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Combining Educational Aspects with New Technology:

Teaching Basic Statistics Using Hypermedia.

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...Namer of a thousand names, maker of meaning, transformer of the world... your parents and the parents of your parents continue in you. You are not a fallen meteor, but a brilliant arrow launched toward the skies. You are the meaning of the world, and when you clarify your meaning you illuminate the earth. When you lose your meaning, the earth becomes darkened and the abyss opens.

From "The Internal Landscape", SILO

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Abstract

The increasing popularity and rapid development of the Internet and specifically the World-Wide Web in recent years has led to an exponential growth of users around the world in many different application areas. Following this growing trend, many eager educators have also embraced this new technology and have begun to use it as a tool in delivering education. A plethora of applications has already been developed in an attempt to implement educational content in this way. A general concern for many researchers is that most of these applications are not efficient in delivering educational outcomes and fail to achieve their educational goal.

In the present project we propose that the present failure to deliver educational outcomes in an efficient way has its origins in the lack of concern and focus of developers on modern learning theory. Therefore, in this work we establish the foundations in terms of an interdisciplinary contribution from areas such as, educational learning theory, human-computer interaction and web design guidelines for the design and implementation of web pages aimed at facilitating the teaching and tutoring of basic statistics concepts.

As a result of this work, a specific set of learning theories were researched and analyzed, the basic ideas of Human-Computer Interaction (HCI) were explored and a set of appropriate principles from HCI were chosen. Furthermore, a selected group of Web design guidelines were researched, studied and selected to ensure that the final product contributes to the efficient delivery of subject content and effective achievement of learning outcomes. In addition, a number of parallels were formulated and discussed between the different areas of research. The establishment of a series of combined principles will not only contribute to the aims of the present project but also to further projects initiated by the Department of Econometrics at The University Sydney.

Chapter One

Principles of Learning and Teaching

1.1 Introduction

The increasing popularity and rapid development of the Internet and specifically the World Wide Web in recent years have produced an exponential growth of users around the world in areas as diverse as "personal home pages, commercial pages, advertising pages, government agency pages, country information pages", etc. (Wilson 1997).

Following this growing trend, many eager educators have also embraced this new technology and have begun to use it as a tool in delivering education. A plethora of applications has already been developed in an attempt to implement educational content in this way. A general concern for many researchers is that most of these applications "not only fail to take full advantage of the potential of these means, but often do so in a pedagogically disastrous way" (Oliveira 1992).

Currently one of the more widely used aspects of the web in relation to delivering educational content is through the provision of a number of on-line resources. This particular usage considers the web mainly as a repository of information or a "beautifully connected library" (Laurillard 1993). Fundamentally, the provision of search engines which allow users to pose queries at different levels makes this information repository a very interesting and practical tool for research (Wilson 1997).

In contrast with this characteristic, Ritchie and Hoffman argue that "web pages have the potential to be more than a compendium of information" and that "when properly structured, pages can guide users through a series of instructional activities which present information, afford practice, and provide feedback to inform users of their strengths, weaknesses, and suggestions for enrichment or remediation" (Ritchie & Hoffman 1996). Schneider also emphasizes this point when he suggests that "WWW-based courseware must not restrict itself to delivery of educational content. It must be grounded in some model of instruction and learning" (Schneider 1994).

There appears to be two main reasons that have led to these problems, the focus of the developers and the accumulation of poorly researched experiences.

Firstly, while it is widely accepted that the Internet and the WWW both have a high potential to improve learning and teaching (Ritchie & Hoffman 1996), many educators have embraced the new technology too rapidly, as a sort of panacea and have placed their emphasis on the technology side of the development, leaving aside important educational aspects (Alexander 1995). Alexander argues that by concentrating on the features of the new technology, ignoring the educational aspects leads to the provision of a "learning experience that is often essentially the same as that provided using existing technologies" (Alexander 1995). In order to produce effective educational tools using new technology the focus should also be levered to answer questions such as "What do I want my students to learn [and] What is known about the way students learn this" (Alexander 1995), as well as considering the features of the technology. In particular, the answer to the latter question necessitates dealing with learning theories.

In addition to learning issues, some other areas have also been left aside in spite of the fact that a number of researchers have indicated the need to ground computer-based developments in sound theoretical principles. For example, in relation to instructional design methods, Chen indicates that current methods in areas such as computer-based learning are 'incomplete in addressing the wide range of cognitive and pedagogical issues involved" (Chen 1994). Also, in regard to computer systems development, Richardson indicates that "unless we streamline existing, and develop and understand new principles of learning, the technology will simply be used for mass implementation of poorly designed packages which will do nothing to improve the position of the learners" (Richardson 1995).

Secondly, the lack of concern for and use of learning and teaching principles is not a recent issue. Long before the advent of the World Wide Web, more conscientious researchers had already identified the need to emphasize proper educational principles and their impact on methodologies in areas such as Computer-Based Learning. For

example, in the area of Statistical Software, (one of the most widely used applications of computers in educational institutions), interfaces "remain uninfluenced by modern [teaching] methods" (Dewey & Harding 1987) and rather than helping users, they add to the difficulties encountered when using them. In spite of these warnings, it appears that educational developers have been building on a poorly researched foundation which has never been carefully examined, contributing progressively to developments further and further away from sound theoretical principles.

Following on from the previous discussion and considering the rapid development of web pages and software production in the educational arena, there is an urgent need to encourage understanding and to foster the use of modern learning principles as vital components of any developments that attempt to deliver effective educational outcomes.

1.2 Learning and Teaching Concepts and Strategies

Any current review of the literature and research in education will indicate that there are many different and often, opposing concepts about the way in which we learn. As a result of this, "virtually every educational arena is wrestling with similar issues as we all try to adjust to advances in cognitive science and philosophy of the mind" (Wilson, Teslow & Taylor 1993). For example, in the area of instructional design, Wilson *et al.* characterize this lack of consensus as "ideological paradigm wars within the instructional design community" (Wilson, Teslow & Taylor 1993).

Not only are there different learning theories, but also refinements to existing theories and new theories emerge constantly within the research community. For example, at present there is "considerable upheaval... [while]... theorists attempt to move from behaviourist roots toward cognitivist and postmodern interpretations of their practice" (Wilson, Teslow & Taylor 1993). On the other hand, in recent years new theories, such as Constructivism (Bednar, Cunningham, Duffy, & Perry 1991), Connectionism and postmodern frameworks "have also begun to receive attention" (Wilson & Cole 1991) from the research community. Many of these theories have their foundations in perceptions of the main psychological characteristics of the learners. These characteristics should be considered as important factors that contribute to or detract from the process of learning.

The impact of this diversity and constant transition of approaches to learning profoundly affects teaching principles and methodologies. In an ideal situation, the perception of learning processes will provide the bases for accommodating particular aspects of teaching. Therefore, an impact is carried over from learning aspects to teaching aspects. Teaching aspects in turn will have a direct influence on particular methodologies, for example in those methodologies that use computers to deliver education. Even further, the impact is not only carried over to teaching methodologies but also to design techniques used to construct computer aids.

In the context of the present project, this line of effects, from learning aspects to teaching aspects and methodologies, strongly suggests that the starting point and emphasis should be set in the study and analysis of current learning theories, prior to any attempt to develop computer-based teaching aids. Later on, and in order to develop effective computer aids, computer related aspects such as Human-Computer Interaction, Hypermedia and Web Design Guidelines are important in the sense that they can contribute to support and enhance the more important learning aspects.

Wilson *et al.* (Wilson, B. G., Teslow, J. R., & Taylor, L. 1993) identify five learning theories that have provided foundations for instructional design:

- Behaviourism;
- Information Processing;
- Constructivism;
- Connectionism; and
- Postmodernism.

Of these five categories, Behaviourism and Constructivism have been researched more exhaustively and are thought to have a more direct impact on current instructional technologies. In particular, Constructivism is considered to be "the guiding theory for much research and reform in mathematics and science education" (Garfield 1994).

In order to understand the principles of learning and their impact on teaching and teaching methodologies, it is necessary to review the main ideas of these two learning theories and analyze their implications for developing educational solutions in areas such as computer-based instruction. In addition, it is also important to consider the individual approaches to learning that people adopt. People learn in different ways, by reading, by receiving explanations, by seeing a demonstration, etc. Learning styles theory, is defined as "the composite of characteristic cognitive, affective, and physiological factors that serve as relatively stable indicators of how a learner perceives, interacts with, and responds to the learning environment" (Keefe 1979).

1.3 The Behaviourist Approach to Learning

The definition of behaviorism establishes that this theory focuses only on "objectively observable behaviors' (HREF1) and disregards all mental activities carried out by the learner during the process. Behaviourism also assumes that the "study of animals is beneficial in that it help us understand/analyze human behaviour" (Black 1995).

Behaviourists argue that the process of learning is merely the acquisition of new behaviours directed by a series of 'conditionings' which regulate the whole process. The term 'conditionings' involves two kinds of behavior patterns:

- Classic conditioning takes into account the natural reflex that is produced in response to a stimulus. This idea is based on the Pavlovian effect of the stimulus-response exemplified in the well known exercise of the 'food presentation-salivation' in dogs. The theory assumes that given a particular stimulus there will be a particular response to it.

- The second pattern involves the idea that by reinforcing certain types of responses these will be more likely to be repeated. Feedback is used to direct the process of learning by either rewarding or punishing certain types of responses. This type of conditioning is also called 'Operant' or 'Instrumental' conditioning.

The classical type of conditioning is more frequently used in our early years of development and tends to disappear as we grow older (Black 1995). On the other hand, provided that the assumption that, as individuals grow older they are not passive in their learning, and but rather tend to take the initiative and 'operate' in their environment (Skinner [1]), is true, Black argues that adult "human learning is based more on operant conditioning than on the classical one" (Black 1995).

Behaviourism as a learning theory however, has not been exempt from implementation difficulties. When translated to the instructional technology field for example, the main

idea of Behaviourism, i.e. "behaviours are learned as a result of reinforcement" (Case & Bereiter 1984) is not enough to provide a foundation for instructional technology. Instructional technology deals with *new* behaviours and not merely with strengthening behaviours already present in the learner as early behaviourist ideas suggested (Case & Bereiter 1984).

The above-mentioned difficulties have guided the developments of Behaviourism over the years and have led to a number of different theoretical refinements in relation to its impact on the learning process. Two main refinements are those of Skinner and Gagne.

Skinner's refinements of the behaviourist approach indicate that it should be possible to "modify the learner's existing behaviour in degrees so that it would be transformed into the desired new behaviour *through successive approximations*" (Case & Bereiter 1984). In order to modify the existing behaviour in degrees, Skinner introduced the idea of "sequencing events in frames in order to give positive feedback at each stage of development" (Whyte 1995). The idea behind this sequencing is to present information to learners in small amounts, therefore their responses could be shaped (reinforced) (Open Learning Tech. Corp. Ltd., 1996). Skinner also indicated that "immediate feedback is also essential in order to imprint the desired behaviour on the learner" (Skinner [2]). For example, in programmed instruction the question-answer (i.e., stimulus-response) is presented to the learner as a frame (stimulus) ensuring that an answer (response) is given at each frame with subsequent immediate feedback (reinforcement) (Open Learning Tech. Corp. Ltd., 1996).

Gagne's approach to Behaviourism is also related to this sequencing, he first proposed a strategy for "identifying and sequencing intellectual skills so that the instruction would progress systematically, building on what the learner already knows" (Case & Bereiter 1984). Based on this Gagne developed the idea of "hierarchical task analysis" which established that learners have some kind of skills layers and that high skills are based in a previous layer of skills and these in turn are based on a lower layer, until we "reach the skill level that the learner already possesses" (Case & Bereiter 1984). Unfortunately, this

idea proved problematic in subsequent experiences and Gagne had to revise and adapt his model. He then, introduced a new model : Cognitive Development which is referred to in the research literature as 'Gagne's Cognitive Behaviourism' (Case & Bereiter 1984). One key idea of this model is that the learner should be shown an *expert's approach* to solve a problem, so that by comparing the expert's approach to their own approach and by appreciating their methodological deficiencies, the learner develops a new way to approach a problem.

How do these ideas translate into specific principles? Black (Black 1995) identified the following five general principles in applying behaviour modification:

- Set behaviour goals;
- Determine appropriate reinforcers;
- Select procedures for changing behaviour;
- Implement procedures and record results; and
- Evaluate progress and revise as needed.

More specifically and from the point of view of the present work, these principles can be translated into a number of design considerations when implementing instructional technology in Computer-Assisted Instruction (Black 1995). These are as follows:

- Stating the purpose of the software;
- Apply the appropriate reinforcer - text, visual or audio;
- Depending on the application, shaping, chaining, modeling, punishment, and reward principles are used;
- Very often, a scoring (monitoring) system is present; and
- Provides status of progress.

Some critics of the behaviorist approach argue that because it disregards the activities of the mind, it is not able to account for all types of learning. In addition, it does not explain some learning experiences such as when small children learn new language

patterns without feedback mechanisms. The positive and negative types of feedback, one of the main components of this approach may be well suited to certain kinds of learning processes but it appears to be a bit primitive for higher education.

According to von Glasersfeld, a rather strong critic of Behaviourism, (von Glasersfeld year unknown) "...for 50 years in this century, we have suffered the virtually undisputed domination of a mindless Behaviourism. The Behaviourists succeeded in eliminating the distinction between *training* (for performance) and *teaching* that aims at the generation of understanding. All learning was reduced to a model that had been derived from experiments with captive pigeons and rats... For education, this learning theory... has tended to focus attention on student's *performance* rather than on the *reasons* that prompt them to respond or act in a particular way. Reinforcement fosters the repetition of what gets reinforced, regardless of the acting subject's *understanding*..."

1.4 The Constructivist Approach to Learning

The constructivist approach to learning and research, on the other hand presents more interesting and complex ideas in relation to the process of learning. The constructivist philosophy is founded in the proposition that all of us construct our own understanding of the world we live in and that this process is done through the reflection about the personal experiences accumulated by each one of us (HREF1).

One study referenced by various authors (Alexander 1995, Hedberg 1995) is a report produced by Saljo (Saljo 1979) categorising what individuals understand by learning:

1. Learning as a quantitative increase in knowledge. Learning is acquiring information or 'knowing a lot';

2. Learning as memorizing. Learning is storing information that can be reproduced;

3. Learning as acquiring facts, skills and methods that can be retained and used if necessary;

4. Learning as making sense or abstracting meaning. Learning involves relating parts of the subject matter to each other and to the real world; and

5. Learning as interpreting and understanding reality in a different way. Learning involves comprehending the world by reinterpreting knowledge.

The last two categories developed by Saljo suggest that learning is an experience that learners carry out in order to make sense of the world, to find meaning, or to understand the real world, as opposed to something that is imposed on the learner by an external entity.

In the process of learning we create certain 'mental models' and certain 'rules' to make sense of these experiences, therefore "learning is the process of adjusting our own mental models to accommodate new experiences" (HREF1). Jonassen *et al.* encapsulate these ideas by saying that "constructivists assume that learners construct knowledge by interpreting [...] perceptual experiences in terms of prior knowledge, current mental structures and existing beliefs" (Jonassen, Mayes & McAleese 1993).

The key assumption of constructivists, that knowledge construction is generated by the learners themselves through "active mental processing of perceptions" (Jonassen, Mayes & McAleese 1993), is referred to as a "generative learning process" (Wittrock, 1974). Generative learning process relates "new information to prior knowledge in order to build more elaborate knowledge structures. These knowledge structures are necessary for interpreting new information, reasoning from what is known, and for solving problems" (Jonassen, Mayes & McAleese 1993).

