Information Technology as a Tool for Teaching Primary Mathematics

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By Nehme Safa

Abstract

New technologies are penetrating education. But new technologies are usually simply added to other topics in schools, not really integrated. New technologies are not widely used in schools as one would have expected some years ago; the pervasion of educational technology tools has become one of the main problems, and integration is now a necessary step. Integration can be defined as combining parts in a whole. In this paper, the researcher describes the attitudes and opinions of a sample of primary Math teachers in Lebanon towards using technology as a tool for teaching math, investigates the importance of integrating technology into Math curriculum in terms of learning theories, and presents an exemplary integrated math lesson plan prepared by the surveyed math teachers. In particular, he discusses the learning theories underpinning integration strategies; explains how each strategy addresses classroom needs, and how each suggests a way to integrate technology resources.

35 primary math teachers are selected on a random basis from a cluster population. The teachers are selected in a way that represents different primary grades (G1, G2, G3, G4, G5, G6, G7), different school systems, different socioeconomic areas, and geographic locations. The researcher prepares and justifies the use of a survey as an appropriate method for studying the above educational issue. Three methods of collecting data were used: documentary sources, observation, interviewing, and mail questionnaires.

On analyzing the results, two findings emerged. First, the main use of the educational technological tools is to enhance higher order thinking skills. Upper and middle teachers rate the use of the educational technological tools to enhance higher order thinking skills higher than do the lower grade teachers. Second the use of the educational technological tools to enhance basic skills was less frequent. Lower grade teachers report using the educational technological tools for this purpose significantly more than do teachers in the middle and upper grades.

The researcher refers the main use of the educational technological tools to foster higher order thinking skills to a growth in various social psychosocial and cognitive skills. The factors that contribute to these outcomes are identified: the software's instructional design and cooperation and collaboration among students. Finally, implications and recommendations for education are presented along with suggestions for further research.
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Appendix
Chapter I: Introduction

I.A. Context

As we stand at the edge of this new millennium, gazing at its uncharted expanse, some of us feel as if we are stepping out onto a launching pad; others feel at the brink of an abyss. Some see the challenges and the marvels to come and are exhilarated; some see only the certainty of change and its uncertain outcomes and are apprehensive. How amazing it is that the influence of technology is a primary force shaping both perspectives. No one can deny the expansion of technology world wide. The personal computer is an essential component of life in this age of technology. Computer technology has enabled previously difficult and even impossible tasks to become part of everyday life. Compound interest could formerly be determined only by specialists. Today, with the availability of computer software or many calculators, any interested lay person has the power to create an amortization schedule with the touch of few keys (Brumbaugh et al, 1997). Computer technology has changed the way people live their lives through the use of automatic teller machines (CD ROM, hand held calculators, cellular phones, home appliances, automobiles, air planes, audiovisual equipment and even video games). Items such as these are readily accepted as desirable ingredients for living both today and in the future (Hubbard, 2000). Grabe(2001) adds "sophisticated technology has become so pervasive and interwined with so many aspects of our private and professional lives that we seldom notice it" (p.1). We watch movies on DVD and listen to music from CDS. Most magazine and television advertisements include e-mail addresses, video games, fax machines, voice mail, personal satellite dishes. The list of technology innovations we have accepted as commonplace goes on and on.

Computer technology has changed the way of teaching of many subject areas, particularly mathematics. MSEB(1989) states "the teaching of Mathematics is shifting from primary emphasis on paper and pencil calculations to full use of calculators and computers" (p.83). NCTM(1989) adds

Because technology is changing Mathematics and its use, we believe that appropriate calculators should be available to all students at all times; a computer should be available in every classroom for demonstration purposes; every student should have access to a computer for individual and group work, students should learn to use the computer as a tool for processing information and performing calculations to investigate and solve problems (p.8)
With the two quotes just given and the idea that teachers tend to teach as they have been taught, what will happen in the profession of Math teachers? Will technology become an integral part of learning primary Mathematics? Will most teachers work smarter and harder in helping their students achieve mathematical power?

Maria Montessori (1967) pointed out the problem by saying “Nothing is more difficult for a teacher than to give up his or her old habits and prejudices” (as cited in Brumbaugh et al, 1997, p.124). The “modern math” movement of the 1960s was prompted for several reasons, but the main one was not meeting the needs of society (Brumbaugh, 1997). Are we facing the same predicament today? That is, are we in the midst of a technological revolution that is being written about and yet not making it into the education setting? The pocket sized calculator has been available for several years. Research shows use of the calculator does not adversely affect students’ learning of Mathematics (Hubbard, 2000). Yet how many teachers permit calculator use?

Part of the reason for a slow transition to the adoption of technology in the classroom is that we, as human beings, resist change. Some people hold the attitude that “if it was good enough for me, it is good enough for my children”. It is almost as if people say things like “Learning Mathematics by doing hand calculations is part of the union dues of life” (Brumbaugh et al, 1997, p.124). With cooperation from teachers, administrators, parents, students and an open minded approach, the Math classroom can be adapted to changing technology. As technological innovations become available for the Math classroom, they can be used to advance learning or hindered by resistance to adopt different approaches (Alessi & Trollip, 1991). Which way would Math teachers have it?

As would be expected, there is not agreement on the use of technology in Math classroom. Should we use it? How should we use it? When should we use it? Steen (1989) stated that computers are not essential for Math learning and instruction until the second year of college (Brumbaugh, 1997). Supporters of technology in education argue that the standards established for teaching and learning Math dictate that technology should be present at the beginning and throughout the curriculum. Others feel educators should adopt a “wait and see” attitude on inserting more technology into the Math learning environment (Alessi & Trollip, 1991).
A choice looms. Should technology be integrated into the math education curriculum or not? One way to test this idea is to look at a sample of primary Lebanese schools which have already integrated educational technology tools into the math education.

I.B. Aim

Technology seldom plays the same natural role in classrooms that it does in other areas of our daily lives. A recent survey of new teachers (Market Data Rettrieval, 1999 as cited in Grabe*, 2001) reports that only one third feels either “very well prepared” or “well prepared” to integrate technology in their classrooms. Many new teachers simply are not ready to take advantage of the resources already available in most primary classroom. It is realized that some teachers are uncertain and anxious about computer software selection, and which technology supported learning activities are likely to be useful and productive for their students. The aim of this thesis is to describe the attitudes and opinions of a sample of primary Math teachers in Lebanon towards using technology as a tool for teaching math, investigate the importance of integrating technology into Math curriculum in terms of learning theories, and to present an exemplary integrated math lesson plan prepared by the surveyed math teachers.

I.C. Rationale

Many educators, parents and students believe the reasons for using technology seem so obvious that everyone should recognize them. Their common sense rationale is based on two major beliefs: (a) technology is everywhere and therefore should be in education and (b) research has shown how and where computer-based methods are effective. Both of these commonly held beliefs have some validity and both provide rationales for using technology—at least as far as they go.

But to justify the expensive time-consuming task of integrating technology into education, teachers must identify specific contributions that technology can and should make to an improved education system. Funding agencies, for example, can reasonably ask why a school should choose a technology-based resource or method over another path to reach its desired goals. As Soloman (1995) said, “It's the vision thing ... we first have to ask: What do we need technology for? We must create our vision, define technology's role in our schools, then plan for its use” (p. 66). The rationale we choose for using technology will guide our goals and help identify the skills and resources needed to accomplish these goals.

*Through out the thesis Grabe(2001) should be Grabe and Grabe (2001)
Several aspects of technology use offer elements of a rationale for continuing or expanding the use of technology in education:

a-The case for motivation

Motivating students to learn, to enjoy learning, and to want to learn more has assumed greater importance in recent years as we recognize strong correlations between dropping out of school and undesirable outcomes such as criminal activity. The drive to keep students in school is an urgent priority. Technology has an important role to play in achieving this goal. Kozma and Croninger (1992) described several ways in which technology could help to address the cognitive, motivational, and social needs of students; Bialo and Sivin (1989) listed several software packages that were either designed or adapted to appeal to students. Technology-based methods have successfully promoted several kinds of motivational strategies that may be used individually or in combination:

Gaining learner attention is considered to be the first motivational strategy. Renowned learning theorist Robert Gagne suggested that gaining the learner's attention is a critical first event in providing optimal conditions for instruction. Although other aspects of instruction should direct this attention towards meaningful learning, the visual and interactive features of many technology resources seem to help focus students' attention and motivate them to spend more time on learning tasks (Pask-Mc Cortney, 1989). Substantial empirical evidence indicates that teachers frequently capitalize on the novelty and television-like attraction of computers and multimedia to achieve the essential instructional goal of capturing and holding students' attention.

The second motivational strategy is engaging the learner through production work. To make learning more meaningful to students, teachers often try to involve them in creating their own technology-based products. This strategy has been used effectively with word processing (Tibbs, 1989), hypermedia (Volker, 1992), computer-generated art (Buchholz, 1991) and telecommunication (Marcus, 1995; Taylor, 1989). Students seem to like the activities because they promote creativity, self-expression and feelings of self-efficacy and result in professional looking products they can view with pride.

Increasing perceptions of control is a third motivational strategy. Many students are motivated by feeling they are in control of their own learning (Relan, 1992). Learner control seems to have special implications for students, in particular for those who have experienced academic failure. When students perceive themselves as in control of their learning, the result
has been called intrinsic motivation, or being motivated by the awareness that they are learning. This finding, reported from the earliest applications of computer based materials, continues to be one of the most potentially powerful reasons for using technology resources as motivational aids. However, when learning paths become complex, with hypertext environments and interactive videodisc applications, students with weak learning skills seem to profit most when teachers supply structure to the activities (Kozma, 1991, 1994).

b-Unique instructional capabilities

Another powerful case for using technology resources is that some technological media can facilitate unique learning environments or contribute unique features to make traditional learning environments more powerful and effective. This can be established through linking learners to information sources, helping learners visualize problems and solutions, and tracking learner progress.

Let us start with linking learner to information sources. In hypertext systems, as seen on many internet webpages, students can select a keyword from a screen and get pointers from several other sources with information on the same topic. These lead to other related sources and topics, forming an endless chain of information. Kozma (1991, 1994) states that while little research has focused on hypertext to date, preliminary findings propose that a hypertext learning environment “both calls on and develops skills in addition to those used with standard texts” (1991, p.203) and “helps the reader build links among text...and construct meaning based on these relationships” (1991, p.204). Computers handle the logistics of this complex activity and, though it remains a complicated process, they make it more feasible for classroom activities.

Coming to helping learners visualize problems and solutions, Kozma (1991) reports that interactive visual media (videodisc application) seem to have unique instructional capabilities for topics that involve social situations or problem solving. He notes that these media provide powerful visual means of “representing social situations and tasks such as interpersonal problem solving, foreign language learning, or more decision making” (p.200). The growing number of videodisc and CD Rom products designed for these kinds of topics (e.g. the AIDS videodisc from ABC news) confirms that designers and educators are recognizing and exploiting these unique and powerful qualities.

Tracking learners' progress is another way of facilitating unique learning environments. Integrated learning systems and subsequent products based on them have capitalized on the
computer's unique ability to capture, analyze, and present data on students' achievement during learning. A teacher attempting to demonstrate a set of skills to a large group of students needs accurate, up to date, easy to analyse information on what each student is and is not learning. A well designed computer based system for data collection can most effectively provide this essential information. Small, palm top computers allow teachers and researchers to keep moment to moment records of their observation of students. Other systems can provide instruction, analyze students' errors and learning styles, and provide feedback tailored to unique learning needs (Mc Arthur, and Stasz, 1990).

An important technological factor which fosters unique learning environments is "linking learners to learning tools". The ability to link learners at distant sites with each other and with widely varied online resources long has been recognized for its unique potential to enhance instruction and facilitate learning (Marcus, 1995). These capabilities include getting access to information not available through local sources, developing research and study skills that will benefit students in all future learning, and providing multicultural activities without leaving the classroom. Some unique affective benefits have also been observed, including increased multicultural awareness as students of different cultures interact online (Grabe, 2001) and enhanced communication skills when students correspond with each other (Cohen & Riel, 1989).

The first instructional initiative that can benefit from applications of technology is cooperative learning. As the traditional culture emphasis on individualism is seen as insufficient for the complex problem solving that lies ahead, there is increased emphasis on small-group instruction that involves cooperative learning. Many technology-based activities lend themselves to cooperative, small-group work: development of hypermedia products and research projects using multimedia.

Problem solving and higher-order skills is the second instructional initiative that is enhanced by the application of technology. Basic communications and mathematics skills remain essential, but so is the need to solve problems and think critically about complex issues. In addition, curriculum is beginning to reflect the belief that students need not master basic skills before going on to higher-level skills. The engaging qualities of technology resources such as "drill and practice" (to be defined later) reinforce basic skills, while other technology resources such as multimedia, problem solving software, and the internet foster higher order thinking.
A final and most essential reason for integrating technology into teaching and learning is the need for students to learn skills that will enable them to become lifelong learners in an information society. Since the emergence of the Internet, many processes involved in locating and communicating information now involve some form of technology. Two kinds of competencies are becoming widely recognized as basic skills for citizens of an Information Age (Moursund, 1995).

(a) Technology literacy.

