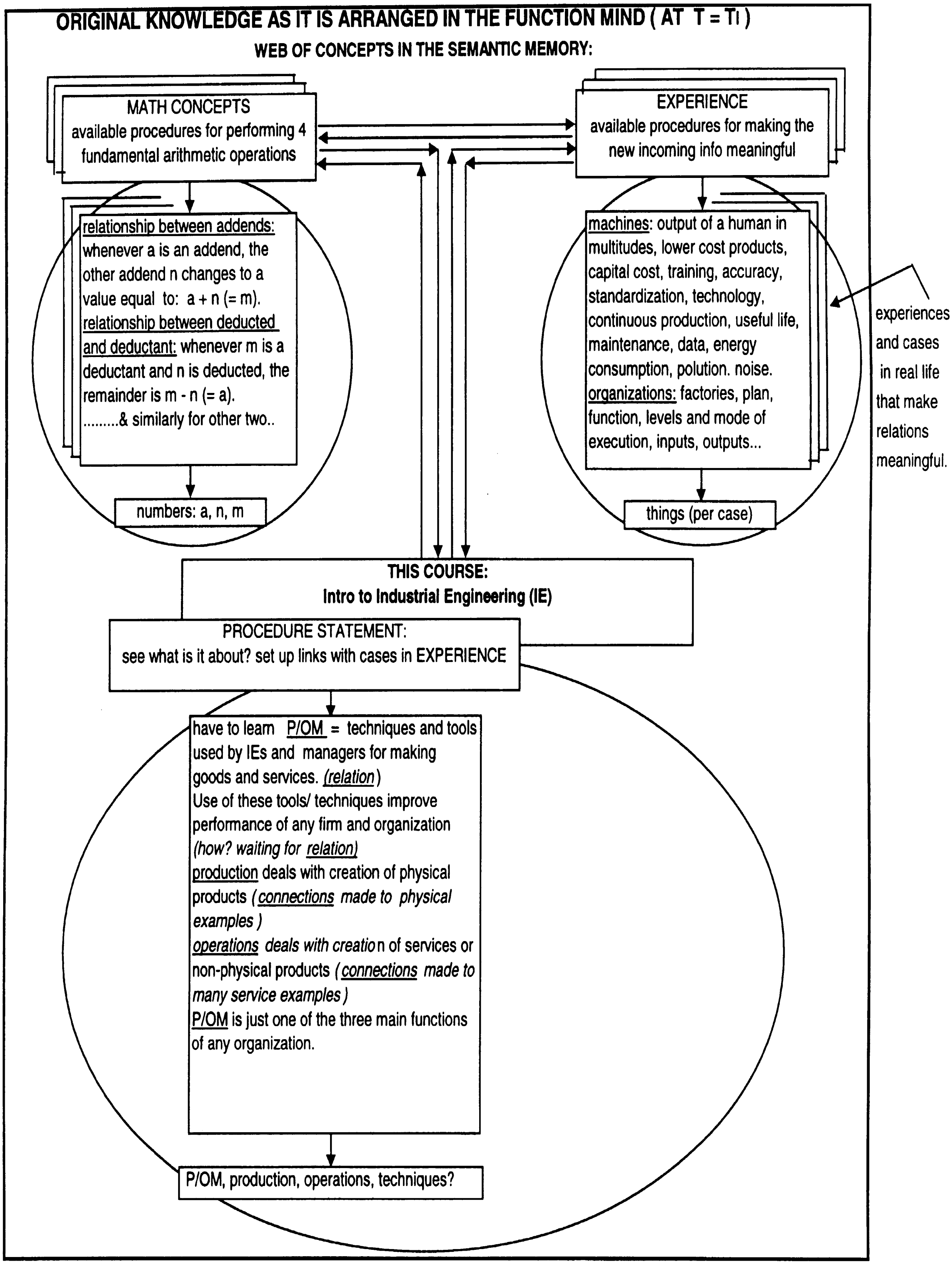

Fig. 4(a). The original knowledge as it is arranged (Function-oriented mind).

say, advance knowledge about the types of students should have a dramatic effect on the control and improvement of the teaching/learning processes. Moreover, the use of such questionnaires may go beyond the boundaries of the educational institutions. The reader can imagine how such questionnaires will serve, for instance, in finding a Function-oriented individual for a technical job or a Form-oriented individual for a clerical job.