The 'layers' of knowledge or knowledge structure that result from building understanding are necessary in order to allow deeper analysis on the part of the learner. In fact, learning is truly exercised at deeper levels of this knowledge structure (Craik & Lockhart 1972). The search for meaning requires a number of elaboration's generated by the learners themselves, in a process that progressively will take these elaboration's from 'surface' or 'preliminary' analysis, to deeper levels of profundity in the knowledge structure (Eysenck & Keane 1990). The outcome related to this generative process is called "generation effect" (Gardiner 1989). Generation effect states that the learning achieved is of superior quality when the "material has been acted upon" (by the learner) and also suggests that the "material is better remembered when [it] is generated by the learner[s]" themselves (Jonassen, Mayes & McAleese 1993).

Furthermore, when learners are actively involved in the pursuit of meaning, they bring along certain existing constructions of reality (Gorsky & Finegold 1994). This has one important impact on instructional design, which is that we should consider *challenge*

inappropriate constructions of reality and support appropriate constructions (Richardson 1995).

Richardson suggests that the resolution of these conflicts involves three stages (Richardson 1995):

- Foreground learners preconceptions;
- Show why learners' preconceptions are inappropriate; and
- Support reconstruction of concepts to produce new, more appropriate ones.

The first stage deals with the idea that failing to pose challenges to learner's preconceptions will lead to a certain type of 'inert knowledge' (Perkins 1991 and Whytehead 1929). This inert knowledge would be a mere accumulation of facts, with no real learning that could be subsequently used in problem solving (Richardson 1995).

The second stage involves the learners in recognizing those preconceptions that are not clear or are incoherent. The suggestion is that by challenging these preconceptions the learners will "develop more powerful explanations" (Lakatos 1970). One of the techniques suggested to accomplish this is the *catastrophe theory* (Richardson 1995) which involves methodically building up a series of inconsistencies, challenging the learners' view until the whole structure collapses opening the door for the learner to reconstruct a new set of more appropriate concepts according to the third stage outlined above.

This third stage is related to what Vygotsky calls the "zone of proximal development" (Woods 1995). The idea is to keep learners in this 'zone of proximal development' until they recognize the limitations in their current conceptions and open themselves to new conceptions (Richardson 1995).

One critical danger of this approach though is that by doing this the instructor may create an excessive cognitive load therefore reaching the state where learners would "suspend genuine knowledge building and opt for playing the school game" (Richardson 1995 & Perkins 1991). To avoid this effect considerable task management effort is necessary along with looping successively between the second and third stages (Richardson 1995).

Within the context of this project there is an important characteristic of Constructivism related to its impact and suitability for different stages of learning. The constructivist approach to learning and teaching is seen by Jonassen *et al.* (Jonassen, Mayes & McAleese 1993) as better suited for higher education, particularly in universities.

Jonassen (Jonassen 1) recognizes different phases of learning, introductory, advanced and expert. These range from ignorance to expertise. He argues that "each phase of knowledge acquisition [....] entails different types of learning and different approaches to learning". As mentioned above, Jonassen proposes the idea that Constructivism is better suited for the advanced stage of learning which normally takes place in higher education. He argues that constructivist approaches "are richer, more complex, and therefore more potentially confusing to novice learners" during the introductory phase of learning and recommends classical instructional design techniques for this first stage. Classical instructional design is built upon "predetermined learning outcomes ...[and more]... constrained and sequential instructional interactions" (Jonassen, Mayes & McAleese 1993) .

During the advanced phase of learning "learners acquire more advanced knowledge in order to solve more complex, domain- or context-dependent problems" (Jonassen, Mayes & McAleese 1993). More specifically, they also indicate that based on the idea that most university curricula, "especially in the student's major area of study purport to promote advanced knowledge acquisition", it follows that universities are "ideally learning contexts for constructivistic learning process and environments" (Jonassen, Mayes & McAleese 1993).

Constructivism provides a number of guidelines that should be taken into account in the process of teaching. These are as follows:

- In order to improve teaching we need to make an effort in understanding the mental models that students posses and use to interpret the world. It is important not only to understand these models, but also the assumptions upon which they are based (HREF1).

- If learning is a search for meaning, it must begin with those issues for which students are actively trying to construct meaning (HREF1). Dewey develops this idea further indicating that "knowledge and ideas emerge from a situation in which learners had to draw them out of experiences that had meaning and importance to them" (Dewey 1966).

- The main objective of learning is to construct one's own meaning and not to have the 'right' answer by repeating someone else's meaning. Hence learning becomes inherently inter-disciplinary and the process of assessment, rather than being a form of punishment takes the characteristic of providing information to the learner about his or her own quality of learning (HREF1).

- The constructivist approach places emphasis on helping to establish connections and the creation of new understandings. It encourages student to student dialogue; focus on open-ended inquiries and concentrates on highlighting the learner's processes of analyzing, interpreting, predicting and synthesizing (HREF1).

In the opinion of the present writer the learning process as seen by Constructivism provides a powerful shift in mentality in relation to teaching. *It is no longer a matter of presenting information to students, but rather providing an adequate environment to allow them to concentrate on the search for meaning*. This shift in the focus of the

learning process, and consequently in the teaching process gives ample space and is more suitable to computer-based instruction.

According to Hedberg, the idea that learners acquire knowledge by trying to find meaning in the world and that this search for meaning is internal to the learner provides encouragement to use some "alternative instructional strategies such as simulations, games and other forms which require active involvement, interpretation and decision-making" (Hedberg 1995).

In particular, current technology that uses hypertext can be seen as an adequate constructivistic learning environment in the sense that it can engage the learner in the achievement and satisfaction of specific needs. "Learning from hypertext is task driven" (Jonassen, Mayes & McAleese 1993) so the engagement will be dependant on the purpose for using the hypertext system, "which in turn drives the level of processing" (Jonassen, Mayes & McAleese 1993).

From another perspective, some characteristics of hypermedia, such as a certain degree of freedom of associations and navigation can also support constructivistic teaching, in the sense that, for example, the pace of the process is set by the learner, providing an adequate environment for the learner to exercise curiosity and research attitudes from an affective point of view (Oliveira 1992).

How do these ideas translate into specific recommendations? Practical implications of constructivist approaches can be found on the following general principles (Kearsley 1995):

- Instruction must be concerned with the experiences and contexts that make the student willing and able to learn (readiness);

- Instruction must be structured so that it can be easily grasped by the student (spiral organisation of the curriculum); and

- Instruction should be designed to facilitate extrapolation and or fill in the gaps (going beyond the information given).

Practical implications can also be drawn from Merril's definition of Constructivism (Merril 1991):

- Knowledge is constructed from experience;
- Learning is a personal interpretation of the world;
- Learning is an active process of meaning-making based on experience;
- Learning is collaborative with meaning negotiated from multiple perspectives;
- Learning should occur (or be situated) in realistic settings;
- Testing should be integrated with the task, not a separate activity;
- Reflection is a key component of learning to become an expert;
- Like instruction, assessment should be based on multiple perspectives; and
- Learners should participate in establishing goals, tasks, and methods of instruction and assessment.

1.5 Learning Styles

The learning styles approach to learning emphasizes the fact that individuals have different ways of perceiving and processing information. These differences have an impact on the degree to which people learn. The learning process will occur to different degrees, depending on whether the learning experience is suitable to the particular styles of the individuals. Following this idea, what is important is not if someone is 'smart' but rather '*how* is this person smart' (HREF1). The foundations of the concept of 'learning styles' lies in the categorization of psychological types. This means that the way in which individuals perceive and process information has its roots in factors such as individual life experiences, incorporating heredity, upbringing and environment.

Learning styles theory suggests that we learn in a "cyclical process involving different styles such as doing, listening and observing" (Soo & Ngeow 1996). This cyclical process is based on the assumption that human beings generate from their experience concepts, rules, and principles to direct their behaviour in new situations and modify concepts in order to improve their effectiveness (Kolb, Rubin & McIntyre year unknown). The process is both active and passive, concrete and abstract and, according to Kolb *et al.* it can be stated in the following four stage cycle (Kolb, Rubin & McIntyre year unknown):

1. concrete/abstract experience is followed by;
2. observation and reflection which leads to;
3. the formation of abstract concepts and generalizations which lead to;
4. hypotheses to be tested in future actions which in turn leads to new experience.

The following observations can be made about this model of learning process:

Firstly, this process is continuously recurring in human beings. In this sense, learning is always *re-learning* (Kolb, Rubin & McIntyre year unknown).

Secondly, the direction of the process is directed by people's needs and goals. The experiences people seek will be related to these needs and goals and will be interpreted accordingly. An implication of this is that if there are no clear goals the process will be erratic and inefficient (Kolb, Rubin & McIntyre year unknown).

Thirdly, as the process is governed by people's own needs and goals it becomes highly individual in both direction and process. For example, a mathematician may be more interested in abstract concepts, whereas a poet may give more emphasis to concrete experience (Kolb, Rubin & McIntyre year unknown).

From the last observation it follows that most of the people will have one predominant style that leads them to be more efficient when their learning experiences can be matched to their style (Soo & Ngeow 1996). In this context, the following definitions apply to learning styles (HREF1 & HREF14):

- Concrete perceivers: take information by direct experience, by doing and acting, by sensing and feeling (Concrete Experience-CE);

- Abstract perceivers: take information by analysis and observation; by thinking (Abstract Conceptualizations-AC);

- Active Processors: make sense out experiences by immediately doing something with the information (Active Experimentation-AE);

- Reflective processors: make sense of out of experience by reflecting on it; by thinking about it (Reflective Observation-RO).

The degree to which individuals match particular learning styles and use them is variable. Commonly, most people would have a combination of these types according to the way they perceive information and the way in which they process it. This general assumption can lead to a combination of several types of learning styles. Kolb suggest that there are four dominant types of learning styles (Kolb, Rubin & McIntyre year unknown). These are summarized in the following table:

Type denomination	*Learning Style*	*Characteristics.*
The Converger	Abstract Conceptualization Active Experimentation	Practical application of ideas. Knowledge organized in a way that through hypothetical-deductive reasoning can focus on specific problems. Relatively un-emotional, prefers things to people. Narrow technical interests, specializes commonly in physical sciences.
The Diverger	Concrete Experience Reflective Observation	Imaginative ability. Can see concrete situations from various perspectives. Performs better in 'brainstorming' sessions. Interested in people, imaginative and emotional. Broad cultural interests.
The Assimilator	Abstract Conceptualization Reflective Observation	Ability to create theoretical models. Inductive reasoning, assimilate disparate observations into integrated explanation. Less interested in people. More concerned about abstract concepts. Much interested in a logical and precise theories rather than in its practical applications.
The Accomodator	Concrete Experience Active Experimentation	Does things. Carry out plans and experiments. Involve themselves in new experiences. Highly adaptive in specific immediate situations. When theory does not match the plan they will tend to discard the plan or the theory. At ease with people, sometimes impatient and pushy.

Learning Styles concepts can be directly implemented using Hypermedia's characteristics of usage of different formats like visuals, music, sound, etc. Students can choose from a range of alternatives (must be present in the package) according to their particular learning styles. Although learning styles have more to do with the learners themselves, i.e. it is important for any person to discover their own learning style, we have to take these ideas and keep them in mind to accommodate the design of hypermedia aids so as to cover and allow for different learning styles.

Chapter Two

Human-Computer Interaction

2.1 Introduction

In the past thirty years computers have developed from large, expensive machines that were used only by a handful of experts into small, relatively easy to use and popular machines. This development is directly related to advances in technology and a consequent reduction in manufacturing cost. Nowadays there is a computer involved as a tool in almost all fields of human activity. This means that people without specific knowledge about computers are using them more and more, and that designers of computers have to think not only about the particular capabilities of the system but also about the interaction that takes place between the human and the machine.

Like many other extensions of human capabilities (cars, phones, etc.) the computer needs to be designed to become a useful and easy to use tool. Software designers claim their products are 'intuitive' and easy to use. Informal conversations with users however, show that these 'intuitive' interfaces designers have implemented, are often not meaningful to the average user. In fact, they cause users to experience difficulties in learning and adapting to these products.

People need to use computers in order to achieve particular tasks. Their goal is the task and not the use of the computer itself, so their effort in relation to the use of the computer should be minimized, leaving space for them to concentrate on the task. According to Preece *et al.* "computers should be designed for the needs and capabilities of the people for whom they are intended" (Preece *et al.* 1994). The ultimate goal is to provide users with a tool (the computer) and a situation where they do not even need to think about how to use that tool. Human-Computer Interaction is the discipline aimed at bridging the gap between computer systems and the users.

2.2 Human-Computer Interaction: a Definition

One of the first issues that emerge when attempting a definition of HCI is the confusion in the research literature with regard to the name of the discipline. It is common to find

it under names such as CHI (computer-human interaction), HCI (human-computer interaction, which is preferred by some who like 'putting the human first', even if only symbolically), UCD (user-centered design), MMI (man-machine interface), HMI (human-machine interface), OMI (operator-machine interface), UID (user interface design), HF (human factors), ergonomics, etc.(Nielsen 1994). Different names involve a broader or narrower scope depending on the researcher's point of view, for example the term Human-Machine Interface is more general than the term Human-Computer Interfaces. This suggest that researchers who adopt the former name do so because it reflects a broader perspective than those who choose the name Human-Computer Interfaces.

This lack of consensus with regard to the name also reflects the fact that researchers from different disciplines will have a tendency to relate to computers *from* the perspective of their own area of specialty. In these cases, the computer-tool will present new challenges which need to be solved from within the specific relationship established between the particular researcher's discipline and the computer-tool. In this regard, Waern suggests that for example, there is an approach starting from psychology that would "bridge the gap between psychology and human-computer interaction [...] several other bridges can be envisaged, for instance there appears to be a computer science of human-computer interaction" (Waern 1989)..

In general, in spite of this lack of consensus the discipline appears to address the same issue*: the relationship between humans and machines.* Current research literature indicates that all these definitions appear to have a common denominator which has its origins in one of the names of the discipline itself, *Human-Computer Interaction.* This name suggests that HCI deals with three main components, *Humans*, *Computers* and the way they relate to each other, i.e. *the interaction.* This idea provides a working context to study HCI. This point will be further elaborated in the following sections.

The main aim of HCI as cited by Preece *et al.* is "to develop or improve the safety, utility, effectiveness, efficiency, and usability of systems that include computers"

(Preece *et al.* 1994). In safety-critical systems the improvement of safety is an issue of extreme importance. Utility in this context refers to the 'functionality of the system', i.e., what the system does. The importance of the terms effectiveness and efficiency is self-evident. The concept of usability is one of the most important concepts in HCI and is basically related to building systems that are easy to learn and to use (Preece *et al.* 1994).