Soloman (1995) says that “Technology for students is about economic competitiveness” (p. 67). The International Society for Technology in Education (ISTE), the group that recently collaborated with the National Council for the Accreditation of Teacher Education (NCATE) to develop educational technology standards for preservice programs, also developed the National Educational Technology (NET) Standards (ISTE, 2000) for all students. Standards are recognition that technology skills are becoming required job skills. Several states are also establishing their own required technology skills for all students. This tendency makes it essential that teachers both model and teach the use of technology-based methods to their students.

(b) Visual Literacy.

Visual literacy may be thought of as a subset of technology literacy. However, as our society relies more heavily on images and visual communication strategies, educators are beginning to focus on the special need for better visual literacy skills (Christopherson, 1997). Christopherson says that “a visually literate person can interpret, understand and appreciate the meaning of visual messages; communicate more effectively through applying the basic principles and concepts of visual design; produce visual messages using the computer and other technology; and use visual thinking to conceptualize solutions to problems” (p. 173). Christopherson (1997) reports on research that correlates visual literacy skills to higher scores on intelligence tests and to later success in more technical vocational areas such as engineering. These reports create a powerful reason for teachers to integrate educational technology tools into math curriculum.
Chapter II: Review of literature: Learning theories underpinning integration strategies.

Before integrating technology into their teaching, educators must know a great deal about why there are different views on appropriate teaching strategies, how societal factors and learning theories have shaped these views, and how each strategy can address different needs.

Debate swirls around the question of what is the most appropriate instructional role of technology. Prior to about 1980, the answer would have been easy. According to respected writers of the time (Taylor, 1980), the issue divided people into three groups: those who advocated using computers primarily as tools (for word processing and numerical calculation), those who viewed them mainly as teaching aids or tutors, for example, drills and tutorials (to be defined later), and those who viewed the most powerful use was programming. But these groups generally would have agreed that each of these approaches had its place, and there were popular classroom strategies for each use (Grabe, 2001).

II. A. Changes Brought about By Technology

In subsequent years, two trends have affected profoundly the course of educational technology: (1) an increase in the number and types of technology resources available and (2) dramatic shifts in beliefs about the fundamental goals and strategies of education itself. These two trends have not developed in isolation; their roots are intertwined in the larger social and economic conditions that define and shape our modern world. In the past, educational goals reflected society’s emphasis on the need of basic skills such as reading, writing, and arithmetic and an agreed-upon body of information considered necessary for every one. Students were considered educated if they could read at a certain comprehension level; apply grammar, usage, and punctuation rules in written work; solve arithmetic problems that required addition, subtraction, multiplication, and division; and state certain series of historical facts (Grabe, 2001).

As technology becomes more capable and pervades more aspects of society, every day life also has become more complex and demanding. When thousands of students graduate, many of them will take jobs that did not exist when they entered school and will use technologies not yet invented. More information is considered important to learn than ever before and the base of essential information develops constantly. Many educators now believe that the world is changing too quickly to define education in terms of specific information or
skills; they believe that education should focus on more general capabilities such as “learning to learn” skills that will help future citizens manage successfully with inevitable technological change (Brumbaugh et al, 1997); to which, ICASE(2001) suggests that the goals of education are to “prepare citizens who are empowered to lead productive lives and to enjoy the best possible quality of life” (p.2). Such goals could be achieved, ICASE(2001) adds, by empowering every member of society to initiate programs for greater technological literacy for all, to satisfy basic needs and become productive members of the increasingly technological world. The program is UNESCO’S commitment to the promotion of technology education around the world at all levels. It is based on the principle that in a world increasingly shaped by technology, technological literacy is a universal requirement. All human beings must understand complex principles and the basics of technology in order to successfully compete, survive and contribute to sustainable development (ICASE,2001). ISTE (2000) adds, “to live, learn, and work successfully in an increasingly complex and information rich society, students must be able to use technology effectively. Within an effective educational setting, technology can enable students to become problem solvers and decision makers (p.1). Hence, educators believe that knowing what questions to ask and to ask them will be as important as, or more important than, giving the “right answer”. In sum, technology seems to have both increased the number of decisions that people must make and forced them to become more skilled decision makers (Grabe, 2001).

II. B. Current Educational Goals and Methods: two views

As education changes to reflect new social and educational needs, teaching strategies also change; consequently, strategies change for integrating technology into teaching and learning. Today, educators’ definition of the appropriate role of technology depends on their perceptions of the goals of education itself and appropriate instructional methods to help students achieve those goals (Watson and Tinsley, 1996).

Most educators seem to agree that changes are needed in education. But learning theorists disagree on which strategies will best achieve today’s educational goals. This controversy has served as a catalyst for two different views on teaching and learning. One view, which we will call directed instruction, is grounded primarily in behaviorist learning theory and the information processing branch of the cognitive learning theories. The other view, which we will refer to as constructivist, evolved from other branches of thinking in cognitive learning theory. A few technology applications such as drill and practice, tutorials, one type of simulation, and one type of instructional game (to be defined later) are associated
only with direct instruction; most others like problem solving, multimedia production, spreadsheet, the internet, and other types of simulations and instructional games (to be defined later) can enhance constructivist learning (Grabe, 2001).

Grabe (2001) sees meaningful roles for both directed instruction and constructivist strategies and the technology application associated with them; both can help schools meet the many and varied requirements of learning.

II.C An Overview of Directed and Constructivist Instructional Methods:
A Comparison of Terminologies, Models, and philosophical foundations

People with radically different views on an issue frequently use different terms to describe essentially the same thing. Sfard (1998) says that differences in the language used to describe learning arise from two different metaphors used for learning: the acquisition metaphor and the participation metaphor. She notes that “...the acquisition metaphor is likely to be more prominent in older writings, and more recent studies are often dominated by the participation metaphor” (p. 5). In any case, these differences in language signal fundamental differences in thinking about how learning takes place and how we can foster it.

How did these differences come about? The differences begin with underlying epistemologies beliefs about the origin, nature, and limits of human knowledge. Constructivists and objectivists come from separate and different epistemological “planets”, although both nurture many different tribes or cultures (Sfard, 1998). It is important to recognize that both directed instruction and constructivist approaches attempt to identify what Gagne (1985) called the conditions of learning or the “sets of circumstances that obtain when learning occurs” (p. 2). Both approaches are based on the work of respected learning theorists and psychologists who have studied both the behavior of human beings as learning organisms and the behavior of students in schools and classrooms. The two approaches diverge when they define learning and describe the conditions required to make learning happen and the kinds of problems that interfere most with learning. They disagree because they attend to different philosophies and learning theories, and they take different perspectives on improving current educational practice (Grabe, 2001).

Adherents to constructivism support the notion that children learn effectively through interactions with experiences in their natural environment. Steff and Killion (1986) stated that, from a constructivist perspective, “mathematics teaching consists primarily of the mathematical interactions between a teacher and children” (p. 207) This indirect approach to
instruction effectively allows the student to learn in the context of meaningful activities. Learning is an endless, life long process that results from interactions with a multitude of situations (Brown, Collins, & Duguid, 1989). The constructivist approach does not solely focus on the action of the teacher or the learner, but on the interactions between the two, the teacher should make a conscious effort to see personal actions as well as the student’s from the student’s point of view (Confrey, 1994).

Constructivism has multiple roots in the psychology of the twentieth century (Perkins, 1991). There is no single concrete definition of constructivism. Piaget is thought to be one of the first learning theorists to advocate a constructivist teaching approach, even though he did not identify himself as such. He believed in the importance of human interaction and physical manipulation in the gaining of knowledge. The emphasis of the constructivist classroom begins with the student. Constructivists believe that students construct all knowledge in their minds by participating in certain experiences. Learning happens when one constructs both mechanisms for learning and his or her unique version of the knowledge, colored by background, experiences, and aptitudes (Sfard, 1998). The constructivist educator demonstrates a respect for the student. The classroom should be a place that fosters and nurtures learning and development of knowledge (Brumbaugh et al, 1997).

The constructivist classroom creates an environment that encourages learning. The teacher should create surroundings where students can make sense of mathematics as it relates to the real world. Students are to be treated with respect and responsibilities. The fear of failing must be erased in order to foster the idea that students can learn from their mistakes. If we are to expect our students to comprehend and deal with complex problems, we need to establish an atmosphere rich with exposure. Students should become aware of their own thinking process, strategies and critical thinking abilities. Each student should become aware of the ability to invent and explore new ideas and concepts. The effective teacher of mathematics should capitalize on these natural thinking abilities (Brumbaugh et al, 1997).

Constructivism focuses on student centered instruction, which is not new in education. The student plays a major role in the decision making process as to what, when and how learning is to occur. This is a bold approach, but students have great insight into themselves that teachers cannot always see. It is needed to show respect to each student by providing the opportunity to shape individual learning (Confrey, 1994).
Directed instructional methods stress that the information students assimilate can be taught more effectively and efficiently by providing a structured approach. Providing a clear sequence of steps will allow the learner to incorporate a greater amount of knowledge. This approach treats mathematics as a collection of skills. Learn all the skills and learn mathematics. The directed approach teacher presents information and develops concepts through lecture and demonstration. As students question, respond to teacher questions, react to assignments, and do practice exercises, elaborations are given that are designed to clarify and strengthen understanding. Reteaching and emphasis shifts are inserted by the teacher as needed. The teacher carries the curriculum to the student (Educational technology, 1993).

The work of Robert Gagne paved the way for the directed instructional method. He believes that knowledge has a separate, real existence of its own outside the human mind; and learning happens when this knowledge is transmitted to and acquired by learners (Grabe, 2001). He used the idea that a sequence of tasks could be established for a desired learning outcome. If the student practiced each required task as it was learned and developed, that student would then be able to move on to the next step in the continuum (Brumbaugh et al, 1997).

II.D. Theoretical foundations of directed instructions:

Two different theories of learning contributed to the development of directed instructions: behavioral theories and information processing theories (Grabe, 2001).

II.D.1. Behavioral theories:

II.D.1.a. Skinner's behaviorist theories of learning

In 1913 with the publication of an article titled “psychology as the behaviorist views it,” the influential American psychologist John Watson argued that psychology would quickly lose credibility as a science if it focused on internal mental and emotional states that could not be directly observed or accurately measured. The solution was to study what could be directly observed and objectively and accurately measured—the external stimuli that people experienced and what people did in response. In a word, behavior. From this point until the late 1960s, behavioral theories of one sort or another dominated the psychology of learning and culminated in the work of B.F. Skinner (Snowman, 1997).

B.F. Skinner put together a theory that not only successfully combines many different ideas, but also serves as the basis for a variety of applications to human behavior. Skinner’s
theory, operant conditioning, takes as its starting point that many of the voluntary responses of animals and humans are strengthened when they are reinforced (followed by a desirable consequence). In this way organisms learn new behaviors. The term operant conditioning refers to the fact that organisms learn to operate on their environment (make a particular response) in order to obtain a particular consequence. Some psychologists use the term instrumental since the behavior is instrumental in bringing about the consequence (Snowman, 1997). Skinner adds that people can have mental control over their responses (Grabe, 2001).

To illustrate, a child reasons he will get praise if he behaves well in school. Eggen and Kauchak (1999) said that Skinner believed “behavior is more controlled by the consequences of actions than by events preceding the actions. A consequence is an outcome (stimulus) after the behavior that can influence future behaviors” (p.201). Skinner’s work made him “the most influential psychologist of the 20th century” (Eggen and Kauchak, 1999, p.201).

Skinner reasoned that the internal processes (those inside the mind) involved in learning could not be seen directly. Scientific work had not advanced sufficiently at that time to observe brain activity. Therefore, he assumed that a change in an organism’s behavior pattern is the only basis for concluding that learning has occurred (Snowman, 1997), and he concentrated on cause and effect relationships that could be established by observation. Increasingly, he discovered that all behaviors are accompanied by certain consequences and these consequences strongly influence whether these behaviors are repeated and at what level of intensity. In general, the consequences that follow behaviors are pleasant and desirable or unpleasant and aversive. Depending on conditions that will be discussed, these consequences either increase or decrease the likelihood that the preceding behavior will recur under the same or similar circumstances. When consequences strengthen a preceding behavior, reinforcement has taken place, when consequences weaken a preceding behavior, punishment has occurred (Eggen &Kauchak,1999). Thus, Skinner found that human behavior could be shaped by contingencies of reinforcement or contingencies of punishment, or situations in which reinforcement for a learner is made contingent upon a desired response; and punishment for a learner is made contingent upon undesirable behavior .He identified three kinds of situations that can shape behavior:

Positive reinforcement: a situation is set up so that an increase in a desired behavior will result from a stimulus. Although the term positive reinforcement may be unfamiliar to someone, the ideas behind it probably are not. It involves strengthening a target behavior that is increasing and maintaining the probability that a particular behavior will be repeated by presenting a stimulus called a positive reinforcer immediately after the behavior has occurred.
Praise, recognition, and the opportunity for free play are positive reinforcers for many students. The term positive as used by Skinner refers to the act of presenting a stimulus. Positive means, "adding". It does not refer to the pleasant nature of the stimulus itself (Snowman, 1997). To illustrate, a learner studies hard for a test in order to earn praise or good grades, studying hard is considered as a desired behavior.