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. 4(b). An example short lecture experiment to show how a Function mind treats incoming information.

SUMMARY AND CONCLUSION

In this part of the study, three fundamental questions were answered.

1. What are the types of the minds that learners possess?

The study combined the results of the previous synthesis [15] and those from the three major studies in the literature (the Myers-Briggs Type Indicators, Kolb's Theory, and Gothenburg Studies by Marton and Saljo). 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

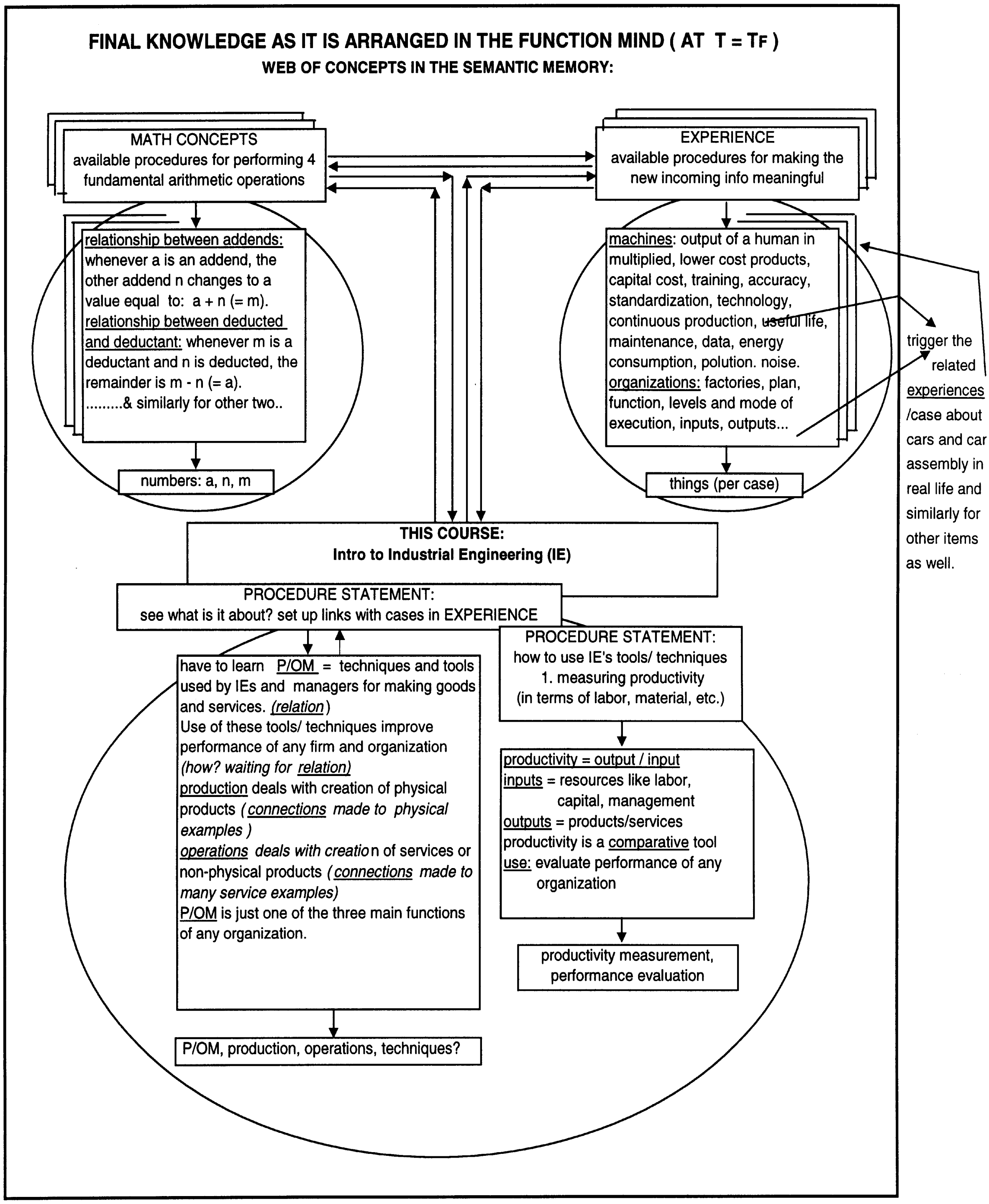

Fig. 4(c). The final knowledge as it is arranged in the Function-oriented mind.

matrix. In fact, countless numbers of learners, each with their own specific intensity in Form/ Function orientation can be placed on such a matrix.