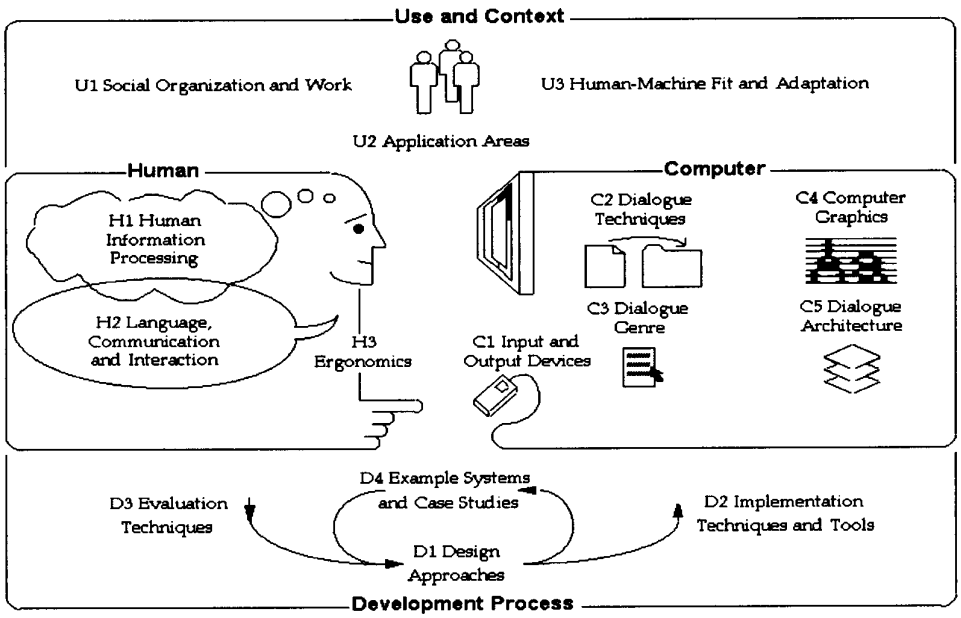
A more general definition is provided by Greenberg (Greenberg 1997). In his opinion "HCI is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use, and with the study of the major phenomena surrounding them". Greenberg's definition is based on the ACM SIGCHI Curricula for HCI (ACM SIGCHI 1992) and implies a more general usage of the term 'computer system'. This definition suggests that HCI is not only concerned with traditional computer systems (the so called IBM compatible computers and workstations), but more generally with all those machines that have any "form of embedded computational machines, such as spacecraft cockpits or microwave ovens, or specialized boxes, such as Nintendo games, or systems that envelope the users' sense, such as virtual environments" (Greenberg 1997).

The term Human-Computer Interaction (HCI) will be used in this study, because the present project deals not with machines in general, but specifically with the computer as a tool in the construction and presentation of statistical learning aids. With regard to this approach, a key element is that the field of HCI will be treated as a tool to enhance and support the learning process. To facilitate and enhance the learning process is the main aim of this work, and in that sense other aspects (Web design guidelines, Hypermedia and HCI) developed here are means to that end. This point will be expanded on Chapter 4.

Within the field of HCI a key idea is the concept of *usability*. In particular, the study of usability principles would allow the enhancement of the learning goals of students. Usability principles will be covered later in this chapter.

2.3 Components of Human- Computer Interaction

According to the ACM SIGCHI Curricula for HCI (ACM SIGCHI 1992) the following schema illustrates the main aspects involved in HCI



From the point of view of the present work, three of these components -humans, computers and the interaction are relevant and will be discussed in the following sections.

2.3.1 The Word 'Human' in HCI

Most of the HCI researchers concur with the idea that the central focus of computers and computer systems is to facilitate human tasks (Preece *et al.* 1994, Dix *et al.* 1993). An interesting and more socially oriented paradigm is proposed by Cox & Walker. They see the process of designing computers as "designing something with which we will communicate with other humans" (Cox & Walker 1993). The idea behind this point of view is that when we write a computer program we are not doing it to communicate with a machine, but we "write it to communicate with a person" (Cox & Walker 1993).

In all cases humans are the target for these designs and an understanding of the characteristics of humans, especially their capabilities and limitations, has been absolutely necessary to lay the foundations for HCI.

Many early researchers have adopted the basic model of human beings as "information processors" (Waern 1989, Dix *et al.* 1993, Preece *et al.* 1994). According to Lindsay & Norman the idea of this model is that "information enters and exits the human mind through a series of ordered processing stages" (Lindsay & Norman 1977). This idea reflects the concept of using the computer as a metaphor: some input, a process and an output. Preece *et al.* elaborate on this input-process-output (Preece *et al.* 1994):

Stage 1. (*Input*) Encoding of information from the environment into some form of internal representation;

Stage 2. (*Process*) this representation is compared with memorized representations that are stored in the brain;

Stage 3. (*Process*) decision about a response to the encoded stimulus, if an appropriate match is made then;

Stage 4. (*Output*) the organisation of the response and the necessary actions are produced.

While some researchers have started from this basic model to propose more adequate models, other authors have departed from the information processing model and have presented more appropriate theories to describe the interaction of humans with computer systems.

One model that maintains the line of information processing is described by Dix *et al.* (Dix *et al.* 1993, also Preece *et al.* 1994) and adapted from Card *et al.* (Card *et al.* 1983). This model is named Model Human Processor and is basically a "simplified view

of the human processing involved in interacting with computers systems" (Dix *et al.* 1993). The model involves three subsystems, the perceptual system which deals with sensory stimulus from the external world, the motor system which controls the actions and the cognitive system which provides the necessary processing to connect the other subsystems (Dix *et al.* 1993).

Two other approaches are the computational approach and the Connectionist approach. These can be described as follows:

- The computational approach, as described by Preece *et al.* "no longer adhere[s] to the information processing framework" (Preece *et al.* 1994). Although it departs from information processing theory it still considers the characterization of the actions of the brain in terms of the computer metaphor. The computational approach, basically emphasizes the "modeling of human performance in terms of what is involved when information is processed rather than when and how much" (Preece *et al.* 1994). To analyze what is involved when information is processed it is necessary to revise issues such as the organisation and classification of information, how relevant stored information is retrieved, decisions that are taken and the reassembling of information (Preece *et al.* 1994). Basically this approach is concerned with "how the system deals with new information" (Preece *et al.* 1994).

- The Connectionist approach, (which is related to the connectionist approach to learning referred to in Chapter 1) also known as neural networks or Parallel Distributed Processing (PDP), is based on the simulation of behaviour using programming models (Preece *et al.* 1994). Instead of using the computer as metaphor the Connectionist approach uses the brain metaphor, which conveys the idea that "cognition is represented at the level of neural networks consisting of interconnected nodes" (Rummelhart *et al.* 1986). In this approach all cognitive activity is seen as "activation of the nodes in the network and the connections between them rather than the processing and manipulations of information" (Preece *et al.* 1994).

2.3.2 The Word 'Computer' in HCI

Computers must have particular features and capabilities incorporated in certain components to facilitate interaction with humans. Some of these components will act merely as "transducer[s] for moving information physically between humans and [computers]" (Greenberg 1997). Other components will relate to the control structure and representation of aspects of the interaction (ACM SIGCHI, 1992).

The taxonomy proposed by the Special Interest Group on Computer Human Interaction SIGCHI (ACM SIGCHI 1992) identified the following components that relate to humans when using computers:

- Input/ Output Devices;
- Dialogue Techniques;
- Dialogue Issues;
- Dialogue Genre;
- Computer Graphics; and
- Dialogue Architecture.

a) Input/Output Devices

There must be an emphasis on designing input/output devices for effective mediation between humans and machines (Greenberg 1997). Input devices include keyboards, mouse, trackers, touch screens, cursor keys, joystick, voice recognition systems, etc.

According to Preece et al. (Preece et al. 1994) the design of a good input device should consider the following:

- Matching the physiological and psychological characteristics of the users, plus their level of training and expertise;

- The appropriateness for the task that they are designed to perform, for example, a drawing task requires an input device that allows continuous movement; and

- The suitability for the intended work and environment, for example, voice input would be necessary for a place where a keyboard can't be located, but would not be very useful in a noisy environment.

Output devices include displays, sound and speech output, printed paper, etc. They allow the provision of "information or feedback in a form perceptible by a human" (Preece et al. 1994).

Issues associated with output devices include taking into account disabilities such as "blindness, colour-blindness, partial sight, hearing impairments" (Preece et al. 1994). Other physical issues are display luminance, contrast between characters and background, resolution and flickering, etc.

b) Dialogue techniques

Dialogue techniques deal with "the basic software architecture for human computer interaction" (Greenberg 1997). Different ways to match human purpose in relation to input/output with regard to particular input/output computer techniques need to exist in the dialogue between humans and computers. In general, four topics need to be addressed: Dialogue inputs, Dialogue outputs, Dialogue interaction techniques and dialogue issues.

i) Dialogue Inputs. For example, types of human input purposes such as selection, continuous control, discrete parameter specification must have a corresponding input technique, such as issuing commands and menus through a keyboard, picking and

rubber-banding with a mouse, and character recognition in pen-based systems, etc. (Greenberg 1997).

ii) Dialogue Outputs. Human output purposes such as summary information, precise information, illustration of processes, creation of visualizations, etc. require corresponding computer output techniques, for example scrolling displays, animations, windows, fish-eyes displays, sprites, etc. These techniques must also be related to screen layout characteristics, such as visual logic, focus, clutter, etc. (Greenberg 1997).

iii) Dialogue Interaction Techniques. Dialogue interaction techniques involves addressing issues such as (Greenberg 1997):

- Dialogue type and techniques, for example form filling, menu selection, icons and direct manipulation, generic functions, natural language etc.;
- Navigation and orientation in dialogues, error management;
- Multimedia and non-graphical dialogues, such as speech input, speech output, video mail,
  active documents, videodisc, voice mail, CD-ROM;
- Agents and AI techniques; and
- Multi-person dialogues.

iv) Dialogue Issues. The following dialogue issues need to be addressed (ACM SIGCHI 1992):

- Real-time response issues;
- Manual control theory;
- Supervisory control, automatic systems, embedded systems;
- Standards;
- "Look and feel", intellectual property protection.

c) Dialogue Genre

Dialogue genre relates to "conceptual uses to which the technical means are put. Such concepts arise in any media discipline such as film and graphical design" (Greenberg 1997). Some of these issues are:

- Interaction metaphors such as tools and agents;
- Content metaphors like desktops, paper documents, etc.
- Transition management, for example fading, pans;
- Techniques from other media: film, theater, graphic design;
- Style and Aesthetics;
- Workspace model etc.

d) Computer Graphics

Computer graphics deal with "basic concepts from graphics that are specially useful to HCI" (Greenberg 1997), such as two or three dimensional geometry, graphical primitives and attributes (bitmaps, device-independent images, page definition languages), solid modeling (surface modeling, rendering, lighting models) and color representations, for example color maps.(Greenberg 1997).

e) Dialogue Architecture

Dialogue architecture is concerned with "software architectures and standards for interfaces" (Greenberg 1997). For example, layer models of dialogue and windowing systems, screen imaging models (for example, postscript), multi-user interface architecture, etc.

2.3.3 The Word 'Interaction' in HCI

Interaction is the process through which humans and computers relate to each other. Interaction is achieved by means of an interactive system. According to Dix *et al.* the objective of an interactive system is to help the user to "accomplish goals from some application domain" (Dix *et al.* 1993). Several models have been proposed to provide a context for this interaction. One of the most influential models is the execution-evaluation cycle proposed by Norman (Norman 1988). The main characteristic of this model is "its closeness to our intuitive understanding of the interaction between [the] human user and [a] computer" (Dix *et al.* 1993).

The execution-evaluation cycle model basically proposes that the human forms "a plan of action which is then executed at the computer interface. When the plan, or part of the plan, has been executed, the user observes the computer interface to evaluate the result of the executed plan, and to determine future actions" (Dix *et al.* 1993). Although Norman's model is intuitive and clear in describing the interaction between humans and computers, it does not reach beyond the interface, it only goes as far as the user's view of the interaction (Dix *et al.* 1993).

Another model which extends the ideas of Norman's model is the *Interaction Framework* as proposed by Abowd and Beale (Abowd & Beale 1991). This model "attempts a more realistic description of interaction by including the system explicitly" (Dix *et al.* 1993).

The *Interaction Framework* model consists of four components: The user, the system, the input and the output. This process can be described as follows (Dix *et al.* 1993)

1. The user starts the process by establishing a goal and a task to accomplish that goal;
2. The input is used to direct the users' goal. This requires that the task has to be set using the input language, or the language provided for input;

3. The input is translated into the system by means of a core language, or language of the system converting the input language into a set of operations that the system will carry out;
4. The system processes this set of operations until the execution is completed;
5. After this, the system is now in a new state which has to be informed to the user through the features of the output; and
6. Finally the user evaluates the output determining what was achieved and is ready to re-initiate the cycle again (Dix *et al.* 1993).

From the HCI designer's point of view, the analysis suggested by the framework depends on the particular task or set of tasks in which the user is engaged (Dix *et al.* 1993). Obviously it is only when we try to carry out a particular task in a certain domain that we are able to assess the adequacy of the tools used. Therefore, the main purpose of this interaction framework is to allow us "to judge the overall usability of an entire interactive system" (Dix *et al.* 1993).

The above-mentioned conceptual models basically establish a means of mapping the user's intentions with the activity of the system and allow for an understanding of the interactions between human users and computers.

2.4 Usability

As usability is a key concept in HCI it is necessary to examine it in more detail. Although there are no clear definitions of usability (Cox & Walker 1993) the common understanding is somehow related to the answer to the question of: what makes a system good? From the user's point of view the system *is* the interface (Dix *et al.* 1993), therefore this question is posed specifically in relation to the user interface, i.e. what makes a user interface good?

The lack of clear definition of the concept of usability, sometimes leads to incorrect interpretations by designers, for example, designers may believe that systems with many alternative functions are usable. This is not necessarily so, since in systems designed with many variations and alternatives, users tend to use only some of the alternatives offered to them. They usually do not take the time and effort to learn new functionalities or alternatives unless it is absolutely necessary (Eason 1984). In the author's own experience, having dealt with computers and assisted users for many years, once users have found a particular technique that does what they want it to do, they tend to always use it in spite of showing them the benefits of some new strategy. It usually takes something drastic (like their particular method no longer being available in the system) for users to learn and start using a different technique.

This reinforces the need to emphasize the HCI objective that suggests that systems should be designed fundamentally to help users to perform their tasks. In fact, systems must be adapted to users and their tasks and not the other way around (forcing users to adapt themselves to the system). Usability is the HCI concept that is concerned with providing principles to facilitate the adaptation of systems to users. Usability can be explored through *paradigms* and *principles* (Dix *et al.* 1993).

Paradigms refer to those advances in computer technology that have helped to close the gap between humans and machines. A number of successful interactive systems provide foundations to these paradigms. These are systems which are believed to have

succeeded in supporting and facilitating usability. Because of their success they are seen as models for subsequent developments. Dix *et al.* identifies a number of paradigms: time-sharing, video-display units, programming toolkits, personal computing, window systems, the WIMP (Window, Icon, Menus and Pointers) interface, use of metaphors, direct manipulation, language versus action, hypertext, multi-modality and computer-supported cooperative work (Dix *et al.* 1993). Although not all of these paradigms are directly relevant to the present work, three of them, the use of metaphors, hypertext/hypermedia and multi-modality are relevant, and will be presented in the following section.

The use of *principles* to support usability involves a more theoretical approach. Principles have their origin in abstract conceptions of the "psychological, computational and sociological aspects of the problem domains" (Dix *et al.* 1993). This means that they are the outcome of efforts made to harness technology to increase the power of humans. In the opinion of the present writer, many tools such as computers are basically extensions of the capabilities of human beings, something like a prosthesis. To a certain extent, a computer can be seen for example, as an extension of the capabilities of human memory, or as an extension of the human capability of processing, etc. This is in the same sense as cars for example, can be seen as extensions of walking capability, or telephones as extensions of the human voice (or hearing or both), etc. If computers are viewed in this light, usability becomes a key issue in adapting the computer to suit human capabilities (for example, memory and processing). The smoother the line between the human capabilities and its technological extension the more adequate these tools will be for humans.

The principles to support usability as indicated by Dix *et al.* have more in common with humans than with technology. They argue that "principles... depend to a much greater extent on a deeper understanding of the human element in the interaction [with computers]" (Dix *et al.* 1993). Dix *et al.* identify in general, three main categories of principles to support usability: learnability, flexibility and robustness. Each category is

sub-divided in more specific principles and will be discussed in detail later in this chapter.