Negative reinforcement: A situation is set up so that an increase in a desired behavior will result from avoiding or removing a stimulus (Grabe, 2001). The goal of negative reinforcement is the same as positive reinforcement in terms of increasing the strength of a particular behavior. The method however, is different. Instead of supplying a desirable stimulus, one removes an unpleasant and aversive stimulus whenever a target behavior is exhibited. Just as positive refers to adding, negative refers to the act of removing a stimulus. By removing something unwanted, you encourage the student to learn new behaviors (Snowman, 1997). To illustrate from my own experiences, consider the following examples: To avoid going to detention, a student is quiet in class. A child picks up his clothes or toys to stop his parents’ nagging. A driver uses a seat belt to stop the annoying buzzer sound. Preventing from going to detention, stopping his parents’ nagging and stopping the annoying buzzer sound are considered as negative reinforcement while staying quiet in class, picking up his clothes, using a seat belt are considered as desired behaviors.

Punishment: A situation is set up so that a decrease in an undesirable behavior will result from undesirable consequences (Grabe, 2001). Snowman (1997) refers to it as presentation punishment. Punishment is defined by operant psychologists as the presentation of an aversive stimulus such as scolding, paddling, ridiculing. From an operant perspective, one can claim to have punished someone else only if the target behavior is actually reduced in frequency. The following example from my own experience illustrates the point: when a student knows he or she will get grounded at home if he or she misbehaves in school. Here, getting grounded at home is considered as punishment and misbehaving in school is considered as an undesirable behavior.

II.D.1.b Educational applications of Skinner’s behaviorist theories of learning.

In the late 1940s when Skinner’s daughter was in elementary school, he observed a number of instructional weaknesses that concerned him. These included the excessive use of aversive consequences to shape behavior (students are studying to avoid a low grade or embarrassment in the classroom), an overly long interval between students taking tests or
hanging in home work and getting corrective feed back, and poorly organized lessons and work books that did not lead to specific goals. Skinner became convinced that if the principles of operant conditioning were systematically applied to education, all such weakness could be either reduced or eliminated (Snowman, 1997). To him, teaching was a process of arranging contingencies of reinforcement effectively to bring about learning.

That belief, which he then reiterated consistently until his death in 1990, is based on four prescriptions that come straight from his laboratory research on operant conditioning: First, be clear about what is to be taught. Second, teach first things first. Third, allow students to learn at their own rate, and, fourth, program the subject matter. The primary means for accomplishing this group of goals are programmed instruction and teaching machines, that is computer-assisted instruction. He believed that programs of stimuli, i.e. material to be learned and consequences, should be designed to lead students step by step to a predetermined end result. In the mid 1950s Skinner turned this shaping approach into an innovation called programmed instruction. This method of instruction presents small amounts of specially designed written material to the student in a predetermined sequence, provides prompts to draw out the desired written response, calls for the response to be repeated in several ways in order to produce mastery, immediately reinforces correct responses, and allows the student to work through the program at his or her own pace (Branden,1996).

When programmed materials were first made commercially available during the mid-1950s, they were designed to be presented to students in one of two ways: in book form or as part of mechanical teaching machines. The earliest teaching machines were simple mechanical devices. To day programmed instruction in book format is very uncommon, and the early mechanical teaching machines have been almost totally supplanted by the computer, particularly the microcomputer, because computers can do everything the books or the machine could do and far more (Snowman, 1997). In later sections, I will discuss in detail how the surveyed math teachers applied the characteristics of behavioral theory (e.g. positive reinforcement, negative reinforcement,....) in integration strategies in terms of programmed instruction.

What can be concluded is that behaviorism centers around a direct approach. This has been the dominant strategy for teaching mathematics in the world for many years. The behaviorist approach essentially treats mathematics as a collection of skills. Learn all the skills and learn mathematics.
II.D.2. Information processing theories.

Behaviorists like Skinner focused only on external, directly observable indicators of human learning (Grabe, 2001). They focus on the nature of a stimulus to which a student is exposed, the response that the student makes, and the consequences that follow the response. They see no reason to speculate about what takes place in the student’s mind before and after the response (Snowman, 1997). Many people found this explanation insufficient to guide instruction. During the 1950s and 1960s, a group of researchers known as the cognitive learning theorists began to hypothesize a model that would help people “describe and visualize what is impossible to observe directly” (Eggen and Kauchak, 1999, p.239). Those cognitive psychologists are especially interested in an area of study known as information processing theory, which seeks to understand how people acquire new information, how they store information and recall it from memory, and how what they already know guides and determines what and how they will learn (Snowman, 1997). Those information-processing theorists were among the first and most influential of the cognitive learning theorists. They hypothesized processes inside the brain that allow human beings to learn and remember (Grabe, 2001). These processes rest on a set of assumptions of which three are worth noting. First, information is processed in steps or stages. The major steps typically include attending to a stimulus, recognizing it, transforming it into some type of mental representation, comparing it with information already stored in memory, assigning meaning to it, and acting on it in some fashion (Snowman, 1997). At early processing stages, human beings encode information, i.e. represent it in thought, in somewhat superficial ways, as when they represent visual and auditory stimulus as true to life pictures and sounds, and at later stages in more meaningful ways, i.e. as when they grasp the gist of an idea or its relationship to other ideas. Second, there are limits on how much information can be processed at each stage. Although the absolute amount of information human beings can learn appears to be limitless, it must be acquired gradually. Third, the human information processing system is interactive. Information already stored in memory influences and is influenced by reception and attention. It is seen what our prior experiences direct us to see, and in turn, what is seen affects what is known (Snowman, 1997).

Hence, according to the information processing view, learning results from an interaction between an environmental stimulus i.e. the information that is to be learned and a learner i.e. the one who processes or transforms the information. To illustrate, different types of learners make various information processing decisions when confronted with a learning task. For example, as you read a book, numerous other stimuli may compete for your attention. Will
you close the book because someone just turned on the radio or because you feel drowsy or hungry? If you decide to read, do you underline keywords or take notes?

II.D.2.a. Kinds of Memory.

Although no single, cohesive information processing theory of learning summarizes the field, the work of the information processing theorists is based on a model of memory and storage originally proposed by Atkinson and Shuffling(1968) (as cited in Grabe,2001). According to them, the brain contains certain structures that process information much like a computer (Grabe,2001). This model of the mind as computer hypothesizes that the human brain has three kinds of memory or stores:

Sensory registers: A description of how human learners process information typically starts with environmental stimuli. Our sense receptors are constantly stimulated by visual, auditory, tactile, olfactory and gustatory stimuli. These experiences are initially recorded in the sensory register, the first memory store. It is called the sensory register because the information it stores is thought to be encoded in the same form in which it is originally perceived. The aim of the sensory register is to hold information just long enough, about one to three seconds, for us to decide if we want to attend to it further. Information not selectively attended to and recognized disappears from the system (Eggen and Kauchak,1999). To illustrate, at the moment you are reading some words, you are being exposed to the appearance of letters printed on paper, to sounds in the place where you are reading, and to many other stimuli .If you recognize and attend to one of these stimuli it will be processed and transferred to another kind of memory.

Short term memory: Once information has been attend to, it is transferred to short term memory, the second memory store (Snowman,1997). It is the part of memory where new information is held temporarily until it is either lost or placed into other kinds of memory (Ormod,2000). Short-term memory can hold about seven unrelated bits of information for approximately twenty seconds. It is like a filing cabinet with a capacity of seven pictures that will hold their images for about twenty seconds. As new items are placed in the file, either they are incorporated into one of the existing pictures, or they push out one that was previously encoded (Ormod,2000).The following example illustrates the point: imagine that you look up and dial an unfamiliar phone number and receive a busy signal. If you are then distracted by something or someone else for seventeen to twenty seconds, there are possibilities to forget the number.
Long Term memory: the part of memory which has an unlimited capacity and can hold information indefinitely. Information processing theorists believe that for new information to be transferred to long term memory, it must be linked in the same way to prior knowledge already stored in long term memory. This occurs when information stored in long term memory is used to add details to new information, clarify the meaning of a new idea, make inferences, construct visual images, and create analogies (Ormod, 2000). In these ways we facilitate both the transfer of information to long term memory and its maintenance in short term memory. Consider this example taken from my own experience:

If a student wanted to learn the concept of “a fraction”, he or she might relate the definition of a fraction to “a part of a whole”. As he or she strives to memorize the definition of “a fraction” his or her mental elaboration will help him or her store this definition in long-term memory so that he or she can retrieve it later.

II.D.2.b. Educational applications of information processing theories.

Information processing views of learning have become the basis for many common classroom practices (Ormod, 2000). For example, teachers ask interesting questions and display eye-catching materials to increase the likelihood that students will pay attention to a new topic. While presenting information, they give instructions that point out important points and characteristics in the new material and suggest methods of encoding or remembering them by linking them to information students already know. To help assure the transfer of information from short to long term memory, teachers give students practice exercises to practice the concept or skill being taught.

Educational psychologists such as Gagne and Ausubel provided many instructional guidelines designed to enhance the process of attention, encoding, and storage. Gagne built on the work of behavioral and information processing theorists by translating principles from their learning theories into practical instructional strategies that teachers could employ with directed instruction. He proposed that teachers use a hierarchical “bottom up approach”, making sure that students learn lower order skills first and build on them (Eggen and Kauchak, 1999). This means that learning happens bit by bit, when you teach you are adding new knowledge to previous knowledge. So teachers teach students by hierarchy from the simple to the complex, as if we are putting the new information in a tube, which works in one way and not in the reverse order. To develop “intellectual skills”, Gagne believed, requires learning that amounts to a building process. Lower level skills provide a necessary foundation for higher level ones (Gagne, 1985). To illustrate from my own experiences, to learn to work
long division problems, students first would have to learn all the prerequisite math skills, beginning with number recognition, number facts, simple addition and subtraction, multiplication, and simple division. Therefore, to teach a skill, a teacher must first identify its prerequisite skills and make sure the student possesses them. This list of building block skills is called a learning hierarchy.

Gagne learning hierarchies have been widely used to develop systematic instructional design. This systematic instructional design or system approach incorporated information from learning theories into step-by-step procedures for preparing instructional materials. Systematic methods came about largely in response to logistical problems in meeting large numbers of individual needs. One component of a systematic instructional design process was the use of learning hierarchies to develop curriculum maps (Gagne, 1985). According to Settler (1990) "the 1960s produced most of the major components of the instructional design process" (p.24 as cited in Grabe, 2001 p.58). Names associated with this era include Robert Mager who spoke of instructional objectives. Instructional objectives are statements that identify explicitly those behaviors the learner will be able to demonstrate at the end of instruction that he was not able to demonstrate at the beginning of instruction (Snowman, 1997). To illustrate from my own experience, one important use of instructional objectives is that they give the teacher clear and precise guidelines to achieving specific student outcomes. That is, the objectives prescribe exactly which behaviors student must manifest as a result of the instruction. Likewise, performance objectives are given to students prior to instruction to inform them specifically of what they will learn to do. This, of course, enhances the process of attention, encoding and storage.

Coming to Ausubel, he, by contrast, recommended a "top down approach". He proposed that teachers provide "advance organizers" or overviews of the way information will be presented to help students develop mental frame works on which to hang new information (Grabe, 2001). Advance organizers are verbal statements at the beginning of a lesson to preview and structure the new material and link it to the students' existing schemata which are interconnected ideas, relationships and procedures (Eggen and Kauchak, 1999). In this sense, advance organizers are like cognitive road maps; they allow students to see where they have been and where they are going.

Hence, the role of advance organizers is to help students acquire ideas that are linked to other ideas, and this, of course, enhances meaningful learning and the processes of attention, encoding, and storage.
Having provided students with advance organizers, the next planning step, Ausubel proposed, is to structure the content so that it is as meaningful as possible for the students. One effective way to structure the content is to use a hierarchical "top down approach" (Eggen and Kauchak, 1999). The following example from my own experience illustrates the point:

When I taught "Fractions", I provided my students with the following advance organizer: Fractions are used to represent numbers that describe the parts of a whole. They are illustrated in terms of circles and number lines.