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) and found to fit very well. Interestingly, Form type fit exactly the absorption approach while Function type fit very well the cognitive approach.

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) with those proposed by absorption and cognitive theories. The results are summarized and reported in Table 4.

Table 4. Validating the proposed Form-Function Theory of Types

Form type	Function type
MEMORIZE ELEMENTS: learning by repetition; MEMORIZE RELATIONSHIPS: learning by association; MEMORIZE PROCEDURES: learning by accumulation.	USE RELATIONSHIPS: learning by relationship; USE LINEAR PROCEDURE: learning by assimilation; learning by integration; USE NON-LINEAR PROCEDURE: learning by changes in thinking pattern.

2. What are the types of incoming information?

This study, through a long investigation and experimentation could 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 is the primary constituent of a statement, the second set is the auxiliary constituent of the statement and is used for testing purposes. These nine types of information are demonstrated in Fig. 5.

The proposed theory of Form/Function prepared the ground for a better understanding of the types of incoming information 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 treated with each type of mind?

In fact, finding an answer to this question cost this study 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. But 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 was defined schematically. Then, both Form and Function minds were posed to a set of the same pieces of information, in order.

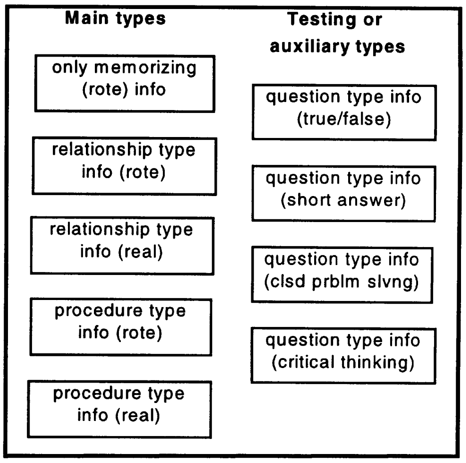

Fig. 5. Nine types of information.

The way each mind deals with (take in, process, and store) each type of information was guessed and 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.

Figure 6 is an effort to demonstrate all the important findings in Part 1 reported in [15] and this part of the study. This figure, in fact, 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 Part 1 of this study [15]) are in the next column to the right.
- The seven types of the external reinforcement factors are in the middle of the diagram. (They represent the characteristics of the teaching system and the learning environment, as proposed and described in part 1 of this study.
- The two columns in the right of the diagram include fourteen types of student 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 that were proposed and discussed earlier).

By placing the new proposed components in Fig. 3 of Part 1 of this study [15] (Influence Diagram for a Teaching/Learning Process), a more comprehensive flow diagram would be generated. Figure 7 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.

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 the next part of this study and in line with the other steps of the System Dynamic method.