2.4.1 Paradigms

a) Use of Metaphors

A metaphor is basically an aid to facilitate the progression of the user from a basic level of expertise (in this case of using a computer) to a greater level of expertise by building a new set of knowledge, based on knowledge already available to the user. The idea is that the users can construct some analogies from their experience and map them to new ideas facilitating the advancement of skills and or knowledge. One key element for designers though is the ability to choose an appropriate metaphor for a particular case.

Some authors indicate that there are certain dangers in the use of metaphors (Cox & Walker 1993, Dix *et al.* 1993). One of the dangers identified by Cox & Walker (also by Dix *et al.* 1993) is the fact that metaphors are good tools at the beginning of the process of familiarization with the computer, but once the users have experienced them, they are presented with the need of having to develop new concepts not initially present in the metaphor. An example taken from Cox & Wilson (Cox & Wilson 1993) is the use of the desktop metaphor. A desktop metaphor presents the users with the idea that the computer is a desktop, so they can use concepts such as file, document, folders, etc. However, when the computer crashes work may be lost. This has no easy analogy on a real desktop. Users therefore have to develop the new concept of saving their work every three minutes (as the author is doing with this work). Dix *et al.* (Dix *et al.* 1993) indicates that this problem will create a certain instability as users will not know how to correctly predict the behaviour of the system by simply relying on the use of a metaphor. Another important problem of the use of metaphors is "the cultural bias that it portrays" (Dix *et al.* 1993). With the increasing globalization of the world today and in particular with regard to software products, a good metaphor in one culture may not necessarily be adequate in another. Metaphors however, can be effective provided we are able to

choose the right one for a particular case. In the opinion of the author, this does not discourage the use of metaphors, but on the contrary encourages effort in the selection of the most appropriate one.

b) Hypertext and Hypermedia

Hypertext is a product of the work done by Ted Nelson in the early sixties. His efforts were directed towards the production of a system where text is interconnected, not only in a linear way but also following a non-linear structure. Normally, a page containing lines of text is read from the top to the bottom, following a sequential pattern. In hypertext, there are special references within the text which point to different pages. This allows a reader to review a document in a pattern other than strictly sequential.

Following the concept of hypertext, a new term was coined: hypermedia. Hypermedia has the same non-linear structure of hypertext, but includes different media such as images and video. Because of its importance to the present work, hypertext and hypermedia will be discussed in more detail in Chapter 3.

c) Multi-Modality

Multi-modality involves the idea of using more than one channel of communication in the interaction between humans and computers. In many cases, a response from the system is conveyed in more than one way, for example a dialogue box followed by certain sound. This is especially useful in cases where it is necessary to keep the user informed of the progress of certain events. In the experience of the author, where there is no obvious response from the system, a sound, like the one made by the hard disk, can indicate that the computer is working correctly. Multi-modality relies on the ability of humans to use more than one of the senses (vision, hearing, etc.). According to Dix *et al.* "designers have wanted to mimic this flexibility in both articulation and observation by extending the input and output expression an interactive system will support" (Dix *et al.* 1993).

2.4.2 Principles

A number of core principles have been formulated by various authors (Cox & Walker 1993, Nielsen 1994, IBM-HREF5, Microsoft-HREF6, Dix *et al.* 1993). A concise and clear summary of these principles can be found in Dix *et al.* (Dix *et al.* 1993). Dix *et al.* group all known principles into three main categories: *Learnability, Flexibility* and *Robustness*. Specific principles follow from the general definition of these concepts.

a) Learnability

A number of principles have been found to help users to know the system initially and to guide them until they are able to accomplish adequate levels of performance after a period of time. These principles are translated into practice by incorporating particular features into the system. Learnability deals with those aspects of a system that promote ease of use at the time when the users begin to interact with the interface. In other words, it relates to the answer to the question of how easy it is to learn the system?

b) Flexibility

In general, flexibility principles deal with the different forms or alternatives in which users and system interchange information during the interaction. According to Cox & Walker, flexibility can be implemented by considering a conceptual model that takes into account a "class of problems rather than a single narrow problem" (Cox & Walker 1993).

c) Robustness.

Robustness is a characteristic that can be applied to the interaction between the user and the system. It refers to the level of support provided by the system in the successful

accomplishment and assessment of the users' goals when using the system (Dix *et al.* 1993).

Adapted from Dix *et al.* (Dix *et al.* 1993) the following tables outline a set of principles which help favour usability.

Learnability

Principle	Definition	Example.
Predictability	Users being able to determine the expected behaviour of the system according to their previous experiences in the interaction with it.	Use of graphical package. Having started a series of graphical objects (Circle, square, etc). Next time users continue work, they should be able to determine which objects are related together (for example, which objects form one selectable set of objects). Especially if the objects overlap
Synthesizability	Supporting the user in assessing the effect of past operations on the present state.	Copying or moving files to different folders. The system should indicate the effect by creating a visual effect such as a new filename appearing in the target folder in case of copy or by erasing the filename from original folder and inserting it in the new folder in the case of move.
Familiarity	The degree of correlation between knowledge accumulated by users in other systems or domains and the present system in order to facilitate a successful interaction.	Metaphors are good examples of implementation of this principle. The 'desktop' interface relates concepts such as files, folders from general desktop tasks into the use of computers. Shape of the objects on the screen to suggest functionality.
Generalizability	Support to enable users to extend knowledge gained in specific interaction to previously un-encountered situations. Can be within same application or across a variety of applications.	Within same application, a user can learn to draw a circle by using previous experience creating a constrained square. Copy/Cut/Paste commands in multiple software packages today are good examples across a variety of applications.
Consistency	Similarity in the behaviour of Input/Output in relation to similar tasks or similar situations	Consistency in command naming. Consistency in the use of arguments for different commands within same system.

Flexibility

Principle	Definition	Example.
Dialogue Initiative	Who takes the initiative in the dialogue between system and users. System-preemptive, system takes initiative. User-preemptive, users take initiative. Principle suggest giving users more control over the initiative and less to the system.	Users can start or interrupt actions at any point in time during the interaction.
Multi-threading	Feature of a system-user's dialogue that allow users to perform more than one task at the same time.	Windows systems, where user can work on more than one task at a time, task editing in one window and file management in another
Task Migrability	Transfer of control for execution between user and system. System should allow the migration from one form of achieving a task for another.	Spelling checker can be done automatically or shared between user and system.
Substitutivity	Admitting corresponding values of input or output to be arbitrarily substituted one by another	Setting up margins for a document can be done in inches or centimeters. Can also be done by 'supplying' the needed value. For example when left margin is required to be twice as large as the right margin, 2/3(8.5-6.5) can be entered.
Customizability	Allowing the user or the system to support definition of preferences. User can modify aspects of the interface. System can adapt to user (modify itself) based in knowledge about the user.	Most current software allows some degrees of customization. MS-Word©, for example, allows customization of the button bars permitting users to select and display those they use most often.

Robustness

Principle	Definition	Example.
Observability	Degree to which users can infer the state of the system judging from its perceivable representation.	Downloading a file using certain ftp packages, displays a continuous bar graphically giving an idea of the percentage downloaded. If that bar disappear from the interface, the downloading process has been completed
Recoverability	Level of support provided to users to take corrective actions when errors arising from users mistakes occur.	The 'undo' and 'redo' buttons of MS-Word© allow users backward and forward recoverability.
Responsiveness	The degree to which users perceive the response time from the system. Response time is the time the system takes to inform users of changes in state.	Launching a program in any system takes some time to be readily available to users.
Task Conformance	Level of support provided to users in relation to the tasks they wish to carry out and level of support in which these tasks match the user's understanding.	System should provide all the users' services identified as necessary and their implementation should match users' understanding of these services.

Chapter Three

Hypermedia and WEB Design Guidelines

3.1 Introduction

The widespread popularity of Hypertext and Hypermedia on the World-Wide Web has attracted considerable interest in extending its original usage as a mere conveyor of large chunks of information, to more specific applications such as using these tools for teaching and learning. In the past, educators with intentions of using computers to deliver educational content have had to deal with complicated authoring languages or programming languages which require considerable learning. Hypermedia has overcome the need to go through these complications (Mayes 1994). The simplicity of the structure of hypermedia and its ease of implementation has gained it interest and support within the educational field.

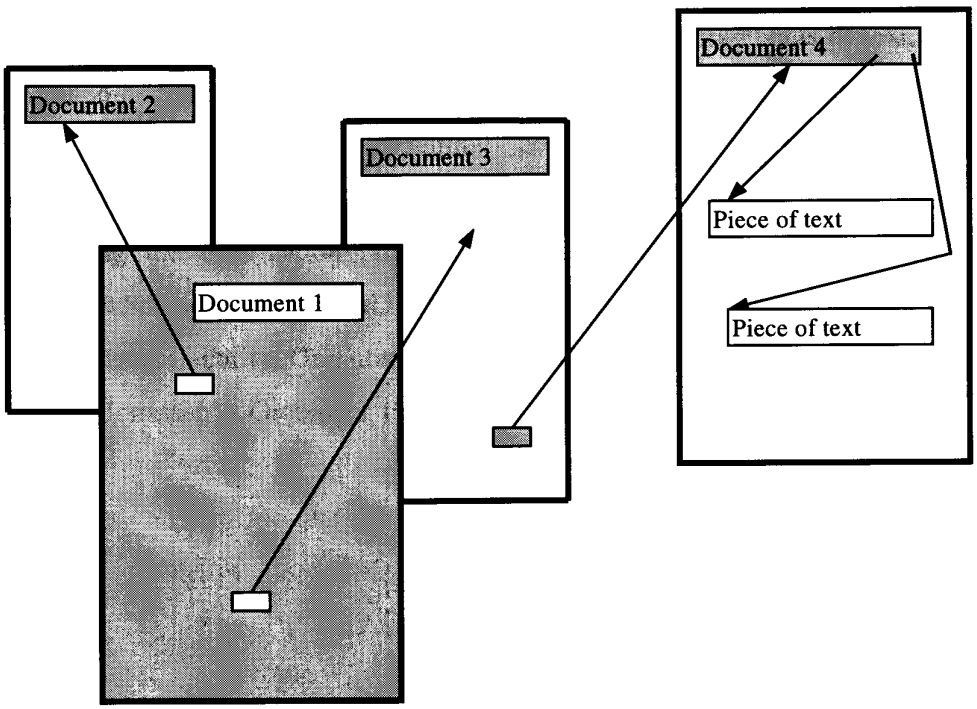
Many of the applications developed on the World-Wide Web have been built with the specific aim of deploying resources to a wide audience. In particular in the educational arena, learning resources such as course syllabuses, course instructions, assignments, course handouts, etc have been extensively implemented using the infrastructure of the World-Wide Web and hypermedia. Deploying these resources is a simple task and with the added capability of graphical enhancements, has led to the production of a wide variety of presentation styles. These styles can range from poorly implemented web pages to highly sophisticated presentations. One critical aspect that has contributed to the production of badly designed web pages is the availability of numerous add-in features (plug-ins, applets, graphical capabilities, etc.) which have been used without careful planning. In this regard, Nielsen encourages "all site and software designers to take usability extremely seriously" (Nielsen, 1996a).

In the context of the present project (production of hypermedia teaching aids) an important supporting element is the revision and selection of a number of adequate principles and guidelines in Web page implementation.

3.2 A brief definition of terms

3.2.1 Hypertext

Ted Nelson, computer visionary created both the concept and the term 'hypertext'. When he first proposed the term he was actually thinking on a bigger context for hypertext than the one that is commonly known today. He was envisaging different kinds of hypermedia, "including discrete hypertext, performing hypergrams, Stretchtext™ , hypermap, queriable illustrations, and hyper-comics" (Nelson 1987). Hypertext has only recently gained extensive popularity thanks to the advent of the world-wide web. Hypertext has, the same characteristics as any other piece of text, this means it can be stored, read, searched, edited, etc. The main difference is that hypertext allows associative connections to other documents or pieces of text. These connections can be made from any sentence (or single word) to other documents or pieces of text. Hypertext breaks the linearity of a written document giving it a property that we could call a third dimension or a depth.



3.2.2 Hypermedia

Hypermedia builds on hypertext. The main difference is that a hypermedia document not only contains text, but can also contain images, videos and sounds. Images, videos and sounds can be used to link to other pieces of text, or other images, videos or sound, allowing for potentially very complex designs. Some authors refer to this complexity as "information-rich environments" (Duchastel 1990).

Basic Characteristics of Hypermedia

There are a number of characteristics of hypermedia. Jonassen & Grabinger have identified the following: Nodes, Links, Network of Ideas: Organizational Structure, Database, Interactivity: Dynamic Control, Paths, Annotation and Collaboration, Authoring Environment. (Jonassen & Grabinger 1989). The following four concepts are expanded upon below, due to their perceived importance in the present work.

Nodes

Nodes are chunks of information that can take the form of fragments of text, graphics, video or other information. Nodes are the basic unit of information on which hypermedia relies. Instead of presenting the information in one large document, hypermedia focuses on the partitioning of information into nodes. One objective of modularizing the information presented to the reader is to allow them to easily determine what node they should access next. The size of the nodes is sometimes referred to as granularity. Granularity can be a single picture, a few words, or a larger document (Jonassen & Grabinger 1989).

Links

Links are the connections between nodes. Links take readers from one node to another, allowing navigation through the information space. The typical relationship between two interconnected nodes is generally associative. In the previous figure, the arrows shown depict the links. Links can be embedded in a single word, a sentence or a bigger fragment of text and in pictures. The types of links can be referential or organizational. Referential links refer to information in another node and allow users to return via the same link. Organizational links are typically arranged in a network of related nodes (Jonassen & Grabinger 1989) and mirror the underlying structure of the information space.

Network of ideas: Organizational Structure

One can think of the structure of nodes and links as a *physical* relationship layer that permits the implementation of a *network of ideas*. Normally nodes and links are structured together in meaningful ways. These meaningful ways constitute the system of ideas that the hypermedia system is trying to convey. In this sense we can talk of an "information model of the hypermedia knowledge base" (Jonassen & Grabinger 1989). This information model "describes the organisation of ideas and the interrelationships which, if explicitly signaled, may help the user comprehend better the information or the problem that is embedded in the system" (Jonassen & Grabinger 1989).

Interactivity: Dynamic Control

The sequence of access to information in hypermedia systems is defined by the user. It allows users' to execute their particular priorities in regard to what information to access next. This leads to a very important issue in the context of the present work, that users *must* be mentally active for the desired outcome to be meaningful. Pointing and clicking (navigating through the hypermedia system) to have access to particular nodes requires

that users follow particular lines of interest, and be actively engaged in the content of the network of ideas presented to them. In this sense, hypermedia systems permit (or demand) a high level of interaction (Jonassen & Grabinger 1989).

3.3 Principles for HTML Web Page Design

A plethora of principles to help the design and construction of web pages exists on numerous web sites. Most of these sites deal with the presentation of web pages in the context of using the Internet as a medium to allow users to find or browse through information in general ways. In the context of the present project however, this aim needs to be refined and particularized to an educational setting, i.e. the delivery of statistical concepts, tools and methodologies aimed at enhancing the learning and teaching of first year university statistics.

A number of appropriate WEB sites have been visited and a set of principles and suggestions have been extracted and revised where applicable. These principles are outlined below.