Then I structured the content as follows:

```
FRACTIONS

| Proper Fraction | Improper Fraction |
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Structuring the content as above helps students understand the interconnections between the concepts of Fraction, Proper Fractions and Improper Fractions. In this sense, learners link new and prior learning and relate the different parts of new learning to each other. This, of course, reinforces meaningful learning and the processes of attention, encoding and storage. In later sections, I will discuss in detail how the surveyed math teachers applied the characteristics of information processing theories in integration strategies.

**II.E. Theoretical Foundations of constructivism.**

As mentioned earlier, Robert Gagne used the idea that a sequence of tasks could be established for a desired learning outcome. If the student practiced each required task as it was learned and developed, that student would then be able to move on to the next step in the continuum. Gagne looks at subject areas and especially mathematics as linear continuums. This means that learning happens bit by bit, when you teach you are adding new knowledge. So you teach students by hierarchy from the simple to the complex. Now the following questions arise: when discussing additions of fractions, can a continuum for addition of fractions be established? Can a similar list be built for each concept in mathematics? Do you have adequate time and background to build a list for each concept you teach? Are you willing to trust someone else to build the list for you? (Essentially, this is what textbooks often do). What happens if you don’t agree with the established list? In addition, a student...
may have all the bits and pieces of a problem and yet he or she can't solve this problem. To which Meyer (1974) indicates that knowing mathematical skills and concepts doesn't guarantee that problem solvers will be successful (Brumbaugh, 1997).

Hence, the discussion about learning theories becomes focused on whether it is wisest to provide an efficient learning environment that results primarily in the acquisition of academic knowledge, or an approach that provides a more in depth, indirect process encompassing the whole learner.

Based on the educational applications of Skinner’s behaviorist theories and information processing theories which were discussed earlier, we can conclude that directed instruction is necessary for learning to occur, but it is not sufficient. So, there is a need to consider another learning theory, “constructivism”, which complements directed instruction.

Constructivist educators believe that every day learners engage in searches for meaning. They continually change their current understandings as they consider new information. They then decide whether they want to hold on to previously held beliefs or whether they want to build new understandings. It’s through this process they learn, and schools should be structured to encourage this process (Confrey, 1994). Molenda (1991) suggests “constructivism comes in different strengths ... from weak to extreme” (p.47). Philips (1995) referred to constructivism as made up of many “sects, each of which harbors some distrust of its rivals” (p.5). The differences among those who think of themselves as constructivists make it difficult to settle on a single definition for constructivism. However, these differences may be explained by examining the variations in learning theories that underline constructivist approaches.

II.E.1. Early Cognitive theories

Constructivist strategies are based on principles of learning derived from branches of cognitive science. This area focuses specifically on student motivation to learn, think critically and ability to use what they learn outside the school culture. Constructivist strategies try to respond to perceived deficiencies in behaviorist and information processing theories and the teaching methods based on them. Besides, constructivists try to inspire students to see the relevance of what they learn and to prevent what the Cognition and Technology Group at Vanderbilt (CTGV, 1990) call inert knowledge, or student failure to transfer what is already
known to the learning of other skills that require prior knowledge. These theories are based on the ideas of educational psychologists such as Vygotsky, Piaget, and Bruner.

Having defined the learning theories associated with constructivism, and the educational psychologists who foster such theories, let us now prove how the work of the above educational psychologists contributes to constructivism.

II. E.1.a. The work of Vygotsky

Vygotsky felt that cognitive development was directly related to and based on social development (Lee and Smagorinsky, 2000). He believed that such development is largely due to social processes, particularly interactions with others who are more skilled and competent in what he called the technologies or psychological tools of a culture (Snowman, 1997). What children learn and how they think are derived directly from the culture around them: "Children begin learning from the world around them, their social world, which is the source of all their concepts, ideas, facts, skills and attitudes... our personal psychological processes begin as social processes, patterned by our culture" (Gagne and Berliner, 1998 p.2). As cultures develop, people create such psychological tools as speech, writing, and numbering to help them master their environment. Early explorers, for example, created maps to help them represent where they had been, communicate that knowledge to others, and plan future trips. Children are first introduced to a culture's major psychological tools through social interactions with their parents and later with classroom teachers (Snowman, 1997). An adult perceives things very differently from the way a child does, but this difference decreases as children gradually translate their social values into personal, psychological ones (Grabe, 2001).

Vygotsky suggests that if teacher instructions are pitched at a level close to but just above the child’s level of understanding, then learning takes place, Vygotsky refers to such stage as the zone of proximal development. He felt that teachers could provide help by finding out where each child was in his or her development and building up on the child’s experiences. He called this process "scaffolding" (Gagne et al, 1998).

Ormond (2000) said that teachers promote student' cognitive development by presenting classroom tasks that "they can complete only with assistance, that is, within each student's zone of proximal development" (p.59). "In the zone of proximal development, social knowledge, knowledge acquired through social interaction, becomes individual knowledge
and individual knowledge grows and becomes more complex" (Gagne et al 1988, p.126). Snowman (1997) refers to such kind of knowledge as one facet of constructivism. The sharing of multiple perspectives enhances the formation and changing of knowledge structures. Open minded, systematic discussions and debates are means of helping individuals create personal views (Glassman, 1995). Snowman (1997) suggests that scholars form and reform their positions on aspects of theory or research as a result of years of discussion and debate with colleagues (peers). The debate between the Piagetians and the Vygotskians is a good example of this facet (Glassman, 1995).

II.E.1.b. Educational application of Vygotsky's works

As mentioned earlier, Vygotsky's works were very much in line with constructivist concepts of instruction based on each child's personal experiences and learning through collaborative and social activities. Hence to implement Vygotsky's works, students should be involved in cooperative or collaborative learning. To illustrate, gathering students in cooperative groups (including peers or older children) is the best way to facilitate generative learning in which accomplishment is not a function simply of individual capabilities but the product of individuals and tools, each of which contributes to achieving designed goals.

Hence, cooperative learning seems an ideal environment for students to learn how to share responsibility and work together toward common goals and skills they will find useful in a variety of settings outside school. In this sense, students' individual knowledge grows and their personalities develop. In later sections, I will discuss in details how the surveyed math teachers applied Vygotsky's work in integration strategies.

II.E.1.c The work of Piaget

Whereas Vygotsky believed that cognitive development is largely due to social processes, particularly interactions with others who are more skilled and competent in what he called the technologies or psychological tools of a culture, Piaget saw such development arising from attempts to overcome cognitive conflict through the internal and genetically determined processes of assimilation, accommodation and equilibration (Snowman, 1997).

His examination of how thinking and reasoning abilities develop in the human mind began with observations of his own children and developed into a career that spanned some 60 years. He referred to himself as a "genetic epistemologist" or a scientist who studies how knowledge begins and develops in individuals. Two features of his work are widely
recognized as underlying all of Piaget’s theories: his stages of cognitive development and his process of cognitive functioning. Piaget believed that all children go through four stages of cognitive development.

Piaget believed that a child’s development from one stage to another takes place through a gradual process of interacting with the environment. Children develop as they confront new and unfamiliar features of their environment that do not fit with their current views of the world. When this happens, he said, a “disequilibrium” occurs that the child seeks to resolve through one of two processes of adaptation. An adaptation is the process of creating a good fit or match between one’s conception of reality and the real life experiences one encounters. The child either fits the new experiences into his or her existing view of the world, and this process is called assimilation, or changes that schema or view of the world to incorporate the new experiences, and this process is called accommodation (Glassman, 1995). The following example from my own experience illustrates the point: a student may wonder, why, for example in a space a square, which is not located in a frontal plane, is represented by a parallelogram since he has always represented it as a square. This discrepancy may cause the student to read about the representation of solid figures in space or to ask the teacher for further explanation. Gradually, the student adapts his or her thinking to recognize that in a non frontal plane, a right angle is not represented by a right angle (accommodation).

II. Educational application of Piaget’s work

As mentioned earlier, children’s development from one stage to another occurs as they confront new and unfamiliar features of their environment that do not fit with their current views of the worlds. In this sense the instructional principle based on Piaget’s stages is the need for concrete examples and experiences when teaching abstract concepts to young children who may not have reached an advanced stage, to which Snowman (1997) refers as a facet of constructivism. He considers such learning as active creation of knowledge structures from personal experience. For example, concepts, rules, hypotheses, and associations are considered to be knowledge structures. In other words, each learner builds a personal view of the world by using existing knowledge to select and interpret currently available information (Snowman, 1997). Perkins et al (1995) refer to this as bridging the gap between the particular and the general. They believe that the theme of the particular and the general is central to the learning, teaching, and making of mathematics. The importance of this theme lies in the fact that it has dominated the evolution of new mathematics over the centuries and intimately links to the notion of conjecture. A conjecture, mathematical for example, is a proposition about a
previously unsuspected relationship thought to be among mathematical objects which are formally defined constructs such as numbers, shapes and vectors. In general, for each mathematical object there will be one or more defined mathematical operations that can be carried out on the object and that can transform it in some way (Perkins et al., 1995). To illustrate, mathematical operations are carried out on whole numbers to transform them into integers. Similarly, integers are transformed into rational numbers, and so on. Since mathematical inventors are inclined to generalize mathematical constructs in this way, mathematical conjectures often take the form of inductive generalizations made from particular cases.

What can be concluded is that making and exploring of mathematical conjectures reinforces the theme of the particular and general and thus fosters constructivism by eliminating disequilibriums. In later sections, I will discuss how the surveyed math teachers applied Piaget’s work in integration strategies.

II. E.I.e. The work of Bruner

Like Piaget, Jerome Bruner was interested in children’s stages of cognitive development. Bruner’s interest in the discovery approach began with his studies on perception (1951) and thinking (Bruner, Gordon Austin, 1956 as cited in Snowman, 1997). Some of the principals associated with this educational theorist seem to coincide with those of Vygotsky and Piaget, providing further theoretical support for constructivist theory. Like Piaget, Bruner believed children go through various stages of intellectual development (Grabe, 2001). They both argue that the conceptions that children arrive at on their own are usually more meaningful than those proposed by others. But unlike Piaget, Bruner supported intervention. He was primarily concerned with making education more relevant to student needs at each stage, and he believed that teachers could accomplish this by encouraging active participation in the learning process (Grabe, 2001). In this sense, students not only develop problem solving skills but also acquire confidence in their own learning abilities as well as the propensity to function later in life as problem solvers (Snowman, 1997). Active participation, Bruner felt, was best achieved by providing discovery learning environments that would let children explore alternatives and recognize relationship between ideas (Ormod, 2000).

Bruner stresses that too much school learning takes the form of step by step study of verbal or numerical statements or formulas that students can reproduce on cue but are unable to use outside the classroom. When students are presented with such highly structured materials, Bruner argues, they become too dependent on other people for guidance and
approval. Furthermore, they are likely to think of learning as something done only to earn a reward (Snowman, 1997).

Instead of using techniques that feature preselected and prearranged materials, teachers should, according to Bruner, confront children with problems and help them seek solutions either on their own or in group discussion. True learning, says Bruner (1983), involves “figuring out how to use what you already know in order to go beyond what you already think” (p.183 as cited in Snowman, 1997). This approach to education is called discovery learning (Snowman, 1997). Perkins et al (1995) refer to such discovery as a cardinal rule of learning in which “.. one is more likely to comprehend what one discovers for oneself than what one is taught by someone else” (p.15).

II. E.l.f. Educational Application of Bruner’s work.

If one accepts the idea that discovery is an important contributor to understanding, one must also recognize the importance of providing students with an atmosphere that encourages them to explore. This means proving an environment that is rich in information resources and aids to exploration of ideas and discovery, as well as maintaining an atmosphere in which ideas can be expressed freely and without fear of ridicule (Perkins, 1991). Perkins et al (1995) refer to such atmosphere as “a richer learning environment” (p.19) in contrast to the minimalistic classroom environment that usually relies primarily on the teacher, a text book, and prepared materials.

Having provided students with a supportive environment, the next step, to foster discovery, is to involve students in problem oriented activities. Such activities focus on students solving problems, either in a specific content area such as mathematics or using an interdisciplinary approach. For example, such a problem might require a combination of mathematics, Science and language skills. Problems may be posed in terms of “what if” questions (Ormod, 2000). For example what would be the rotation of a quadrilateral if we rotate it according to a certain angle. Another way of posing problems is in terms of open ended questions (Grabe, 2001). To illustrate, what can you say about medians of a triangle?. In later sections, I will discuss how the surveyed math teachers integrated Bruner’s work in their strategies.
II. F. Role of technology in fostering directed instruction

Although they are based primarily on early theories of learning, directed instruction methods address some very important problems. As known, teachers face problems in meeting the individual pacing and remedial needs of each student while confirming that all students are learning required skills. Hence individualization becomes both the goal and the terror of teachers.

Since, as mentioned earlier, directed instruction methods stress the structured approach of teaching and require teaching when needed, systems approaches were widely proposed as a way for teachers and others to design self instructional packages, for students to separate directed instruction from the need for the teacher to deliver it. Self instruction was more efficient than trying to serve the pacing and content needs of each student. It also assured that instruction's quantity was uniform from presentation to presentation. However systems approaches also were seen as a way to design more effective teacher – delivered presentations (Educational technology, 1991).

Nowadays, teachers still face the problems of having too many students, too many required skills to teach, and not enough time to deal with individual learning differences and to prepare effective presentations. Educators recognize how technology resources such as computer software could help them overcome some of the logistical obstacles to individualized instruction and design more effective teacher delivered presentations. Watson and Tinsley (1996) refer to such computer software as “computer ensured learning” or computer “assisted teacher”. The vision of the learning conveyed by this type of approach was originated from the Skinnerian trend which had already widely influenced programmed teaching. The contents to be mastered are dissected and split up in many cells which will be successively proposed to the learner. According to the answers given, the learner is dragged along a more or less individualised-learning track (Watson and Tinsley, 1996).