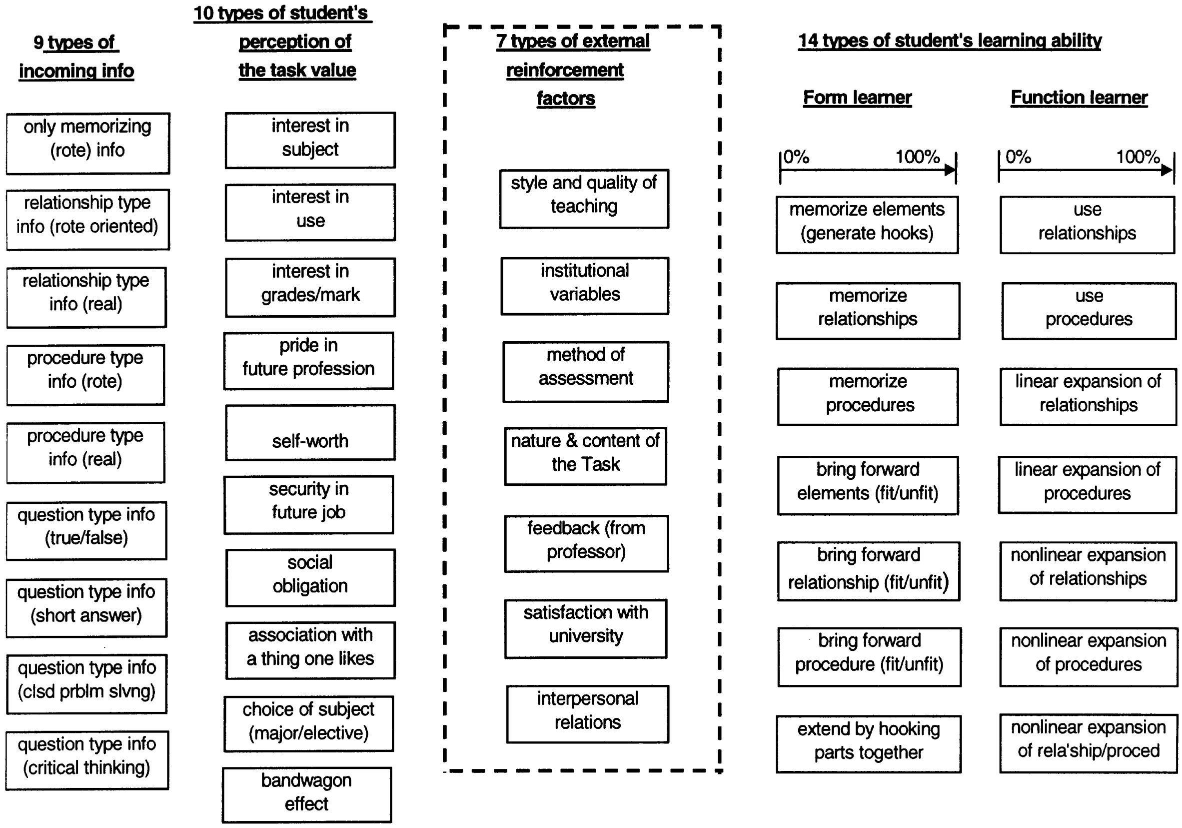

Fig. 6. Proposed major components for a teaching/learning process.

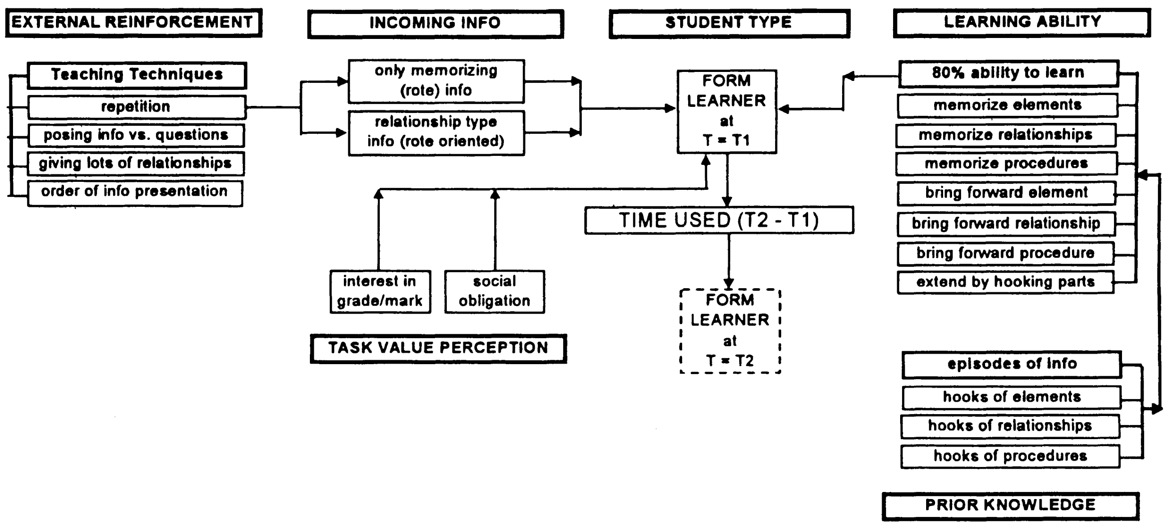

Fig. 7. An example flow diagram for a Form learner: connecting the major blocks.

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