3.3.1 The Audience

One of the first suggestions that is presented by various authors is the emphasis on the users' characteristics. A number of issues are related to this topic, but in the context of the present work the following are important:

a) *Language*. Deals with the use of language. What kinds of language would best suit the targeted audience? The levels of complexity and formality of language needs to be carefully considered (IBM © 1997).

b) Approach. What kind of presentation would be used? Various styles of presentation can be used. For example playful, scholarly, pictorial, etc. (IBM© 1997).

c) Input and Output media. What kind of media are most appropriate to convey the information? The type of specific media used should also receive careful consideration. For example, it can be visual, voice, text only, or a combination? (IBM© 1997).

3.3.2 Size of the documents

For various reasons (for example, access time charges, slow connections, etc.) it is suggested that the size of the documents be kept small (Comber 1995). Research has shown that on-line reading reduces the speed of reading down to 20% or 30% compared with paper-based text (Comber 1995). One implication of this, is the suggestion to provide for complete downloadable versions of documents in cases where they are manuals, guidelines, research papers, etc. However, preparing a document to be printed requires some considerations. For example, if the pages contain sounds or videos it would be important to translate the information to the printed version in a meaningful way (IBM© 1997).

In addition, with regard to the characteristics of users, it is important to consider the fact that many users will abort the process of downloading a document after a certain amount of time. One of the parameters that strongly influences downloading time is the use of images as well as file size. Apple© recommends minimizing the file size and using small images (graphical considerations will be examined in more detail in the next section). Minimizing the file size can be achieved by breaking large chunks of text into multiple pages (Apple© 1996). In addition, Nielsen recommends explicitly indicating the size and the file format in parenthesis after the link every time a link points to a file that would take more than 15 seconds to download (Nielsen 1995). Research indicates that, in order to maintain the user's attention the best response time should be about 10 seconds (Nielsen 1995). However, because web users are "trained to endure so much

suffering [...] it may be acceptable to increase the limit value to 15 seconds" (Nielsen 1995).

Another issue related to the size of the documents, mentioned at the beginning of this chapter, is the concept of *granularity*. *Granularity* refers to the amount of information that should be displayed on one page. Grant indicates that "one page (or node) should contain the amount of information that a user is likely to want together in one unit" (Grant 1996). On the other hand, this is a highly relative suggestion as there is no way of knowing exactly what amount of information users would like to access in one hit. In spite of this relativity, Grant indicates that "thinking about this [issue], and making a guess is better that not thinking about it at all" (Grant 1996). One suggestion from Apple© that looks at the same issue from a specific view point is to build the size of pages in such way as to avoid the need for scrolling and resizing (Apple© 1996).

3.3.3 Use of Graphics

In relation to the use of images, Apple© gives the following tips (Apple© ,1996):

- Limit the physical size of the images;
- Use thumbnail graphics. If the size cannot be avoided put it on a separate page;
- Repeat images whenever possible. Once an image is downloaded it can be re-used from the local cache memory. This suggests using standard bullet characters, title banners and separator images;
- Specify the WIDTH and HEIGHT (in hypertext mark-up language) attributes of images. Some web browsers can determine the page layout before downloading graphical images. This would give the appearance of faster downloading;

- Use interlaced images. They are loaded in multiple passes. Each pass reveals more resolution details.

An important aspect, although more technical is the selection of an appropriate format for images. Most web browsers support at least JPEG and GIF formats.

- JPEG format compresses better, therefore pictures are smaller in size and also load faster (Apple© 1996). The main disadvantage of JPEG format is that it causes some loss of the images' original information. Given this loss, JPEG's quality is still acceptable, specially for photographic images. Unfortunately, some older versions of web browsers do not support this format.

- GIF format, on the other hand, does not lose information when compressing images. GIF format is said to be more suitable for line drawings and colored graphics (Apple© 1996).

A general suggestion from IBM© for dealing with images is to use them "sparingly and for effect" (IBM© 1997). In certain situations graphical images convey information in a more suitable manner than text. On the other hand, if there are too many, or they have little to do with the message that is being transmitted, they may distract the reader from grasping the message and increase downloading time.

3.3.4 Model/View Separation

In the opinion of the present writer, an important issue is drawn from concepts of object-oriented programming. It refers to the separation of content and presentation in independent ways. This would allow changes to the "view of the information without requiring changes to the content, and vice-versa" (IBM© 1997). Separating the model from the view will allow easier maintenance to correct problems detected after the pages have been implemented. In addition, it will permit some flexibility in situations where

other changes are required, for example, to improve the quality of the information presented.

3.3.5 Navigation Issues

The issues associated with navigation are of crucial relevance to web design and implementation. They deal with a number of concerns, which have been extensively explored in numerous sites. One of the first issues raised is the navigation structure.

a) Navigation Structure.

Navigation structure, relates to the design stage of the web pages. It prompts careful study and planning of the final pages' structure. IBM© suggests the use of flow-charts to assist in the initial planning of the structure (IBM© 1997). In this way, defining the overall structure of the pages at an early stage will avoid "last minute surprises" (IBM© 1997). An interesting method is suggested by SUN Microsystems© to assist the initial design. This method recommends bringing a number of users individually to a room with an adequate sized desk and to offer them small cards (3x5") with the topics that are to be included in the web site. Users are then asked to organize these cards "into little piles of those they think belong together. So, whatever weird ways [users] have of thinking about information, that's what we'll get" (Nielsen 1996b). Once users have formed the initial piles the procedure is repeated in order to obtain some hierarchy. Finally, users are asked to name the different piles (Nielsen 1996b). Nielsen's studies suggest that by using this method, "half of the results are clear in that a consensus trend is identifiable" (Nielsen 1996b). The other half will require further decision-making processes.

Another issue concerning navigation structure deals with the well known problem of "users being lost in hyperspace". This is a common problem which many of us have experienced at some point in time. IBM© suggest that a good solution to this problem is

the use of an "organizing metaphor" as a way to relate groups of pages into a coherent site (IBM© 1997). In many cases the common metaphor of a *notebook* is used with some success. The *notebook* metaphor refers to the organisation of the information and web pages in chapters and sections. In addition, another proposal by IBM©, is to provide one or more navigation pages, i.e., pages specifically dedicated to help users with navigation. This strategy is, however, not very useful if the whole hierarchy is bigger than three levels of depth (IBM© 1997). Careful consideration, however should be given to this issue of navigation pages. According to Grant, pages dedicated to navigation should provide users with the right amount of information. Too little information may lead to users taking the wrong decisions and too much may clutter the screen making the decision process itself too complicated (Grant 1996).

Another issue related to navigation structure is raised by Nelson (Nelson, Year unknown) in what he calls *sequence*. Given the fact that most users scan the pages first and *then* read them, *sequence* suggests that a good design should provide for clear ways of leading users throughout the pages. This must begin with a clear starting point and thereafter, leading from one point to the next "in the proper order for maximum understanding" (Bohle 1995). This, again indicates the need for careful planning of the presentation's overall structure. In relation to this, Berners-Lee presents the following considerations. He recommends keeping in mind the reader's preconceived structure of the material presented (Berners-Lee 1994). Users of web pages will have different degrees of expertise, ranging from novices to experts, in relation to the concepts presented to them through the web pages. Berners-Lee suggests on the one hand, to be "firm about the structure of [the] work" (Berners-Lee 1994) in those cases where users have less expertise. For example, if the author of the presentation strongly believes that the topics to be presented fall into three different areas, this then should be firmly maintained to ensure that users will learn "the structure of the knowledge itself" (Berners-Lee 1994). On the other hand, in cases where readers have greater expertise, enforcing the structure could confuse them and consequently put them off. The basic argument behind the latter consideration is the assumption that expert users more or less know where to find information if they know the subject well (Berners-Lee 1994). In the

opinion of the author of this work, a good design for the structure of the presentation should provide harmoniously for varying degrees of expertise.

b) Visibility of the Navigation Structure

Another issue related to navigation is the visibility of the navigation structure. According to IBM© there are two main navigation structures in a web document, firstly the hypertext links that refer to other pieces of text within the same document, as well as the links to external references. Secondly, the navigation structure presented to users and which is normally related to the structure of the information (IBM© 1997). In the previous section we have discussed the structure of web pages from various points of view in order to facilitate navigation. The suggestion now is that this structure should be presented as clearly and visibly as possible. As the web is a highly un-structured environment, it is important to add minimal levels of structuredness to it. IBM©'s suggestion of a well visualized navigation scheme will give the appearance of a structured presentation (IBM© 1997).

In addition, a specific suggestion to aid in the visibility of the navigation scheme, is to duplicate navigational items at the bottom of pages (Apple© 1996). This is particularly useful if scrolling of pages cannot be avoided. Consistency in maintaining this suggestion across all of the pages in the site would help users to "develop a perception of stability" of the site and would clearly make navigation easier (Apple© 1996). In the opinion of IBM© consistency of presentation "will contribute to the site's visual identity and convey that site as a unique place on the net" (IBM© 1997).

Stressing the point about visibility even further, one way of helping to make the navigation framework visible is to represent specific navigation elements in a consistent way across the entire site. An example proposed by IBM© is the use of a "[coloured] button with a label indicating the destination of the link" (IBM© 1997). This would allow users to easily find this particular navigational element and would ensure that its destination would also be easily understood.

Another way of increasing the visibility of the navigation framework would be to represent the configuration of the site in some way. When exploring the web, the author of this work has visited sites which present users with a tree map of their position within the entire site. This proved to be a useful way of implementing visibility of the navigation scheme. Apple© also stresses the idea that users should be shown where they are in the context of the site. They suggest that this recommendation could be implemented by displaying the present location in, for example a content's table that could also present the main levels of the site (Apple© 1996).

3.3.6 General Visual Appearance

a) Consistency of the presentation

Although consistency of the presentation has been touched upon in previous sections it requires a more detailed analysis. Nelson suggests that web pages should look *as if they belong together*, "as if they were designed thoughtfully by the same person, even if they weren't" (Nelson year unknown). The implementation of this principle could be accomplished, for example by maintaining a certain level of consistency in the use of art elements, similar overall structure of pages, usage of headers and footers with the same information, etc. (Nelson year unknown).

From an educational point of view, consistency of presentation will also minimize the effort required to learn or to become familiar with the navigation scheme. Developers however, need to be careful when designing the web pages in order to provide for this principle. There may be good reasons to vary the general visual 'tone' of the presentation, for example to avoid boredom (Cox & Walker 1993). Nevertheless, it is suggested that consistency in the overall aspect of the pages be maintained. This will help users in the sense that they will be more likely to think of similar situations to produce corresponding actions (Grant 1996).

b) First Impression

The 'first impression' conveyed by the initial part of the pages loaded in the first hit is also a relevant issue to explore. In general, the management of space on the pages must be taken into account. For example, IBM© suggest that this initial display must have a meaningful layout. In some cases, this can be achieved by presenting the more relevant information close to the top of the page. Consistent use of contrast in different ways, such as position, font size and font type, use of colours, emphasis, etc. would help users to grasp an initial global idea of the content of the whole site.

c) Balance and Proportion

Other elements such as balance and proportion should also be considered. Nelson (Nelson year unknown) suggests that these contrast elements (mentioned in the above paragraph), should also be used for balance and proportion of the presentation. For example, a large photograph followed by a small caption and small text is not appropriate. Balance should be exercised to harmonize the pages and make them more inviting. A general rule to exercise balance and proportion is known as the *Golden Section.* This is a relationship based in the assumption that "the human eye tends to prefer certain proportions [...] between sizes" (Bohle 1995). The *Golden Section* rule suggests that a proportion of 0.62 to 1 is adequate to establish relationship between objects (seen for instance in 3x5 size cards, A4 paper, etc). In this sense, squares are out of the question unless they are unavoidable (Nelson year unknown).

d) Affordance

Another issue which affects the visual appearance of the pages is what IBM© calls *affordance*. Affordance not only has implications for the general visual appearance of the pages but also for navigation issues. Affordance is a characteristic of an interface control that is said to be present when users can "infer its function from its appearance" (IBM© 1997). In the case of navigation elements for example, users should be able to

understand clearly what is the purpose of each of these elements. One default element in web browsers that has some degree of affordance is implemented in the cursor when it changes shape when pointing for example, to a link. In this case the cursor changes to a small hand. Another example, is the change in color when a particular link has been visited. This last example however requires that users have previously learnt the meaning of this colour change.

According to IBM©, a "visual designer must not lose sight of the affordance requirements" (IBM© 1997).Keeping this in mind the central problem to be resolved with regard to affordance is to differentiate between navigational elements and information content. IBM© indicate that "the audience knows it has to click to navigate, the question is where" (IBM© 1997).

According to Apple©, the use of appropriate buttons is a very important issue. For example, if a notebook metaphor has been selected and if the content of the site is linear then the presence of previous and next navigation controls is useful (Apple© 1997). In this case, buttons that depict horizontal arrows to the left and right would be adequate to provide for affordance.

e) Feedback of actions.

Another important element in the context of visual appearance is to provide users with some degree of information as to the status and results of their previous action. For example, some graphical interfaces have buttons that are made to look 'pushed-in' after the user has clicked on them. This element should provide users with visual feedback about the completion of the action initiated by them (IBM© 1997).

3.4 Summary Guidelines

All the guidelines and principles discussed in the previous sections are important when designing a Web page, however, the following summary highlights those of crucial relevance to the present design:

- Stress the structure of the presentation at an early stage;
- Provide a clear and consistent navigation scheme;
- Whenever possible, minimize downloading time;
- Emphasize the consistency of appearance of the presentation;
- Choose adequate selection of the size of the pages (granularity);
- Whenever possible separate content from the navigation structure.

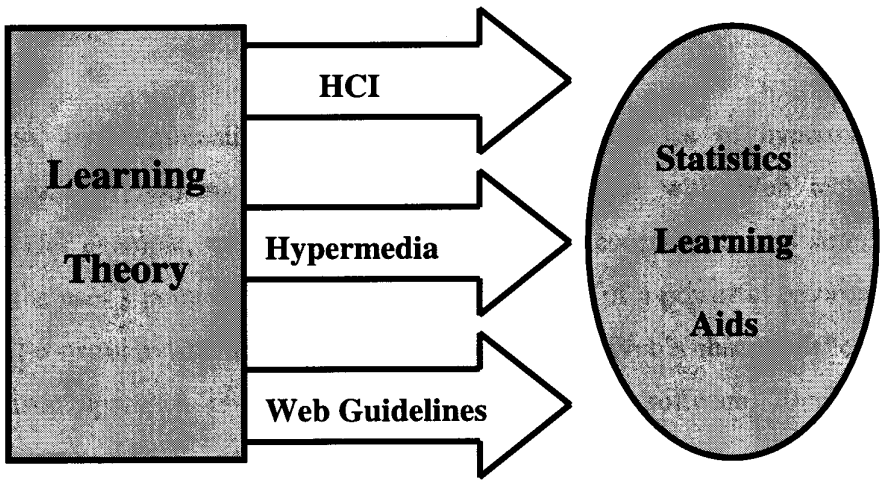
Chapter Four

General Principles for the Design of Hypermedia Learning Tools

4.1 Introduction

The central focus of this research is to enhance the *learning process* of statistical concepts through the construction of computer-based tools. Specifically, the aim is to design hypermedia-based tools to enhance the process of learning statistical concepts. In order to achieve this goal, the study concentrated on the revision of modern learning theories simultaneously with the study of HCI principles, Hypermedia characteristics and Web design guidelines.

The analysis carried out in previous chapters has led us to propose a general model to frame the relationship between these different disciplines in the context of this project. This general model is shown in the following figure:



In accordance with the main objective, stated in the above paragraph, the figure suggests that learning theory provides the main foundation for the construction of learning aids for statistics. From this perspective HCI, Hypermedia and Web Guidelines are vehicles which allow us to support this objective.