Every teacher feels the huge difficulty of this prior dissection of the subject to be taught which requires both a great expertise in the contents but also a deep knowledge of the difficulties encountered during learning. It requires a complete vision of the subject to be taught and its organization. One way to overcome such difficulty is to use technology, which has the potential of providing teachers access to a wide variety of subject dissection. To illustrate, some software helps students get needed practice; other courseware guide their learning of difficult concepts through step by step, self paced teaching sequences; still other
software involves activities which the teacher decides on, prepares and carries out in the context of a traditional lesson. In front of the class, near the board or the overhead projector, the teacher uses the facilities of a graphical software to illustrate a concept and to shorten repetitive and tedious calculations. All of these activities allow teachers time to work with students who need personal help and make life easier for teachers by assisting teachers with dull activities such as practical exercises and their correction and checking of factual knowledge.

What can be concluded here is that directed instruction strategy, which plays an important role in the learning process, can be fostered through the use of technology.

II. G. Integration strategies based on directed methods:
The role of programmed instruction, “drill and practice”, one type of simulation, One type of instructional game software in fostering individualised instructions and motivating students

Having discussed how technology can foster directed instruction strategy, let us now describe integration strategies based on directed methods, which address specific instructional needs.

II.G.1. Tutorial software
II.G.1.a. Definition and characteristics of tutorials

Programmers begin developing a program by defining precisely what is to be learned in the instructional objective (Branden, 1996). This means that programmed instructions are based on Gagne principles. Then programmers arrange facts, concepts, and principles in a sequence designed to lead students to the desired end result (Snowman, 1997). Thus, this enhances the process of attention, encoding, and storage by linking instructions to information students already know. Additionally, such arrangement fosters Gagne’s principles of learning hierarchies. This arrangement requires programmers to make the steps small enough so that reinforcement occurs with optimal frequency (Snowman, 1997) which means that Skinner’s reinforcement principles which motivate stimuli are applied. Then the steps are arranged so that students will be adequately prepared for each step, or numbered exercise, when they reach it (Branden, 1996).
In arranging the sequence of steps, programmers may use a linear program, which tries to ensure that every response will be correct since there is only one path to the terminal behavior, or they may use a branching program, in which there is less concern that all responses be right. If students give a wrong answer, the program provides a branching set of questions to enable them to master the troublesome point. Another type of branching program provides students with a more complex explanation of the misunderstood material and urges them to go back and study the original explanation more carefully (Snowman, 1997).

These programmed instructions are called tutorials. Sometimes, they are referred to as dialogue programs because they mimic the instructional interchange that often occurs between student and teacher (Snowman, 1997). Tutorial courseware uses the computer to deliver an entire instructional sequence similar to a teacher’s classroom instruction on the topics. This instruction usually is expected to be complete enough to stand alone; the student should be able to learn the topic without any help or other materials from outside the courseware (Graham, 1994). Unlike other courseware activities, tutorials are true teaching courseware. Gagne, Wager, and Rojas (1981) stated that tutorial courseware should address all instructional events which are gaining attention, informing the learner of the objective, stimulating recall of prerequisite learning, presenting new material, providing learner guidance, eliciting performance, providing feedback about correctness, assessing performance, and enhancing retention and recall (Eiser, 1988). Gagne et al. show how a tutorial may vary its strategies to accomplish events for different kinds of learning (Educational Technology, 1993). For example, a surveyed math teacher incorporated a program in math instruction that begins with the computer examining a student’s file to determine current math level and then displaying appropriate math exercises. The student reads the material, is presented with a set of questions, and types responses on the keyboard. The computer evaluates the responses and displays the result of the evaluation. If the student’s responses are correct, the computer provides more difficult passages and questions. If the responses are incorrect, hints or less difficult exercises are presented. The software “pre Algebra CD” illustrates this point.

Some tutorials also have computer-management capabilities; teachers may “tell” such a program at what level to start for a student and get reports on each student’s progress through the instruction. Although a tutorial program does need these components, data collection and management features often make it more useful to teachers (Kraemer, 1990).
As the description of events of instruction implies, tutorials are most often geared toward learners who can read fairly well. Since tutorial instruction is expected to stand alone, it is difficult to explain or give appropriate guidance on-screen to a nonreader. However, some tutorials aimed at younger learners have found clever ways to explain and demonstrate concepts with graphics, succinct phrases or sentences, or audio directions coupled with screen devices (Murray, 1988).

In addition to meeting general criteria for good instructional courseware, well-designed tutorial programs should also meet several additional standards:

First, tutorials should be extensively interactive. The most frequent criticism of tutorials is that they are "page-turners", that is, they ask students to do very little other than read. Good tutorials, like good teachers, should require students to give frequent and thoughtful responses to questions and problems and they should provide appropriate practice and feedback to guide students' learning. Second, tutorials should be supplied with "thorough user control". User control refers to several aspects of the program. First, students should always be able to control the rate at which text appears on the screen. The program should not go on to the next information or activity screen until the user presses a key or gives some other indication of completing necessary reading. Next, the program should offer students the flexibility to review explanations, examples, or sequences of instruction or move ahead to other instruction. The program should also provide frequent opportunities for students to exit as desired (Baeck and Layne, 1988). Third, tutorials should provide students with an appropriate and comprehensive teaching sequence. The program's structure should provide a suggested or required sequence of instruction that builds on concepts and covers the content adequately. It should provide sufficient explanation and examples in both original and remedial sequences (Baeck and Layne, 1988). In sum, it should compare favorably to an expert teacher's presentation sequence for the topic. Fourth, tutorials designs should be supplied with adequate answer-judging and feedback capabilities. Whenever possible, programs should allow students to answer in natural language and should accept all correct answers and possible variations of correct answers. They should also give appropriate corrective feedback when needed, supplying this feedback after only one or two tries rather than frustrating students by making them keep trying indefinitely to answer something they may not know (Eiser, 1988). Note here that the software Super Tutor Geometry, used by some surveyed teachers, meets the above standards.
Although some authors insist that graphics form part of tutorial instruction (Baek & Layne, 1988), others emphasize judicious use of graphics to avoid interfering with the purpose of the instruction (Eiser, 1988). Eiser is among those who recommend online evaluation and record keeping on student performance as part of any tutorial. Other authors criticized tutorials for teacher-directed methods; that is, they deliver traditional instruction in skills rather than letting students create learning experiences through generative learning and development projects (Educational Technology, 1993). However, tutorials are necessary in the learning process. The main function of tutorial software is to teach required skills which are considered prerequisite to developing projects. Also, since good tutorials are difficult to design and program, critics charge that tutorials represent trivial or even counterproductive uses of the computer. A number of tutorials fail to meet criteria for good programs of this kind, thus contributing to this perception (Eiser, 1988).

Tutorials are difficult to find, even for those who want to use them. Software publishers describe fewer packages as tutorials than any other kind of microcomputer courseware. Part of the reason for this comes from the difficulty and expense of designing and developing them. A well designed tutorial sequence emerges from extensive research into how to teach the topic well, and its requirements for programming and graphics can become fairly involved. Designers must know what learning tasks the topic requires, what sequence students should follow, how best to explain and demonstrate essential concepts, common errors that students are likely to display, and how to provide instruction and feedback to correct those errors. Tutorials can be large, so they often work slowly on microcomputer (Eiser, 1988).

These problems become still more difficult because teachers frequently disagree about what they should teach for a given topic, how to teach it most effectively, and in what order to present learning tasks. A teacher may choose not to purchase a tutorial with a sound instructional sequence because it does not cover the topic the way he or she presents it. Not surprisingly, courseware companies tend to avoid programs that are problematic both to develop and market (Graham, 1994), hence a question arises: How do the surveyed teachers apply tutorials in their classrooms?

II.G.1.b. The use of tutorials in teaching math

According to the surveyed interviewed teachers, self instructional tutorials should in no way threaten teachers, since few conceivable situations make a computer preferable to an
expert teacher. However, the tutorial's unique capability of presenting an entire interactive instructional sequence can assist in several classroom situations:

On many occasions, students need repeated math instruction on a topic after the teacher's initial presentation. Some students may be slower to understand math concepts and need additional time on them. Others seem to learn better in a self-paced mode without the pressure to move at the same pace as the rest of the class. Still others may need review before a test. Teachers can help these students by providing tutorials at learning stations to review previously presented material while the teacher works with other students. Hence, it could be used as self review of instruction.

Tutorials also provide alternative means of presenting material to support various learning strategies. Some students, typically advanced ones, prefer to structure their own learning activities and proceed on their own. A good tutorial allows students to glean much background material prior to meeting with a teacher or others to do assessment and/or further work assignments. Therefore, some surveyed teachers use them for providing alternative strategy.

Some students have problems when they surge ahead of their class rather than falling behind. The teacher cannot leave the rest of the class to provide the instruction that such an advanced student needs. Some surveyed schools, especially those in rural areas, may not offer certain courses because they cannot justify the expense of hiring a teacher for comparatively few students who will need Math, or science. Well-designed tutorial courses, especially in combination with other methods such as distance learning, can help meet these students' needs. In this sense, tutorials provide students with instruction when teachers are unavailable.

What can be said here is that tutorial functions are designed primarily to serve individuals. Depending on which of the above strategies it promotes, a tutorial may form a classroom learning station or may be available for checkout at any time in a library/media center.

II.G.2. “Drill and practice” software

II.G.2.a. Definition and characteristics of “Drill and practice”

Although curriculum increasingly emphasizes problem solving and higher-order skills, teachers still give students on-paper practice (e.g., worksheets or exercises) for many skills to
help them learn and remember correct procedures. Many teachers feel that such practice gives students more rapid recall and use of basic skills as prerequisites to advanced concepts. They like students to have what Gagne (1982) and Bloom (1986) call automaticity or automatic recall of these lower-order skills to help them master higher-order ones faster and more easily (Bloom, 1986). The following examples, selected from my own experiences, cite basic skills that are prerequisite to higher-order skills: (1) automatic recall of multiplication facts is required for most higher-level mathematics ranging from long division to algebra, (2) keyboard proficiency is a prerequisite for assignments that require extensive typing. The usefulness of drill programs in providing this kind of practice has been well-documented (Hasselbring, 1988; Okolo, 1992; Higgins & Boone, 1993). "Drill and practice" programs provide students with opportunities to practice knowledge and skills that were presented earlier by the teacher or by a text book (Branden, 1996). Drill and practice courseware activities were among the earliest and most well recognized instructional uses of computers and are still used extensively in schools. These activities have frequently been shown to allow the effective rehearsal students need to transfer newly learned information into long-term memory (Merill & Salisbury, 1984; Salisbury, 1990).

Drill and practice activities provide exercises in which students work example items, usually one at a time, and receive feedback on their correctness. Programs vary considerably in the kind of feedback they provide in response to student input. They range from a simple display like "No, try again" to elaborate animated displays or verbal explanations. Some courseware designers stress the importance of positive feedback for correct answers. If students' answers are timed, or if their session time is limited, they may find it more motivating simply to move quickly to later questions (Merill and Salisbury, 1984). The Grade Builder Algebra Software, incorporated by some surveyed teachers, reflects such function. Positive feedback should not be so elaborate and time-consuming that it detracts from the lesson's purpose. No matter how attractive the display, students tend to tire of it after a while and it ceases to motivate them.

Other programs inadvertently motivate students to get wrong answers. This happens when a program gives more exciting or interesting feedback for wrong answers than for correct ones (Salisbury, 1990). The most famous example of this design error occurred in an early version of a popular microcomputer-based math drill series. Each correct answer got a smiling face, but two or more wrong answers produced a full-screen, animated crying face that students found very amusing. Consequently, many students tried to answer incorrectly to see it.
Types of drill and practice are sometimes distinguished by the sophistication with which the program tailors the session to student needs (Merrill & Salisbury, 1984). The most basic drill and practice function often is described as a flashcard activity. A student sees a set number of questions or problems on the screen and answers one at a time. Unless the questions are part of a timed review, students have as much time as they wish to answer and examine the feedback before proceeding to later questions. If the program provides no specific feedback for correct answers, it usually is acceptable to present later questions without any further entries from students (Alessi and Trollip, 1991).

A more sophisticated form of drill and practice moves students on to advanced questions after they get a number of questions correct at some predetermined mastery level; it may also send them back to lower levels if they answer a certain number wrong. Some programs automatically review questions that students get wrong before going on to other levels. Movement between levels often is not transparent to students since the program may do it automatically without any indication. Sometimes, however, the program may congratulate students on good progress before proceeding to the next level, or it may allow them to choose their next activities (Higgins and Boone, 1993).

II.G.2.b. The use of “Drill and practice” in teaching math

In later sections, I will discuss in details the methods used, the sample and the results of data collection. At this point, it is important to provide some of the data collected from my observations and interviews. Now, let us see how and why the surveyed interviewed math teachers incorporated “Drill and practice” software in teaching:

According to the surveyed interviewed teachers, “Drill and practice” programs may be used whenever teachers feel the need for on-paper exercises such as worksheets. They see that drill and practice courseware provides several acknowledged benefits as compared to paper exercises:

Immediate feedback: When students practice skills on paper, they frequently do not know until much later whether or not they did their work correctly. A surveyed interviewed teacher quotes a common saying, “Practice does not make perfect; practice makes permanent”. As they complete work incorrectly, students may actually be memorizing the wrong skills. Drill and practice courseware informs them immediately whether or not their answers are accurate, so they can make quick corrections. This helps both “debugging”
(identifying errors in their procedures) and retention (usually necessary to place the skills in
long-term memory for ready access later). Another surveyed interviewed teacher illustrates