With regard to learning approaches, Constructivism is highlighted in the present work as the most appropriate theory to provide a general framework for the implementation of learning aids for statistics. One of the advantages of Constructivism is that it incorporates the most recent ideas and advances in the field of learning theory.

Hypermedia and the World-Wide Web are recent technologies that have great potential for the support of learning processes. In fact, a profusion of learning applications using these technologies has already been developed (see for example, Goldberg 1997). In particular, Hypermedia provides a suitable vehicle for the implementation of constructivistic ideas. This suitability is reflected, fundamentally in Hypermedia's engaging structure, in the provision of a non-linear medium, in the ability to facilitate the exploration of ideas and in the ability to convey ideas and concepts through different types of media (textual, visual and audio). These characteristics provide an adequate modeling environment to map concepts and ideas from almost any knowledge domain to the real world.

In addition, the combination of more general characteristics of hypermedia (for example, ease of construction and flexibility of design) with Web technology's properties (for example, wide deployment of resources, accessibility and simplicity of use from the user's point of view) leads to the provision of a powerful environment to implement constructivistic ideas. Both, Hypermedia's and Web's characteristics provide an optimistic approach to implementing computer-based software. Some of these characteristics will be discussed in more detail in following sections.

Human-Computer Interaction (HCI) is also a novel approach aimed, in general, at bridging the gap between users and computers. HCI provides the right set of principles to foster awareness and implementation of design issues that can support the more fundamental concerns of Constructivism. In particular, in a constructivistic learning environment some models of interaction, the use of metaphors, socially related issues and a number of principles are useful to support the transmission of statistical concepts. These issues will be discussed later in this chapter.

4.2 Constructivism as the Central Learning Theory

Constructivism asserts that knowledge is not merely transmitted from teacher to student but instead is *actively constructed* in the mind of the learner (Math Forum 1995). This fundamental premise has a strong impact on the current dialogue in mathematics education (Math Forum 1996). Constructivism focuses on *how* people learn. For example, in the field of mathematics, it proposes that knowledge will result if the following three characteristics are present:

- ✓ a challenge is posed to the learner in
- ✓ an engaging dialogue with mathematical problems in
- ✓ an adequate environment.

This dialogue will foster the formation of new models in a dynamic process involving "evaluation, communication and application of the mathematical models needed to make sense of these experiences" (Math Forum 1996).

At present, Constructivism implies an interesting shift in teaching strategies by phasing out old structures in the pedagogy of mathematics such as, 'definition-theorem-proof' which can result in the process of forcing concepts onto learners from an abstract and usually boring perspective. This shift is proposed in relation to the provision of more adequate and modern proposals like sense-making by establishing relationships between mathematics and the real world (Wilensky 1995).

As a result of our study, a number of characteristics of Constructivism are highlighted. Firstly, Constructivism is better suited for advanced stages of knowledge acquisition (particularly in universities). However, consideration should be given to the fact that during initial stages of learning students require more support than a classical Constructivistic environment can provide. This support can be easily provided by the lecturer.

Secondly, Constructivism focuses on the following principles:

- Search for meaning;
- active mental processing of perceptions;
- active construction of knowledge;
- understanding the learner's mental models and their underlying assumptions;
- challenging inappropriate constructions and supporting appropriate constructions;
- building on previous knowledge;
- facilitating the extrapolation of knowledge and filling the gaps;
- creation of affectively attractive environments with the aim of engaging the learner.

Thirdly, Constructivism suggests that:

- Material is better learnt when it is generated by learners themselves;
- Learning is more effective through one's own experience, in particular those that have meaning and importance to learners; and
- Real world experiences and realistic settings are more appropriate for learning.

4.3 Hypermedia and the Constructivist Approach to Learning

The constructivist approach to learning establishes that the learning process is achieved when learners create or construct meaning in their constant interaction with the world. In the search for meaning, learners relate their mental models and rules to the situations presented to them. Following this idea, an ideal learning situation would be one in which students are presented with situations in which they have to exercise this dynamic. In this sense, Oliveira indicates that hypermedia grants a privileged means of learning support, through the provision of a context where learners could exercise and "develop critical capacity, conflicting explanations, historical perspectives, personal opinions, facts, etc." (Oliveira 1992). In addition, from an affective point of view, in order to develop constructivistic attitudes such as, curiosity and research "hypermedia can serve as an excellent means of configuration in order to privilege a constructivist

perspective of learning, guided by the structure imposed on the presentation of information" (Oliveira 1992). In addition, the hypermedia architecture characteristic of non-linearity presents us with appropriate tools to support the assumption that "natural human thought processes are not sequential but conexial, that is, by the associations of ideas" (Oliveira 1992).

An important issue, which requires a more detailed analysis from a constructivistic point of view is related to the structure of the presentation of information in Hypermedia. From this perspective, technology-based learning environments should be designed in order to fulfill the knowledge construction need of learners. If this need is discovered, learners will be able to initiate a dialogue with the learning environment. However, the interaction will be engaging only when the structure presented to learners is able to satisfy this need (Jonassen, Mayes & McAleese 1993). Jonassen *et al.* indicates that hypermedia systems such as hypertext retrieval systems should support this need and engage the learner. They propose the idea that "hypertext is among the best examples of constructivistic learning environments, because acquiring knowledge from hypertext requires the user to engage in constructivistic learning processes" (Jonassen, Mayes & McAleese 1993).

In addition, a general principle is that in a constructivist environment, instruction is centred around problem solving, reasoning, critical thinking and the active use of knowledge. According to Grau & Bartasis, this principle can be supported in a Hypermedia environment. They argue that in hypermedia and in the World-Wide Web, with point-and-click graphical browsers "we find a new user-friendly hypermedia environment which can be used to implement constructivistic learning strategies" (Grau & Bartasis 1995).

Another characteristic of a constructivist environment, is that learners build knowledge actively, both at an individual level and a social level. To this effect, simulations pose a challenge as well as opportunities for "collaborative learning and socially constructed responses to problems" (Hedberg 1995). Simulations are representations of the real

world used in the context of particular subject matter, to engage students in a process of learning. In this assertion, we find a critical point in regard to the representation of the real world.

This critical point is, according to Jonassen *et al.*, that "technology environments, such as hypertext, can represent the world to students in its natural complexity" as opposed to an "interpretation of reality in order to make them more easily understandable" (Jonassen, Mayes & McAleese 1993). In the opinion of Jonassen *et al.*, if we want to engage the learner in a meaningful, real-world context, these representation should incorporate the "natural complexity and ill-structuredness that the real world contains" (Jonassen, Mayes & McAleese 1993). In fact, this idea of representing the 'world-as-is' is derived from Cognitive Flexibility Theory (a constructivistic theory of learning) (Spiro *et al.* 1995). This theory is particularly related to hypermedia/hypertext. To illustrate this relationship, Spiro *et al.* use the metaphor of a Criss-Cross landscape "with its suggestion of a non-linear and multidimensional traversal of complex subject matter, returning to the same place in the conceptual landscape on different occasions coming from different directions" (Spiro *et al.* 1995). Therefore, Hypermedia/hypertext environments are "good candidates for promoting cognitive flexibility in ill-structured domains" (Spiro *et al.* 1995).

In addition to the previous discussion, Constructivism highlights the need to provide an environment which engages learners and is affectively attractive. Various authors (see for example Grabinger 1989) have indicated that hypermedia has the characteristic of participatively engaging learners and favouring mental activity. This relationship between Hypermedia and Constructivism needs further analysis. In the opinion of the author of this work, not all cases where students are engaged in some kind of interaction activity with the system imply a truly effective learning process. In relation to interaction activity, we must differentiate between the following three concepts. Firstly, there is the concept of *active participation.* Being engaged in an interaction through keyboard and mouse commands may not, in itself be conducive to effective learning. Mayes *et al.* support this idea by stating that "when learners simply follow the links

offered in a passive way there is little reason to suppose that learning is any more effective than that from old-fashioned branching programme in the programmed instruction tradition" (Mayes *et al.* Year unknown). Secondly, there is the concept of being *mentally active.* When browsing through web pages, mental relationships must be established between a present state in the browsing activity and the next, for example, making decisions on what to access next, what to read, etc. In spite of these relationships, there is nothing to indicate that a process of real learning is taking place. The third concept is that of *active learning. Active learning* involves the presence of a learning goal and a process of learning guided by an engaging and active involvement which is related to the concepts and information presented to learners. Learners must therefore be conceptually active. *Active learning* requires *active participation* and the learner needs to be *mentally active* to successfully accomplish the learning task.

4.4 HCI Principles and the Constructivistic Approach to Learning

In the context of the present work, it is emphasized that in general, the role of Human-Computer Interaction (HCI) is to provide adequate support in order to achieve the goals for a constructivistic implementation of statistical learning aids. There are three concepts drawn from HCI which deserve some theoretical consideration in regard to Constructivism. Firstly, the use of metaphors, an important topic of discussion in the field of HCI. Secondly, the interaction framework suggested by HCI which has already been discussed in Section 2.3.3. Thirdly, the idea that computer-based tools should be designed keeping in mind that, effectively we are communicating with other human beings. This idea has been discussed in Section 2.3.1. In addition, HCI principles will also be discussed in relation to Constructivism and an important relationship between Hypermedia and HCI will be briefly discussed.

a) The use of metaphors

Two of the assertions of Constructivism establish that learning is based on previous knowledge and in that the formation of adequate mental models in learners must be fostered. In this sense, metaphors can be seen as tools to relate previous knowledge of learners to new structures of knowledge presented to them. Many educators have observed that providing students with comparisons helps them to learn (Smilowitz 1996). For example, some experimental studies conducted, in the area of teaching programming using metaphors, indicate that "programming constructs [...] could be learned more easily when they [are] presented in the context of a concrete metaphor" (Mayer 1976). Therefore, many educators extrapolate these results to other knowledge domains and believe that learners can "import conceptual relations and operations from one domain to another" (Smilowitz 1996).

In addition, one key aspect of metaphors is their ability to guide learners towards the construction of an appropriate mental model. The construction of a suitable mental, can be facilitated, as long as a good metaphor is chosen, when a relationship can be drawn between the "real world of an hyperdocument and the real world or a scientific theory which is to be studied" (Oliveira 1992).

The ability to support the formation of a suitable mental model is a key issue in designing learning applications. Metaphors are one fundamental way of helping users to construct mental models. Unfortunately not much research has been carried out on how to design an effective metaphor and little is known about the particular characteristics that can enhance the potential and utility of metaphors (Smilowitz 1996). Smilowitz conducted some experiments in this area by comparing interfaces where a metaphor is used with a non-metaphor interface. One important conclusion from Smilowitz's study is that poorly chosen metaphors are sometimes no better than not using a metaphor at all (Smilowitz 1996). Although Smilowitz acknowledges that little information is available in order to select what may constitute a good metaphor, she still proposes that one important characteristic of a good metaphor is the degree to which it can map the target

domain, or resemble it (Smilowitz 1996). Another conclusion of Smilowitz's research, indicates that using one single metaphor to map the target domain for a given situation is slightly better than using several metaphors simultaneously (Smilowitz 1996).

b) Interaction Framework

An important perspective can be drawn from the analysis of the Interaction Framework discussed in Section 2.3.3. The interaction framework proposes a model to analyze the interaction between humans and computer systems. One characteristic of this model is that it recognizes that the system changes as a result of the interaction. Through the interaction, users are able to modify the internal status of the system. In fact, the concept of interaction, in this context, suggests that the system *continually* changes its status as a result of the interaction. Hence, *the system presents a behaviour that is not static, but dynamic*. This has an important parallel with the Criss-Cross landscape paradigm reviewed in Section 4.3.

The Criss-Cross landscape paradigm, establishes that the user-learner of a hypermedia system will return to the same place in the conceptual landscape, at different times and from different perspectives. This idea can be further expanded. Firstly, in a hypermedia learning environment, the meaning and understanding of a visited conceptual landscape, will have undergone a change in the perception of the learner during repeated visits. This is consistent with the Constructivistic idea of building layers of knowledge in the learner's knowledge structure. Secondly, the perception of the visited conceptual landscape changes not only in time, but also in space. The particular path followed by the learner before his/her arrival at a particular conceptual landscape will also contribute to a change in the perception of this conceptual landscape (it is not the same arriving at E from A then B then C then E – as it is arriving at E from G then I then D then E). This spatial change is consistent with the idea of active mental processing of perceptions from Constructivism. As a consequence of this, the interaction framework proposed by HCI, from our point of view (hypermedia learning environment), should be extended to provide recognition not only of the changes *in the system* because of the interaction, but

also to acknowledge the changes in time and space, that take place *in the learners' perception of the system.*

Another concept that needs to be addressed in relation to Interaction Framework is who has control of the interaction. In general, it appears that HCI is predicated on the system being in control of the interaction. For example, in a given interaction the system normally prompts the user for input, perhaps from a set of alternatives, but still predefined (programmed). Therefore, the system is *more* in control of the interaction than the user. In hypermedia, and from the point of view of the Criss-Cross paradigm, this is reversed. In a hypermedia-web context the user ***is*** actively in control of the interaction without being limited to specific sets of alternatives.

c) Designing to Communicate with Other Human Beings

A fundamental idea of Constructivism lies in its social implications. Constructivism fosters interaction between human beings at three levels. Firstly, the interaction between learners and experts. Secondly, learners' interaction with their peers and thirdly, interaction between learners and their environment (Richardson 1995). Cox and Walker have proposed that from an HCI point of view, designing is a process that should always be focused on the fact that the ultimate goal of what is being designed, is to communicate with other human beings. (Cox & Walker 1993). To provide an example of this idea, we need to go no further than this project. In one way, the objective of this work can be paraphrased as, helping the expert (teacher/instructor) to *communicate* statistical concepts to learners. In this regard, designing the computer-based tool requires the need to provide for this implicit human-to-human way of communication.

d) HCI Principles

A number of HCI principles were discussed in Section 2.4.2. Although these principles are somehow specific to the design of usable interfaces, from a constructivistic point of view they can contribute to emphasize or favour the implementation of constructivistic

ideas. HCI principles can contribute to support the requirement of placing control of the presentation and the activity in the hands of learners, by, for example, providing a clear and consistent navigational structure. HCI principles can also assist in the design process to foster adequate presentation of the conceptual structure in such a way that learners can more easily make sense of the information presented to them. HCI principles can also guide the design of the learning tools in such a way as to provide for the constructivistic concept of engaging learners from an affective point of view. In addition, HCI principles may also contribute to lift the stress of 'learning the learning tool' leaving students space to concentrate on the statistical concepts.

4.5 The World-Wide Web and the Constructivist Approach to Learning

The World-Wide Web possesses a number of benefits from an educational perspective, but it also reveals some associated problems. One important issue is that the creation of web pages can be very easy to implement using HTML. In fact, it is very difficult to resist the temptation of rushing to assemble educational material using web technology. In the context of this project and in order to concentrate on learning aspects, the guidelines identified in Chapter 3 will assist in the implementation of the learning tools, focusing on facilitating the accomplishment of constructivist goals. In particular, web design guidelines can support (as well as HCI principles and Hypermedia characteristics) the organisation of the content in such a way as to provide for the constructivistic concept of facilitating knowledge construction on the part of the learners.

4.6 Design Principles

From the analysis carried out in the previous chapters, a number of general guidelines for the design and implementation of the present project can be enumerated. These are as follows:

1. **Provide a real world setting**
2. **Accommodate different learning styles**
3. **Accommodate different views of the problem and the solution (Criss-Cross)**
4. **Use a problem solving approach (learning goal)**
5. **Encourage the construction of a mental model of the subject problem domain before attempting a solution**
6. **Provide a pictorial and engaging environment but use no more graphical aids than are necessary**
7. **Accommodate flexibility in browsing**
8. **Structure presentation to foster the creation of understanding and meaning**
9. **Use metaphors to map learner's existing knowledge to the target domain**
10. **Keep in mind that we are communicating with other human-beings**
11. **Be clear and consistent with regard to the navigation structure**
12. **Balance use of language in the interaction. (Enough to express concepts, but not too formal or complex so as to confuse the learners)**
13. **Carefully establish the appropriate granularity of the web pages**

Chapter Five

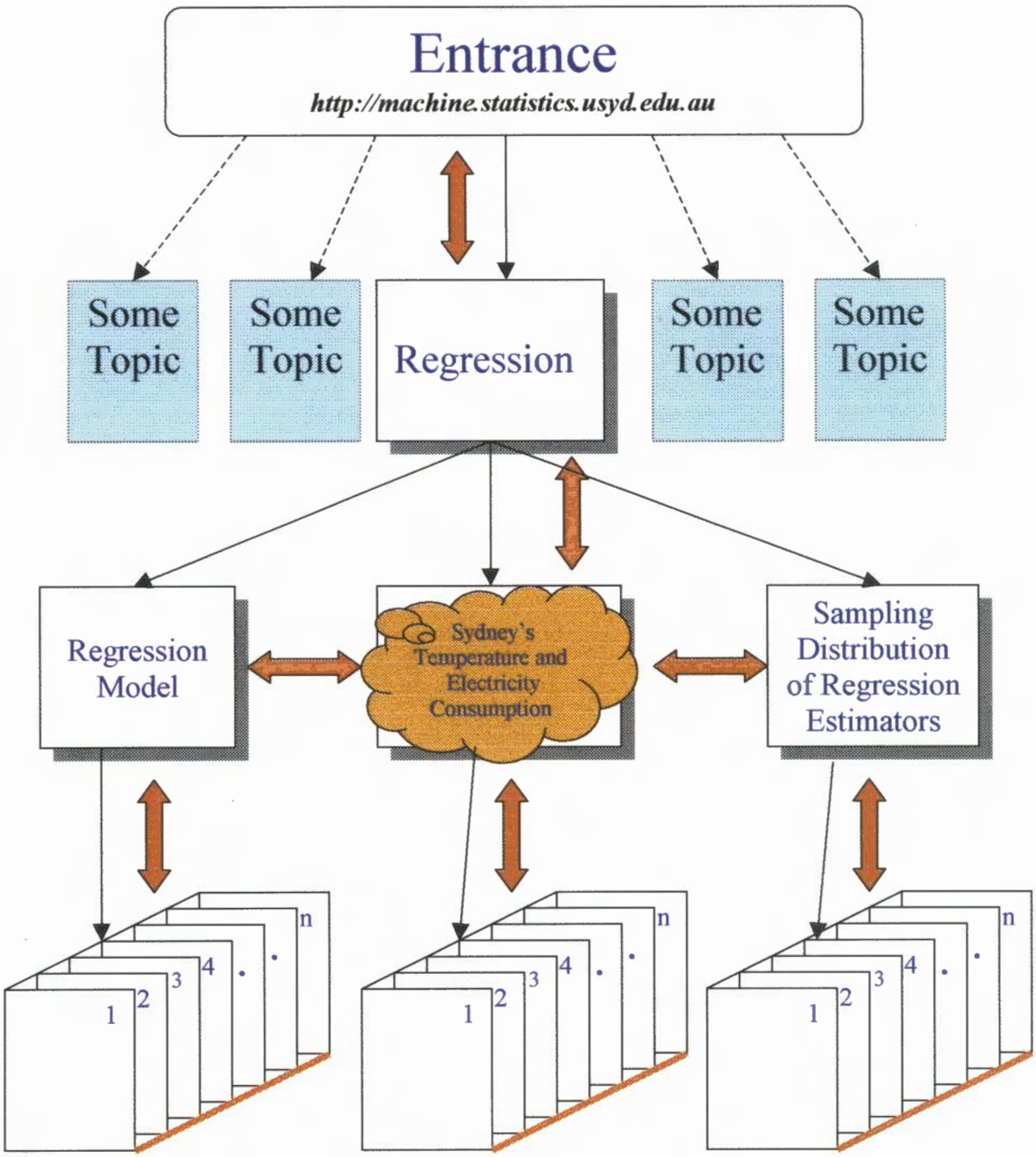
The Actual Pages

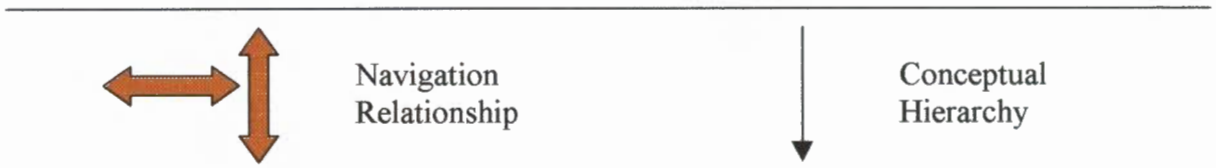
5.1 Introduction

For the design of the actual web pages emphasis was given to the planning stage of the whole structure. Therefore, firstly in this chapter the general structure of the pages is shown. Secondly, the detailed structure is presented, and finally, some of the actual pages printed directly from the browsers will give an idea of the final product.

During the planning stage of the development, constant discussion was carried out with the lecturers that will be using the learning tools.

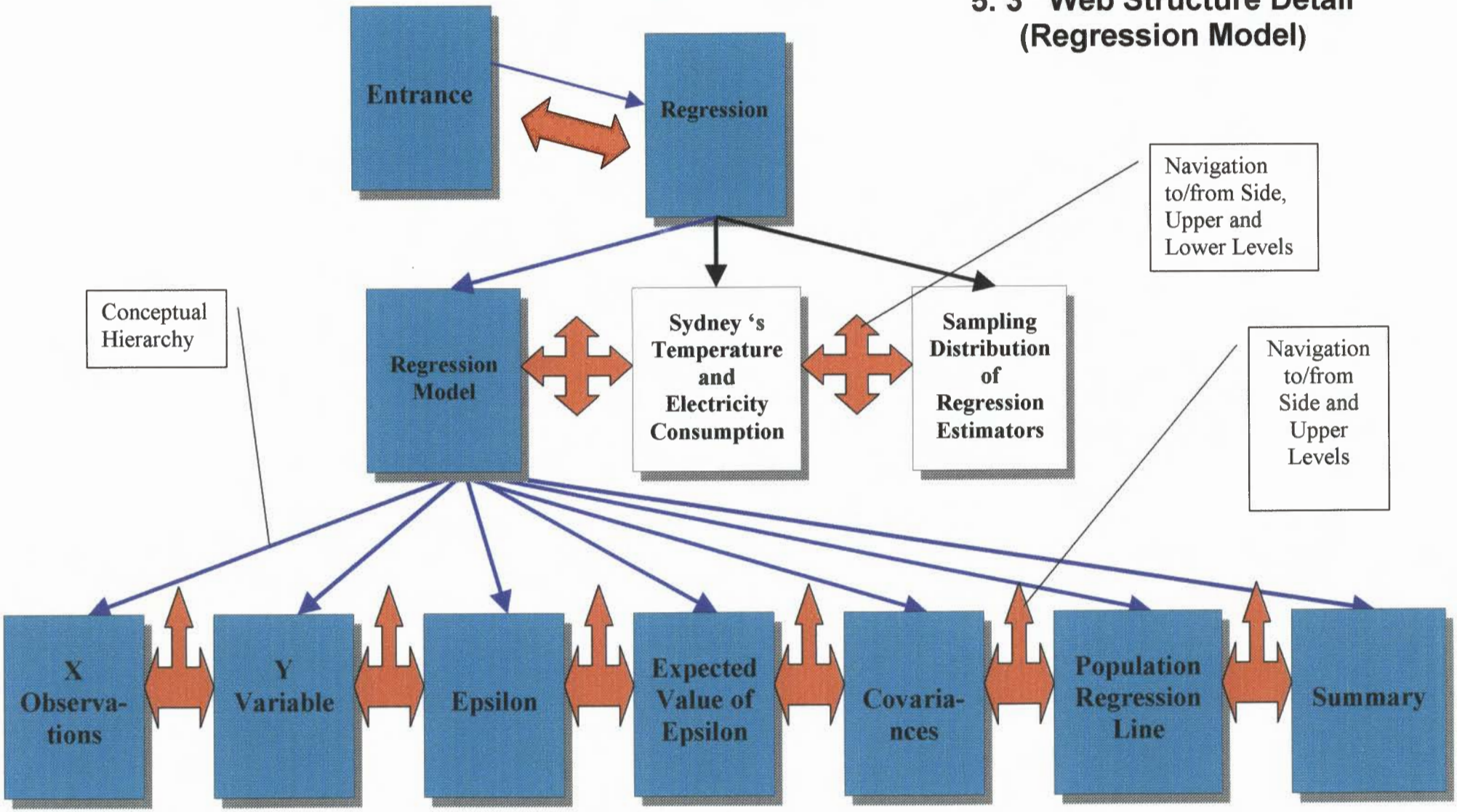
5.2 General Web Structure





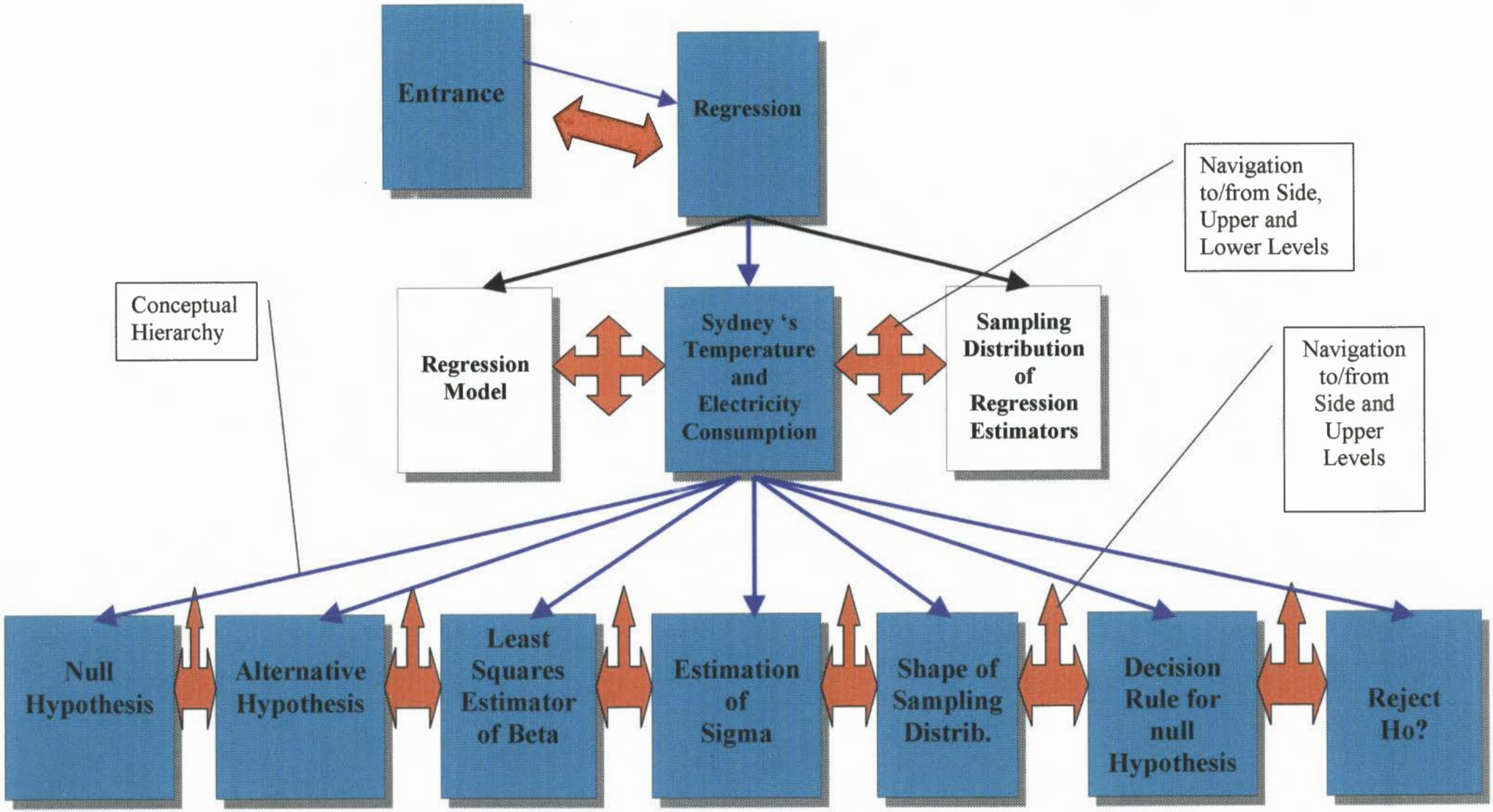
5.3 Web Structure Detail (Regression Model)

5. 3 Web Structure Detail (Regression Model)



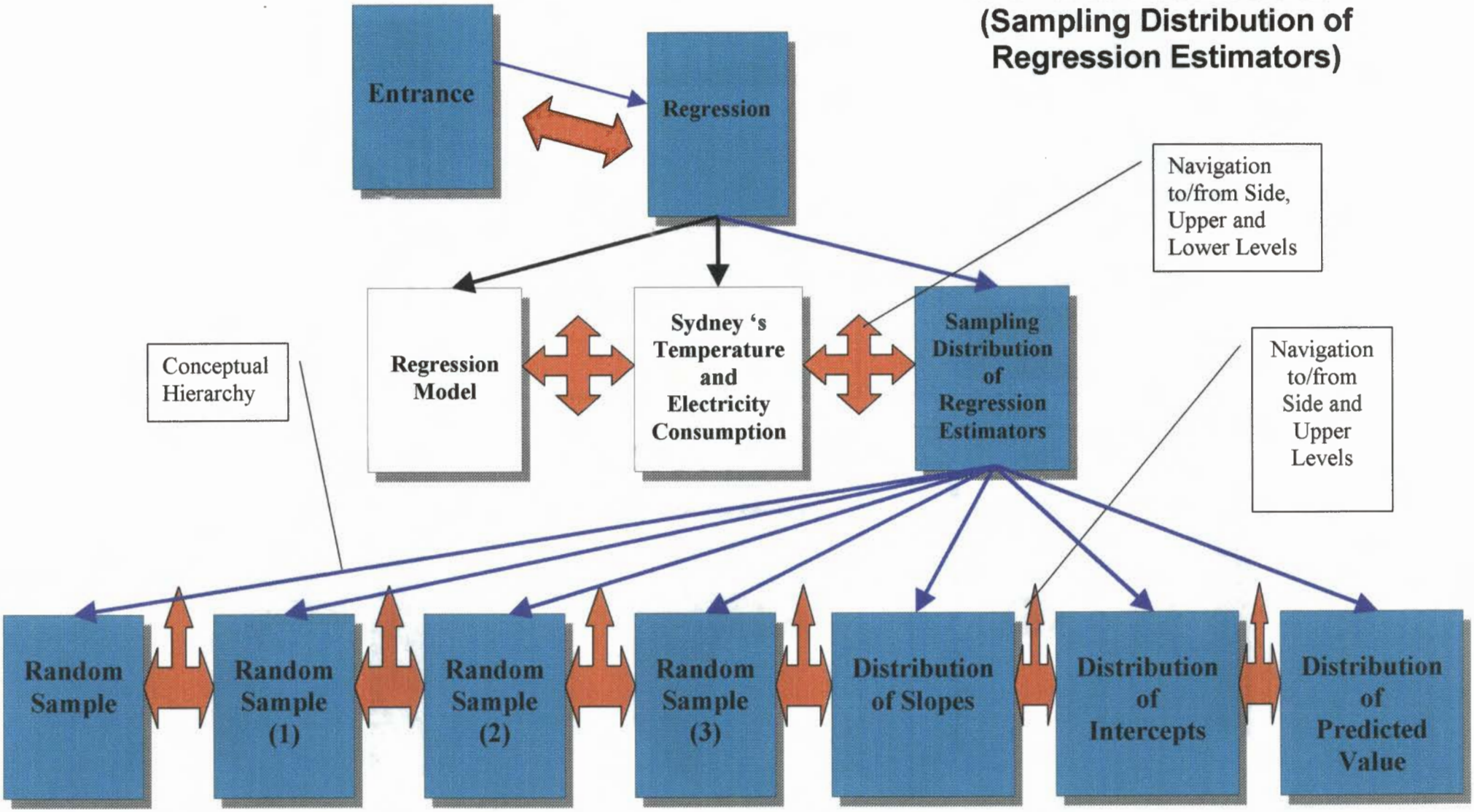
5.4 Web Structure Detail (Sample Application)