more, "I am incorporating Pre Algebra software in my classrooms since it reflects this type of
function". The software Pre Algebra, used by some surveyed teachers, presents an arithmetic
problem; the student types an answer; and the computer checks the accuracy of the response,
provides positive reinforcements like "Good job", "that's right", "Correct" and negative
reinforcement like "try again", incorrect", "missed that one", "wrong answer". Then the
computer presents the next item. Another surveyed interviewed teacher (from another school)
adds "Some programs keep track of how many errors a student makes, provide help when a
student gets stuck, and adjust the difficulty level of the problems or questions to the
proficiency level of the student". This means that such programs enhance individualized
instructions and promote fluency or automaticity of prerequisite skills. Some kinds of
requisite skills help students more if they can apply the skills without conscious effort.
Students need rapid recall and performance of a wide range of skills throughout the
curriculum like simple math facts. Some students acquire automaticity through repeated use
of the skills in practical situations, others acquire this automatic recall more efficiently
through isolated practice. In both ways, information is linked to information students already
know. Thus, "Drill and practice" software provides an ideal means of practice tailored to
individual skill needs, learning pace, and information encoding.

Motivation: Some surveyed interviewed teachers said that many students refuse to do the
practice they need on paper, either because they failed so much that the whole idea is hateful;
or they have poor handwriting skills; or simply dislike writing. In these cases, "computer -
based practice may motivate students to do the practice they need. Computers don't get
impatient or give disgusted looks when a student gives a wrong answer", as one teacher
comments.

Saving teacher time: Other surveyed interviewed teachers see that since they do not
have to present or grade drill and practice, students may do this activity essentially on their
own while the teacher addresses other student needs.

Coming to classroom applications of drill functions. The surveyed interviewed teachers
may take advantage of the benefits of "Drill and practice" courseware to have students
practice using isolated skills. The surveyed interviewed teachers say that whenever students
have difficulty with higher order tasks ranging from reading and writing to mathematics,
teachers may have to stop and identify specific prerequisite skills that these students lack and
provide the instruction and practice they need to go forward. In these cases, learning may require a rehearsal activity to make sure information is stored in long-term memory so students can retrieve it easily, drills motivation, immediate feedback, and self-pacing can make it more productive for students to practice required skills on the computer rather than on paper. Other interviewed teachers add that despite the new emphasis on student portfolios and other authentic assessment measures, students can expect to take several kinds of objective examinations in their education careers: When they need to prepare to demonstrate mastery of specific skills in important examinations (e.g., for end-of-year grades), “Drill and practice” courseware can help them focus on their deficiencies and correct them.

Now, the following guidelines were observed when the surveyed teachers designed integration strategy for “Drill and practice” software in their classroom:

Set Time Limits: The surveyed teachers limit the time devoted to 15 minutes per day. This ensures that students will not become bored and that the “Drill and practice” strategy will keep its effectiveness. Also, the surveyed teachers are sure students have been introduced previously to the concepts underlying the drills; drill courseware should serve to debug and to help students keep their grasp of familiar concepts.

Assign Individually: Since self-pacing and personalized feedback are among the most powerful benefits of drills, these activities usually work best for individual computer use. However, some surveyed teachers with limited technology resources have found other, skilful ways to capitalize on the motivational and immediate feedback capabilities of drills. If all students in a class benefit from practice in a skill using a drill program the teacher may divide them into small groups to compete with each other for the best group scores. The class could even be divided into two groups for a “relay race” competition over which group can complete the assignment the fastest with the most correct answers.

Use learning stations: If not all students need the kind of practice that a drill provides, the teacher may make courseware one of several learning stations to serve students with identified weaknesses in one or more key skills. The key to using “Drill and practice” appropriately is to match its inherent capabilities with the identified learning needs of individual students.
Hence, the results of my observations and interviews lead to conclude that the Lebanese surveyed primary math teachers favor the use of “Drill and practice” in teaching math in terms of practice and motivating students through reinforcement.

On the other hand, despite the increasing emphasis on problem solving and higher-order skills, it is likely that some form of “Drill and practice” courseware probably will be useful in many classrooms for some time to come. Such programs address needs for these and other required skills and help students build automaticity. Rather than ignoring “Drill and practice” software as outmoded, teachers should seek to select and use these kinds of programs for use they can best accomplish.

II.G.3. Simulation
II.G.3.a. Simulations: Definition and characteristics

Coming to simulation, it is a computerized model of a real or imagined system designed to teach how a system works. Simulations differ from tutorial and drill and practice activities by providing learner-structured activities (Estes, 1994). Hence, simulations are based on Gagne’s principles. The person using the courseware usually chooses tasks and the order in which to do them. A simulation’s focus on a limited number of key elements provides a simplified version of the real world that allows the student to learn a topic or skill very efficiently (Mintz, 1993). A simulation is designed so that the actions a student takes within the simulated environment produce results similar to those that would occur in the actual environment. The student acts, and the simulated environment reacts (Richards, 1992). Alessi and Trollip (1991) identify two main types of simulations: “those that teach about something and those that teach how to do something” (p. 119). They further divide the “about” simulations into physical and process types and they divide the “how to” simulations into procedural and situational types. Procedural and situational types deal with the constructivist integration strategies. Hence, they will be discussed later.

Physical simulations: Users manipulate objects or phenomena represented on the screen (Alessi and Trollip, 1991). For example, students see selections of chemicals with instructions to combine them; they see the result or they may see how various electrical circuits operate or how solid figures (e.g. prism) move. Hence, students learn the basic skills of performing an experiment.
Process simulations: These speed up or slow down processes that usually either take so long or happen so quick so that students could not ordinarily see the events unfold (Alessi and Trollip, 1991). For example, courseware may show the effects of changes of demographic variables on population growth or the effects of environmental factors on ecosystems. Biological simulations like those on genetics are popular, since they help students to experiment with natural laws like the laws of genetics by pairing animals with given characteristics and showing the resulting offspring. Other courseware help students simulate the construction or dissection of geometrical figures. In this sense, students are motivated to learn because of speeding up or slowing down processes.

Simulations can be used before the formal presentation of new material to gain students' interest, activate what students already know about the topic. This enhances the process of attention, encoding, and storage by linking instructions to information students already know. To illustrate, a surveyed interviewed teacher incorporated the "geometry" software which is designed to allow students to simulate the dissection of a prism. The program presents students with a set of dissection tools, a dissection tray, and an examination tray for organizing and examining the faces removed from the prism. Moreover, informative text, labeled graphics, and digitized photographs from an actual dissection are available for each face. Occasional animations (for instance, rotation of the prism) or quick time movies are also provided. (Quick time is a common format for presenting digital video on a variety of computers).

According to one surveyed interviewed teacher, this software (geometry) exemplifies some of the features of simulations. Simulations tend to present a simplified version of the real thing and attempt to focus learners on key ideas, skills or components. In contrast to the clumsiness and messiness that comes with dissecting a prism, work with a simulated prism uses simpler procedures and reveals simplified information. He adds that developing the physical dexterity necessary to use dissection instruments is not a target behavior, so there is no attempt to teach these skills. The faces to be removed at a particular stage of the simulation are designated by color to make them easier to compare. Hence, the simulated dissection clearly focuses the student on the number and properties of faces of a prism. Hence, such simulations aim at developing basic skills. Moreover, such software simulate teacher's classroom instructions in a way that students are able to learn or review any experiment alone without any help. Hence, simulations could be used to enhance individualization.
As mentioned earlier, there are four types of simulations: physical simulation, process simulation, procedural simulation, and situational simulation. Since simulations promote such widely varied purposes, it is difficult to provide specific criteria for selecting high quality. By one frequently cited criterion, fidelity, a more realistic and accurate representation of a system makes a better simulation (Reigeluth & Schwartz, 1989). However, this is not a criterion for judging all simulations (Alessi, 1988). Reigeluth and Schwartz (1989) describe some design concerns for simulations based on instructional theory. They list important simulation components including a scenario, a model, and an instructional overlay that lets learners interact with the program. Since the screen presents no set sequence of steps, simulation more than most courseware-need good accompanying documentation. A set of clear directions helps the teacher learn how to use the program and show the student how to use it rapidly and easily.

Most educators acknowledge the instructional usefulness of simulations; however, some are concerned about the accuracy of the programs’ models (Mintz, 1993). For example, when students see simplified versions of these systems in a controlled situation, they may get inaccurate or imprecise perspectives on the systems’ complexity. Students may feel they know all about how to react to situations because they have experienced simulated versions of them. Many teachers of very young children feel that learners at early stages of their cognitive development should experience things first with their five senses rather than on computer screens. But consider, for example, learning to fly an airplane. Would it be ideal to expose a novice to experiences in an actual plane? Even if the issues of cost and safety were ignored or somehow taken care of, the situation of high fidelity is still not necessarily the best learning situation. The student would be too anxious and the situation too confusing to allow much learning (Alessi, and Trollip, 1991). Similar situations may happen in classroom settings more familiar to you. In presenting new concepts or principles, most experienced instructors initially ignore the exceptions and complications that might just confuse and increase the anxiety of students. The initial presentation describes concepts and principles with less than perfect fidelity. It appears that a moderate degree of fidelity is best for initial learning.

II.G.3.b. Benefits of simulation function

Having discussed the definition and characteristics of simulations, let us now investigate the benefits of simulation functions: Simulations have long been recognized for their unique teaching capabilities. Depending on the topic, a simulation can provide one or more of the following benefits (Alessi & Trollip, 1991):
Compress time: This feature is important whenever students study the growth or development of living things (Reigluth and Schwartz, 1989) (e.g., pairing animals to observe the characteristics of their offspring) or other processes that take a long time (Richard, 1992) (e.g., the effect of changes of demographic variables on population growth). A simulation can make something happen in seconds that normally takes days, months, or longer. Consequently, feedback is faster than in real life and students could be provided with more variations of the activity in a shorter time.

Slow down processes: Conversely, a simulation can also model processes normally invisible to the human eye because they happen so quickly (Hasselbring and Goin, 1993). For example, Biology students can study the slowed-down movement of muscles and limbs through biological simulations.

Get students involved: Simulations can capture students' attention by placing them in charge of things and asking motivating questions such as: “What would you do?” The results of their choices can be immediate and graphic. It also allows users to interact with the program instead of just seeing its output (Estes, 1994).

Make experimentation safe. Whenever learning involves physical danger, simulations are the alternative strategy (Richard, 1992). This is true any time students are learning to perform a dangerous experiment, drive vehicles, handle volatile substances, or react to potentially dangerous situations. They can experiment with strategies in simulated environments that might otherwise result in personal injury to themselves or others in real life.

Make the impossible possible. This is the most powerful feature of a simulation. Very often, teachers simply cannot give students access to the resources or the situations that simulations can (Richard, 1992). Simulations can show students what it would be like to walk on planets. They can show cells mutating or hold countrywide elections. They can even design new societies or planets and show the results of their choices.

Save money and other resources: Many school systems are finding dissections of animals on a computer screen much less expensive than on real animals and just as instructional. Depending on the subject, a simulated experiment may be just as effective as a learning experience but at a fraction of the cost (Richard, 1992).
Repeat with variations: Unlike real life, simulations allow students to repeat events as many times as they wish and with unlimited variations (Allen, 1993; Simmons & Lunetta, 1993). They can pair any number of animals or perform endless number of experiments in a variety of conditions to compare the results of each set of choices.

Make situations controllable: Real-life situations often are confusing, especially to those seeing them for the first time. When many things happen at once, students have difficulty focusing on the operation of individual components (Mintz, 1993). Who could understand the operation of a stock market by looking at the real thing without some introduction? Simulations can isolate parts of activities and control the background noise. This makes it easier for students to see what is happening later when all the parts come together in the actual activity.

II.G.3.c. The use of simulation in teaching math

Now, let us see how the surveyed teachers applied the simulation software in their classroom: according to the surveyed teachers, real systems are usually preferable to simulations, but a simulation can suffice when a teacher considers the real situation too time-consuming, dangerous, expensive, or unrealistic for a classroom presentation. They see that simulations are considered in the following situations:

In place of or as supplements to lab experiment: When adequate lab materials are not available, teachers should try to locate computer simulations of the required experiments. Many teachers find that simulations offer effective supplements to real labs, either to prepare students for making good use of the actual labs, or as follow-ups with variations on the original experiments without using up consumable materials. Some simulations actually allow users to perform experiments that they could not do otherwise or that would be too dangerous for students.

In place of or as supplements to role playing: When students take on the roles of characters in situations, computer simulations can spark students’ imaginations and interests in the activities. However, many students either refuse to role play in front of a class or get too enthusiastic and disrupt the classroom. Computerized simulation can take the embarrassment and logistical problems out of the experience and make classroom role playing more controllable.
In place of or as supplements to field trips: Seeing an activity in the real setting can be a valuable experience, especially for young children. Sometimes, however, desired settings are not within reach of the school and a simulated experience of all or part of the process is the next best thing. As with labs, simulations provide good introductions or follow-ups to field trips.

II.G.4. Instructional games

II.G.4.a. Definition and Characteristics

Let us now identify the role of instructional games in teaching math. Instructional games are courseware whose function is to increase motivation by adding game rules to learning activities. Even though teachers often use them in the same way as “Drill and practice” or simulation courseware, games usually are considered as a separate courseware activity because their instructional connotation to students is slightly different. When students know they will play a game, they expect fun and entertaining activity because of the challenge of the competition and the potential for winning (Randel, Morris, Wetzel, & Whitehill, 1992). Naturally, classroom instruction should not consist entirely of these kinds of activities, no matter how instructional or motivational they are. Teachers diversify games with other activities to hold attention or to give rewards for accomplishing other activities.