5. 4 Web Structure Detail (Sample Application)

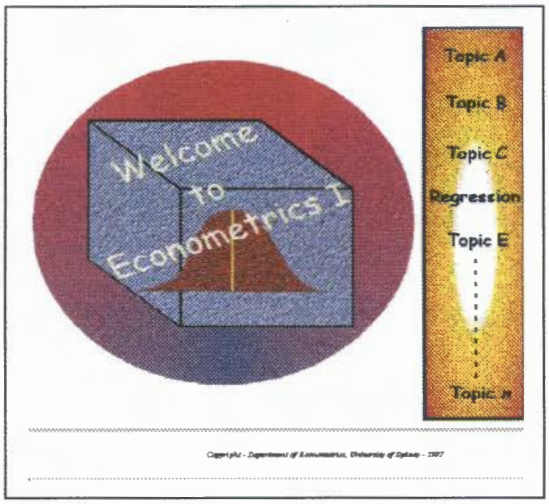


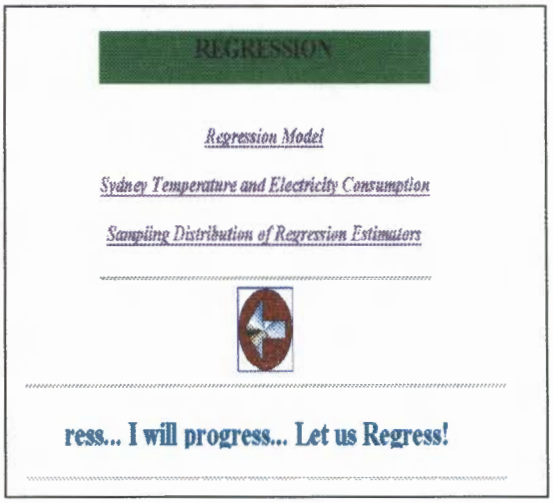
5.5 Web Structure Detail (Sampling Distribution of Regression Estimators)

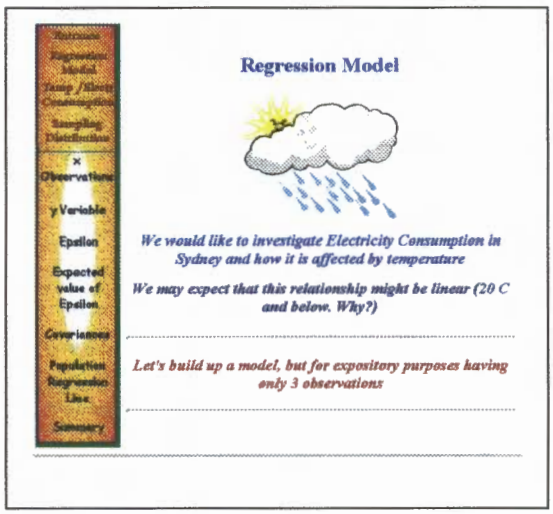
5. 5 Web Structure Detail (Sampling Distribution of Regression Estimators)

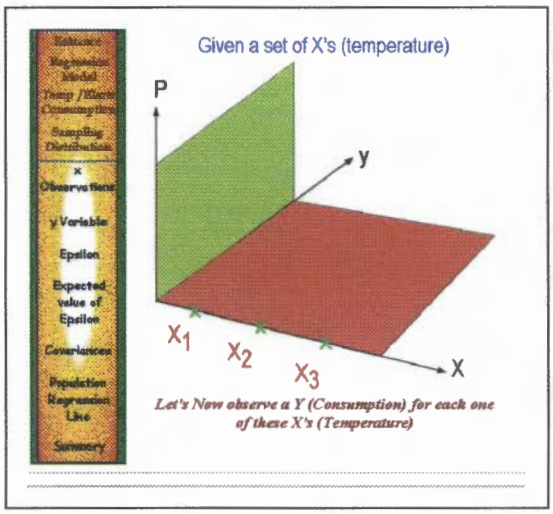


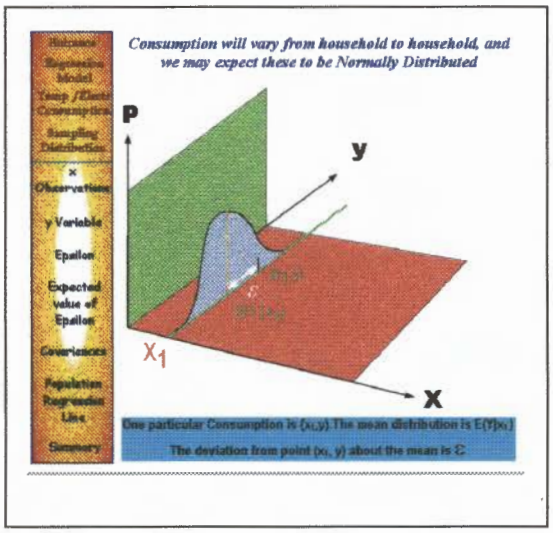
5.6 Sample Pages

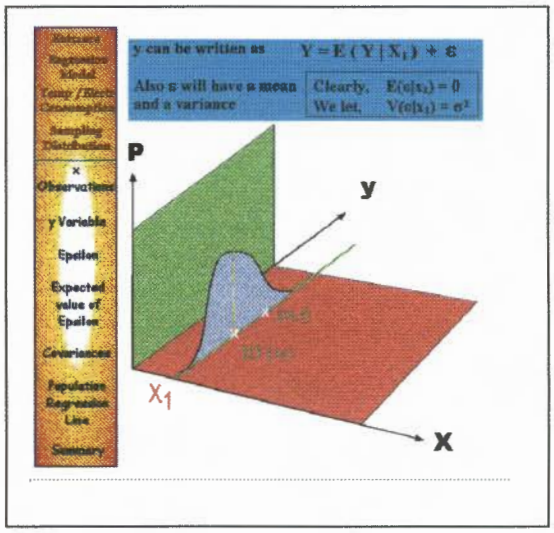


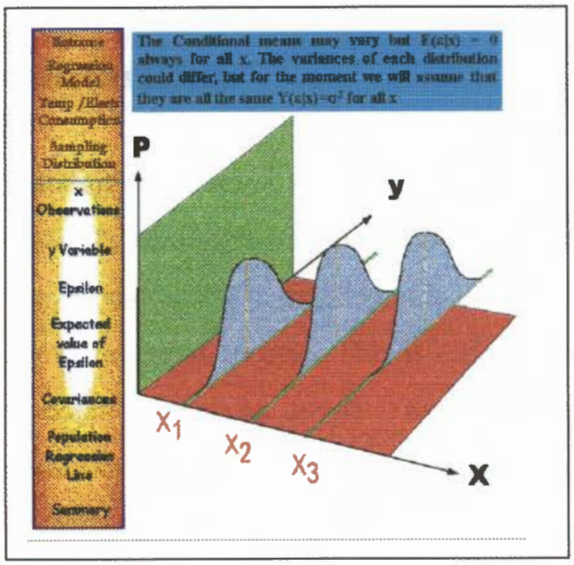


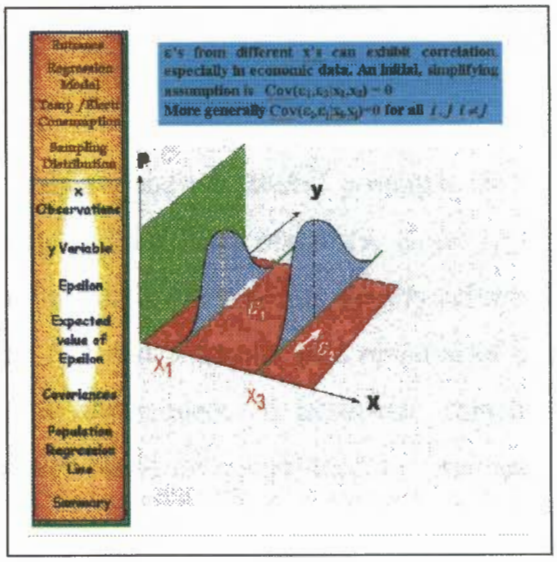


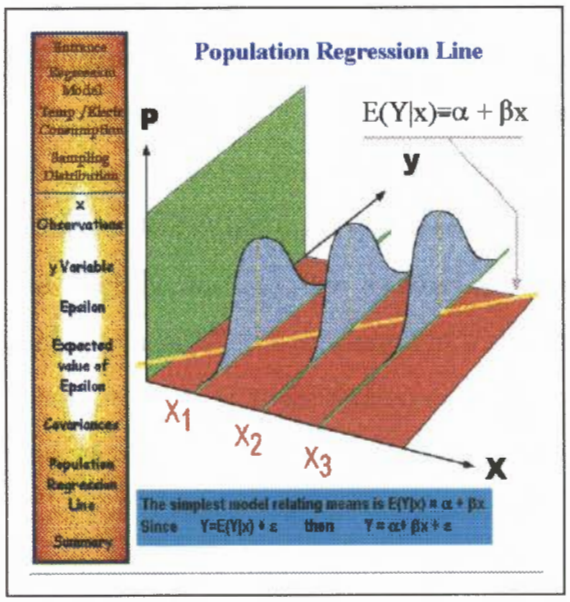


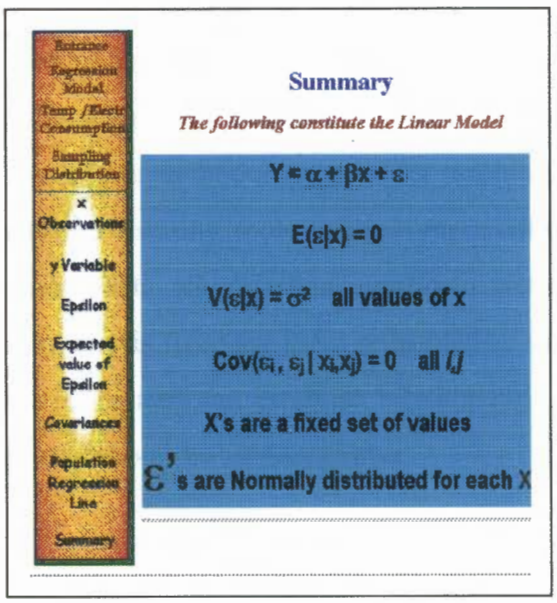





Intrance
Regression Model
Temp /Electr Consumption
Sampling Distribution
x
Observations
y Variable
Epsilon
Expected value of Epsilon
Covariances
Population Regression Line
Summary
The Conditional means may vary but E(ε|x) = 0 always for all x. The variances of each distribution could differ, but for the moment we will assume that they are all the same V(ε|x)=σ² for all x
P
y
X1
X2
X3
X


Intrance
Regression Model
Temp /Electr Consumption
Sampling Distribution
x
Observations
y Variable
Epsilon
Expected value of Epsilon
Covariances
Population Regression Line
Summary
ε's from different x's can exhibit correlation especially in economic data. An initial, simplifying assumption is Cov(εi,εj|xi,xj) = 0
More generally Cov(εi,εj|xi,xj)=0 for all i, j i≠j
P
y
X1
X3
X


Intrance
Regression Model
Temp /Electr Consumption
Sampling Distribution
x
Observations
y Variable
Epsilon
Expected value of Epsilon
Covariances
Population Regression Line
Summary
Population Regression Line
E(Y|x)=α + βx
P
y
X1
X2
X3
X
The simplest model relating means is E(Y|x) = α + βx
Since Y=E(Y|x) + ε then Y = α+ βx + ε


Intrance
Regression Model
Temp /Electr Consumption
Sampling Distribution
x
Observations
y Variable
Epsilon
Expected value of Epsilon
Covariances
Population Regression Line
Summary
Summary
The following constitute the Linear Model
Y = α + βx + ε
E(ε|x) = 0
V(ε|x) = σ² all values of x
Cov(εi, εj | xi,xj) = 0 all i,j
X's are a fixed set of values
ε's are Normally distributed for each X

Conclusions

Although the original idea of the present work, using sound educational principles as the basis for developing a computer based teaching tool for basic statistics, is yet to be proven successful in practice, it is believed that the whole exercise has already achieved some degree of success. This is reflected in the fact that it has led to a revision of the teaching techniques adopted by the lecturers of the subject. In particular, this has contributed to the incorporation of new techniques based on constructivistic principles of learning and teaching.

This change in the approach to teaching has also been brought about by the inclusion of HCI principles and Web design guidelines. It was necessary to look at these principles and guidelines from the perspective of constructivist learning principles. This, in some cases contributed to clarification and enhancement of the methodology used for teaching statistics. In addition, the decision to implement the learning tools using Hypermedia and Web technology has resulted in a novel approach, which when combined with learning theory, has contributed to a shift in the emphasis from the mere presentation of content to a more sophisticated environment where learners can establish relationships, explore possibilities and revise their pre-conceptions about the subject matter.

The Statistics Learning Tools have been designed to be used in at least two different ways. Firstly, some modules will require the leading role of the instructor during the lectures in order to complement the concepts presented and to engage the class in discussions about them. Secondly, students will be able to have access to the pages in order to revise past lectures and to explore the conceptual landscape at their own pace and convenience.

An important issue, and a difficult one, was how to translate conceptual content into a Hypermedia-Web structure. This leads us to propose that further research is necessary in order to satisfy this need by extending the synthesis of principles of Constructivism, HCI, Hypermedia and Web design guidelines discussed in Section 4.6. In particular, this

is reflected in the need to produce a consistent *design methodology* that specifically incorporates the general design principles proposed in Chapter 4.

In the process of combining the three fields researched in this work (Chapter 4) an important issue was raised in the domain of HCI. HCI is a recent discipline, which is still undergoing considerable development to establish its basic foundations. It is proposed that incorporating educational theories into the field of HCI will contribute to its enhancement. In particular the inclusion of learning theories, going beyond mere psychological aspects, as at present, would add a new perspective to HCI.

Another relevant point to this conclusion is related to the process of creating the statistics learning tools. Because of the characteristics of the process, it is necessary to consider the development as an *interdisciplinary effort*. In addition to educational and computer expertise it is necessary to include skills from other areas such as artistic design and screen layout design techniques. This supports the team based approach, adopted by some organizations, to developing educational software.

In addition to these concerns, there are some technical issues which have to be investigated further. Once the design of the pages is finalized, it will be necessary to specify the technical requirements for the Web server that will host the pages.

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