As with simulations, there are categories of instructional games that illustrate the various forms an instructional game may take. Teachers should not feel that they have to classify specific games into categories. But it is important to recognize the common characteristics that set instructional games apart from other types of courseware: game rules, elements of competition or challenge, and amusing or entertaining formats. These elements generate a set of mental and emotional expectations in students that make game-based instructional activities different from nongame ones (Flowers, 1993).

Since instructional games often amount to drills or simulations overlaid with game rules, the same criteria, such as better reinforcement for correct answers than for incorrect ones, should apply to most games. This means that Skinner’s principles of reinforcement are applied. When Malone (1980) examined the evidence on what makes things fun to learn, he found that the most popular games included elements of adventure and uncertainty and levels of complexity matched to learners’ abilities (Flowers, 1993). Thus, such games enhance individualized instruction and critical thinking which means that games promote direct and constructivist strategies. However, teachers should examine instructional games carefully for
their value as both educational and motivational tools. Teachers should also assess the amount of physical readiness that games require of students and make sure that students will not be frustrated instead of motivated by the activities. Games that call for violence or combat need careful screening, not only to avoid parent criticism, but also because girls often perceive the attraction of these activities differently than boys and because such games sometimes depict females as targets of violence.

A classroom without elements of games and fun would be a dry, barren landscape for students to traverse. In their review of the effectiveness of games for educational purposes, Randel et al (1992) found “the fact that games are more interesting than traditional instruction is both a basic for using them as well as a consistent finding” (p. 270). They also observed that retention over time fosters the use of simulations/games. Yet many educators believe that games, especially computer-based ones, are overused and misused (McGinley, 1991). Other teachers believe games convince students that they are escaping from learning, and that they draw attention away from the intrinsic value and motivation of learning. Critics also feel that winning the game becomes a student’s primary focus and the instructional purpose is lost in the pursuit of this goal. Observers disagree whether getting lost in the game is a benefit or a problem. Some teachers believe that any time they can sneak learning in under the costume of a game, it is altogether a good thing (McGinley, 1991). Other teachers believe that students can become confused about which part of the activity is the game and which part is the skill; they may then have difficulty transferring their skill to later nongame situations. For example, the teacher's manual for Sunburst's How the West Was One + Three x Four, incorporated by a surveyed interviewed teacher, reminds teachers that some students can confuse the math operations rules with the game rules and that teachers must help them recognize the need to focus on math rules and use them outside the game.

Although students obviously find many computer games exciting and stimulating, educational value sometimes is difficult to pinpoint. Teachers must try to balance the motivation that instructional games bring to learning against the classroom time they take away from nongame strategies. For example, students may become immersed in the challenge of the Cannen Sandiego series, but more efficient ways to teach geography may be just as motivating. Successful uses of games have been reported in many content areas (Trotter, 1991; Flowers, 1993).
II.G.4.b. The use of instructional game in teaching math

Now, let us see how the surveyed teachers applied instructional games in their classrooms: according to the surveyed interviewed teachers, several kinds of instructional opportunities invite teachers to take advantage of the motivational qualities of games.

In place of worksheets and exercises: This role resembles that of “Drill and practice”. A surveyed interviewed teacher illustrates “I incorporated adding and subtracting and Mighty math software in my classroom, they are games designed so that children can play on their own. Children proceed through the module at a self selected pace. While learning facts about real life situations, children will practice the addition and subtraction skills”.

As a reward. Perhaps the most common use of games is to reward good work. This is a valid role for instructional courseware, but teachers should avoid overuse of it. Otherwise, the game can lose its motivational value and become an “electronic babysitter”. Some schools actually bar games from classrooms for fear that they will overemphasize the need for students to be entertained. Note here that the role of games in enhancing constructivist strategies will be discussed in later sections.

What can be concluded is that integrating well designed resources like “Drill and practice”, tutorials, simulations, and instructional games in teaching math not only gives students effective instruction but also is frequently more motivating and less threatening than teacher delivered instruction to students who find learning difficult.

II. H. The role of technology in enhancing constructivism.

As mentioned earlier “Programmed instruction” and “Drill and practice”, one type of simulation, and one type of instructional game enable students to learn isolated skills and memorize facts. Many educators felt that education should go beyond the objectives of such programs. They called for more emphasis on the abilities to solve problems, find information, and think critically about information. In other words, critics called for more emphasis on learning how to learn instead of learning specific content (Grabe, 2001) i.e. they focused on programs that enhance constructivism.

Much problem solving software, such as logo and cabrigeometre, seem to provide ideal conditions for nurturing constructivist curriculum goals. They provide vivid visual support which helps student develop better mental models of problems to be solved. These visual
media help to involve and motivate students by using graphics and other devices students find interesting and attractive. Visual media also let students work together in cooperative groups to construct products (Grabe, 2001). Watson and Tinsley (96) refer to such software as “the computer world to explore”. They stress that learners are found engrossed in a little world which they are going to explore gradually. The actions posed are going to cause modifications of the environment and force students to construct hypotheses which will then be tested. Little by little, with the help of their companions or the teacher, they are going to reconstruct in their minds the world on which they act and the rules which govern it; thus they are going to build themselves new knowledge. In short, they meet all of the requirements for fulfilling the constructivist prescription for improving learning environments and refocusing the curriculum.

II. Integration strategies based on constructivism:

The role of problem solving software, spreadsheet, multimedia, the internet and other types of simulation and instructional games in enhancing generalization, discovery, and critical thinking.

Having shown how technology enhances constructivism strategies, let us now describe the integration strategies based on constructivism which address generalization, discovery and critical thinking.

II.1. An overview of the role of the other types of simulation and instructional games in fostering constructivism

As stated earlier, Alessi and Trollip (1991) identify the other types of simulation as “...those that teach how to do something” (p.119). These types of simulation “provide a concrete example to relate to the more general discussion that follows” (Grabe, 2001). This means that such simulations are based on Piaget principles and thus promote constructivist strategies. Furthermore, Alessi and Trollip (1991) divide the “how to” simulations into procedural and situational types:

Procedural simulations: These activities teach the appropriate sequences of steps to perform certain procedures. They include diagnostic programs, in which students try to identify the sources of medical or mechanical problems, and flight simulators, in which students simulate piloting an airplane or other vehicle (Alessi and Trollip, 1991). To illustrate, a surveyed math teacher incorporates the software “E lab” which reflects this type of function
by having students simulate drawing straight lines and generalize a common property among them. Other surveyed math teachers incorporated a program in which student teams are called on to figure out the most efficient way to rescue a bald eagle that has been shot. To develop the optimum solution, the teams must sort through a variety of mathematical data and correctly apply that data to a series of variables like rate of speed, fuel consumption, distance, time, etc. In using technology in this manner, students learn to transfer prior knowledge to problem solving.

Situational simulations. These programs give students hypothetical problem situations and ask them to react. Some simulations allow for various successful strategies such as letting students play the stock market or operate businesses. Others have most desirable and least desirable options such as choices when encountering a potentially volatile classroom situation (Alessi and Trollip, 1991). For example, some interviewed surveyed teachers incorporated a simulation program which includes mock stock market trading, immersion in occupation as doctors, engineers, detective, and fire fighters to learn how math is applied in real life situations; manipulates the layout of buildings on a city block to develop spatial reasoning skills; and experiences many of the financial dilemmas that may occur when operating a business.

Now let us see how the surveyed teachers applied the above simulations in their classrooms. According to the surveyed teachers the "how to" simulations are applied in classrooms as follows:

Courseware that allows students to explore the elements of an environment in a hands-on manner frequently provides students’ first in-depth contact with a topic. This seems to accomplish several purposes. First, it is a nonthreatening way to introduce new terms and unfamiliar settings. Students know that they are not being graded, so they feel less pressure than usual to learn everything right away. A simulation can become simply a get-acquainted look at a topic. Simulations can also build students’ initial interest in a topic. Highly graphic, hands-on activities draw them into the topic and whet their appetite to learn more. The surveyed interviewed math teachers often use content-free simulation as motivation for students to explore their own cognitive processes. Since this kind of courseware requires students to learn no specific content, it is easier to get them to concentrate on problem-solving steps and strategies. However, with content-free products, it is even more important than usual that teachers draw comparisons between skills from the courseware activities and those in the content areas to which they want to transfer the experience. For example, The
Mathpedia software brings an implicit emphasis on Math process skills that the teacher may want to point out. These kinds of activities may be introduced at any time, but it seems more fruitful to use them just prior to content area activities that will require the same processes. Sometimes a simulated demonstration, an interviewed teacher illustrates, can capture students’ attention quickly and effectively and interest them in working together on a product. For example, a simulation on parallelepiped might be the “grabber” a teacher needs to launch a group project in a geometry unit.

What can be said is that simulations offer more versatile implementation than tutorials or drills. They usually work equally effectively with a whole class, small groups, or individuals. A teacher may choose to introduce a lesson to the class by displaying a simulation or to divide up the class into small groups and let each solve problems. Because they instigate discussion and cooperative work so well, simulations usually are considered more appropriate for pairs and small groups than for individuals. However, individual use certainly is not precluded.

Coming to the other type of instructional games, Malone (1980) found that most popular games included elements of adventure and uncertainty and levels of complexity reflecting the development of critical thinking at students (Flowers, 1993). For example, an interviewed teacher incorporated “The adventure of Jasper Woodbury” in her classroom. The interviewed teacher describes this instructional game as a series of learning activities based on a combination of video, text, and computer software. It was originally developed by the Learning Technology Center of Vanderbilt University as a research program focused on contextualized learning.

The Jasper adventures present students with believable stories, each ending with a challenge. The challenge is a complex problem that includes several subproblems. The typical classroom approach is to have the entire class view one of the adventures and then have small groups of students work to propose solutions to the challenge at the end of the adventure. To solve the challenge, which requires a problem solving approach and focus on mathematical concepts, students have to examine the content of the videodisc carefully for data relevant to the problems. The developers of the series argue that this “embedded data design” improves the transfer value of skills that students develop.

In this sense, the interviewed teachers applied such kinds of instructional games in order to foster cooperation and group work. Like simulations, many instructional games serve as the
basis for or introduction to group work. A game’s interactive and motivational qualities help interest students in the topic and present opportunities for competition and group work.

Hence, simulations and instructional games are considered among the most potentially powerful computer courseware resources; however, as with most courseware, their usefulness depends largely on the program’s purpose and how well it fits in with the purpose of the lesson and student needs. Teachers are responsible for recognizing the unique instructional value of each simulation and using it to best advantage.

II.1.2. Problem solving software:
II.1.2.a. Definition and characteristics

Teachers may find the topic of problem solving both enticing and bewildering. No goal in education seems more important today than making students good problem solvers, yet no area is as ill-defined and difficult to understand. Even scientists have difficulty defining problem solving. Funkhouser and Dennis (1992) quoted an earlier author as saying that “Problem solving means the behaviors that researchers who say they are studying problem solving, study” (p. 338). Sherman (1987-1988) was somewhat more specific, claiming that all problem solving involves three components: recognition of a goal (an opportunity for solving a problem), a process (a sequence of physical activities or operations), and mental activity (cognitive operations to pursue a solution). Sherman said that problem solving is a relatively sophisticated mental ability that is difficult to learn and that it is highly idiosyncratic. That is, problem-solving ability depends on knowledge prior experience, and motivation, and many other attributes (Sherman, 1987-1988).

This definition of problem solving covers a wide variety of desired component behaviors. The literature mentions such varied subskills for problem solving as metacognition, observing, recalling information, sequencing, analyzing finding and organizing information, inferring, predicting outcomes, making analogies, and formulating ideas. Some teachers suggest placing students in problem solving environments and, with some coaching and guidance, letting them develop their own heuristics for attacking and solving problems. Some software is specifically designed to focus on such approaches, and is designed for implementation using more constructivist models. These models give students no direct training in or introduction to solving problems; rather they place students in highly motivational problem-solving environments and encourage them to work in groups to solve
problems. Hence, such software reflects Bruner's and Piaget's principles of discovery and exploration.

Constructivists believe this kind of experience helps students in three ways. First, they expect that students will be more likely to acquire and practice content-area, research, and study skills for problems they find interesting and motivating. Second, constructivists claim that this kind of activity helps keep knowledge and skills from becoming inert because it gives students opportunities to see how information applies to actual problems. They learn the knowledge and its application at the same time. Finally, students gain opportunities to discover concepts themselves, which they frequently find more motivating than being told or as constructivists might say, programmed with the information (McCoy, 1990). The following section illustrates the point.

**II.I.2.b The use of problem solving software in teaching math**

As noted earlier, making and exploring of mathematical conjectures reinforces the theme of the particular and general and fosters constructivism. Many constructivist models of technology use the principle based on Piaget's stages which is the need for concrete example and experiences when teaching abstract topics to young children who may not have reached an advanced stage. Such problem solving software is designed in such a way that it allows its users to fit unfamiliar features of their environment that do not fit with their current views of the world by making mathematical conjectures (Perkins et al, 1995). One feature of such a software environment is that while the user explores a particular question, the environment can display a logical universe of inquiries to which the user's particular inquiry belongs. An example of such environments is the series of programs with the collective name "the geometric supposer" which is used by some surveyed math teachers. (Shwartz and Yeshalmy, 1993). Maybe the best way to introduce the supposers is to explain the cognitive riddle that Math teachers face when they set out to teach geometry.

It seems evident that the human cognitive apparatus needs the external aid of drawings and diagrams in order to think about spatial and visual matters (Perkins et al, 1995). Yet as soon as one moves to answer that need by making or providing diagrams to be used in the learning of geometry, one runs the risk of defeating one's own purpose.

Here is the heart of the matter. Consider for example, the class of shapes we call regular polygons. We can construct a regular 4 gon, a regular 15 - gon, a regular (any particular number )-gon, but we can not construct a regular N-gon. Similarly, we can construct any
particular triangle, but we can't construct a triangle that is any triangle. If we produce a
diagram of a triangle, then aside from the size of the triangle, there is only one such triangle.
This contrasts sharply with the situation in Algebra where we have a notation system that
allows us to write symbols that can denote any number.

The geometry we wish to learn, teach and make does not deal with the properties of
particular shapes but rather with the properties of classes of shapes. How can we solve this
conflict between the cognitive need for diagrams and images on the one hand and the
necessarily particular and specific nature of those diagrams on the other?

The geometric supposer is the solution to such a problem. Assume that starting with a
particular triangle we make some geometric construction and discover some interesting
property of our figure. Obviously, we would like to know whether this interesting property is
true for other triangles as well. One can view the construction made on the original triangle
ABC as a procedure that takes the three points in the plane A, B and C as its argument.
Imagine that as the procedure is executed we record the steps of the procedure, the recorded
procedure can then be repeated on any other triplet of points in the plane. While this repetition
of the procedure clearly can not prove anything, it can lead to added or lessened conviction
that the property observed to be true in the original particular case is indeed generally true.

What can be deduced from the above is that the supposer is a tool for exploring
particularity with an eye toward the problem of generality. The supposer does not necessarily
induce users to greater degrees of generalization, but it does provide the setting and the
occasion.

Other constructivist uses of technology employ a discovery learning approach suggested
by Bruner. These uses of technology are based on Bruner's interest in the discovery approach.
Papert (1980) suggests that logo, which is problem-solving software used by the surveyed
math teachers, has the potential of providing students access to a wide variety of discovery.
Papert has influenced profoundly the field of educational technology. He began his career as a
mathematician. Then, he became impressed with Bruner's work of looking at children as
active builders of their own intellectual structures. Papert subsequently joined the Artificial
Intelligence Laboratory at the Massachusetts Institutes of Technology and began experi­
menting with logo, a new programming language, and its uses with young children. One of
his colleagues was also working with children, teaching them to control a robot in the shape
of a turtle. The MIT team decided to combine the two concepts, integrating an on- screen
“turtle” into the logo language. This addition provided the vital link that Papert felt would allow children to move more easily from the concrete operations of the earlier stages of Piaget’s theories to more abstract ones. In 1980, Papert published his theories in a book entitled Mindstorms: children, computers, and powerful Ideas. This book illustrates that the Logo company also employs logo computer language in its programmable RCX™ bricks. Kits containing the RCX bricks were named Mindstorms, after Papert’s 1980 seminal book, Mindstorms. These bricks are small, yellow three-dimensional rectangles that can be easily held in the palm of your hand. They are computers and contain receiving devices so that a program can be written on a laptop or desktop computer and then downloaded through infrared light rays into the RCX brick (Papert, 1980).

When the “run” button is pushed on the RCX, whatever program has been downloaded into it will run. If the brick is part of a Logo vehicle, for instance, then children can control the operation of the vehicle by programming the brick to do whatever they wish (Lego® Mindstrom, 1998). This book challenged then current instructional goals and methods for both mathematics and educational technology, and it became the first widely recognized constructivist statement of educational practice with technology resources (Grabe, 2001).

In this book, Papert felt that children should be allowed to “teach themselves” with logo reflecting Bruner’s concept of discovery. He explained that “in a logo environment, new ideas are often a required as a means of satisfying a personal need to do something one could not do before” (Papert, 1980, P.74). He felt that children need great flexibility to develop their own powerful ideas or insights about new concepts. In other words, Papert has dedicated his work to helping teachers and students use Lego R/logo technologies as intelligent manipulative tools to nourish children’s active construction of knowledge. Papert’s “constructionism”, a theory of education, is based on two different senses of “construction” of knowledge. First, it is grounded in the idea that children learn by actively constructing new knowledge, not by having information poured into their heads. Second, constructionism asserts that effective learning takes place when the learner is engaged in constructing personally meaningful artifacts, such as using creating computer animations, robots, plays, or pictures representing one’s own learning (MIT epistemology and Learning group, 2000).

Papert perceived logo as a resource with ideal properties for encouraging learning. Since logo is graphics oriented, it allows children to see cause and effect relationships between the logic of programming commands and the pictures that result. This logical, cause and effect quality of logo activities makes possible “Microworlds” or self contained environment where
all actions are orderly and rule governed. He called these Microworlds “incubators for knowledge” where children could pose and test out hypotheses (Brumbaugh et al, 1997). It allows children to create their own miniature (micro) world where they learn through experimentation, exploration, and self-directed activity about the cause and effect relationships encountered in computer programming and throughout most of life’s experiences (Microworld Pro®, 2000). The following example illustrates the point: I asked my students to use logo-programming commands to draw a cube, hexagon, heptagon, and an octagon.

Now, let us explore how cognitive skills are developed and reinforced within Logo: Logo can be used in developmentally appropriate ways with young children. The National Association for the Education of Young Children (NAEYC) defined developmentally appropriate practice as age appropriateness. When determining age appropriateness NAEYC counsels to turn to developmental theorists to determine what a typical child should be doing at a particular age (Bredekamp & Copple, 1997). This approach seems to lend itself well to stage theorists who predict what children should and should not be focusing on throughout various ages and stages of development. For instance, let us consider the Piaget’s preoperational stage:

Piaget’s preoperational child, from approximately ages two to seven, is predictably endowed with certain characteristics that defy adults’ conceptions of logic. A preoperational child is very rule bound and will hold fast to a rule, despite evidence to the contrary. Cognitive features of a preoperational child include (a) centration where the child focuses on one central feature of a situation and ignores what the child deems to be its peripheral aspects; (b) no reversibility, where the child does not yet recognize that in order to get back to a starting point, the procedure of an operation must be gone through in reverse order; and (c) egocentrism, where the child is not yet aware of viewpoints or perspectives other than their own (Snowman, 1997). These characteristics of the pre-operational child are considered in turn.

If a preoperational child is employing centration when building a Lego structure, it is very possible that engineering problems will take a long time to solve. Let us take the example of a child whose vehicle is destroyed when it bumps into something. A child who focuses on only one aspect of the vehicle may not be effective in building something stronger. For instance, the child may pile more legos on top of the vehicle. When this proves not to work after some trial and error, a child who is exhibiting centration is likely to add even more
legos to the pile, rather than trying a different approach. This can lead very quickly to frustration and disappointment. Therefore, teachers must assist children to attend to different aspects of a situation. It may be too much to ask the child to attend to more than one aspect at the same time, but after attending to one aspect unsuccessfully, a teacher can guide the child in focusing on a different aspect of the problem.

When using Microworlds on the computer, non-reversibility can present a problem. Most often, a computer is loaded with many software programs and it is not at all difficult or uncommon for a child to close Microworlds and open another program within the space of a few seconds. A teacher is usually summoned, but sometimes not until the child has already attempted to rectify the situation, and without the concept of reversibility, the child is unlikely to retrace his steps, and is more likely to get deeper into a problematic situation. Thus, teachers need to be aware of this tendency and encourage them to seek help immediately, rather than attempting to fix it themselves.

Egocentrism can pose problems when children are animating objects on the computer screen in Microworlds. It is easier to anticipate the behavior of a turtle if one understands how animated objects think. An egocentric child is likely to assume that an object on the screen will “do as I do; think as I think”. But of course this is not true. So they may be dismayed when a number of moving objects on the screen unconcernedly run right over one another and keep on going. “I” would not do such a thing, therefore it seems impossible from an egocentric point of view to understand why an animated object would do it. Fortunately, many neo Piagetians have challenged the age of onset of understanding others’ perspectives (Newcombe and Huttenlocher, 1992) and point out that although young children are still self centered, by three years of age most children can understand others’ perspectives.

It is clear to deduce that the importance of the actual or potential connections between logo and mathematics lies in the development of cognitive knowledge (mathematical). The very structure and interactive aspects of logo enhance logical and mathematical processes while providing a rich environment for exploration and discovery.

Other problem solving software like Cabrigeometer fosters Bruner’s concept of discovery. Cabrigeometer makes feasible the development of representations that are dynamic and interactive to a degree not practical, if possible, before (Perkins et al, 1995). For example, Cabrigeometer provides the means for developing systems that can show the user on demand a dynamic visual rotation of a quadrilateral at different angles and centers. Such facilities can
be interactive in the sense of permitting the user to specify the angle of rotation, the center, and other parameters of the representation and thereby observe the same process from a variety of vantage points. Additionally Cabrigeometer allows the user to drag the vertices of a triangle in order to prove that the three medians of a triangle meet at one point whatever the position of the triangle is.

What can be inferred here is that this kind of dynamic and interactive representation foster discovery of a physical system since it begins with a causal model that mirrors the system’s behavior in the more global respects, and then elaborates the model as the students growing understanding permits.

Now, to apply such software in classrooms, the following guidelines were obtained from the observation of some surveyed teachers when they designed integration strategies for problem solving software:

- Allow students sufficient time to explore and interact with the software, but provide some structure in the form of directions, goals, a work schedule, and organized times for sharing and discussing results.
- Vary amount of direction and assistance, depending on each student’s needs
- Promote reflective learning environment; let students talk about their work and the methods they use
- Stress thinking processes rather than correct answers
- Let students work together in pairs or small groups
- Assess students using alternative to traditional paper and pencil tests

II.1.3 Spreadsheet

Having discussed the importance of using problem solving software, let us now investigate the importance of spreadsheet in terms of constructivist strategies.

II.1.3.a. Definition of spreadsheet:

Electronic spreadsheet programs organize and manipulate numerical data. The term spreadsheet comes from the pre-computer word for an accountant’s ledger: a book for keeping records of numerical information such as budgets and cash flow. The term spreadsheet can refer either to the program itself or to the product it produces. Spreadsheet products are sometimes also called worksheets. Information in a spreadsheet is stored in rows and
columns. Each row-column position is called a cell, which may contain numerical values, words or character data, and formulas or calculation commands (Bozeman, 1992).

A spreadsheet helps users manage numbers. Bozeman (1992) described spreadsheets as a way to “word process numbers” (p. 908). Spreadsheets were the earliest application software available for microcomputers. Some people credit them with starting the microcomputer revolution, since the availability of the first spreadsheet software, Visicalc, motivated many people to buy a microcomputer (Klass, 1988).

Teachers today typically use electronic spreadsheets for work that involves keeping track of and calculating numerical data such as budgets and grades. Spreadsheets process calculations faster, more accurately, and with more visual feedback than other tools such as calculators. For example, if a worksheet is set up to add a column of expense items, the cell showing the sum will change automatically in response to any change to one of the expense items. If a worksheet is set up to calculate a student’s grade average, the cell showing the cumulative average will be updated if the points change for any of the grades. These capabilities allow both teachers and students to play with numbers and see the results.

Spreadsheets offer significant improvements over calculating values by hand or with a calculator. Spreadsheets can easily be edited and stored for later use, and they have the following features in common:

Calculations and comparisons: Spreadsheets calculate and manipulate stored numbers in a variety of ways through formulas (Goldberg, 1990). In addition to adding, subtracting, multiplying, and dividing specified in formulas, spreadsheets also manipulate data in many more complex ways through function commands. These include mathematical functions such as logarithms and roots, statistical functions such as sums and averages, trigonometric functions such as sines and tangents, and financial functions such as periodic payments and rates.

Automatic recalculation: This is the most powerful advantage that spreadsheets offer. When any number changes, the program updates all calculations related to that number (Bozeman, 1992).

Copying cells: Once a user enters a formula or other information into a cell, it can be copied automatically to other cells (Klass, 1988). This can save time, for example, when
placing a long formula at the end of each of 30 rows; the user can simply copy the information from the first row to other rows.

Line up information in columns: Spreadsheets store data by row-column positions, a format that makes information easy to read and digest at a glance (Bozeman, 1992).

Create graphs that correspond to data: a spreadsheet program displays entered and calculated data in a chart or graph such as a pie chart or bar graph (Goldberg, 1990). The following figure, taken from the experience of some surveyed teachers, shows an example of spreadsheet and a bar and pie charts derived from its data.

<table>
<thead>
<tr>
<th>Grades</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>4</td>
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<tr>
<td>17</td>
<td>4</td>
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<td>16</td>
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<td>12</td>
<td>2</td>
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<tr>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

There are charts showing grade distribution for First intermediate.

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What can be concluded here is that spreadsheet is used to enhance student learning of the concept statistics. It helps students interpret the data graphically by seeing a multitude of charts (pie, bar charts) in a short time. To illustrate more, spreadsheet is used to deepen understanding, to accelerate the pace at which students learn, to decrease the amount of time spent on interpretation, to make students active, and to help them investigate. Hence, this implies that spreadsheet is based on Bruner's and Piaget's principles in discovery and exploration approach.

II.3.b. The impact of spreadsheet on education:

Spreadsheet programs are in widespread use in classrooms at all levels of education. Teachers use them primarily to present mathematical topics but sometimes for other purposes. They can help teachers and students in several ways:

Spreadsheets save valuable time by allowing teachers and students to complete essential calculations quickly. They save time not only by making initial calculations faster and more accurate, but their automatic recalculation features make it easy to update products such as grades and budgets. Entries also can be changed, added, or deleted easily, with formulas that automatically recalculate final grades (Ploger et al. 1996).

Although spreadsheet programs are intended for numerical data, their capability to store information in columns makes them ideal tools for designing informational charts (Klass, 1988) such as schedules and attendance lists that may contain few numbers and no calculations at all. Increasingly, spreadsheets help people visualize the impact of changes in numbers. Since values are automatically recalculated when changes are made in a worksheet, a user can play with numbers and immediately see the result. This capability makes it feasible to pose "what if" questions and answer them quickly and easily. Because it is so easy to change variables in a spreadsheet, students can quickly learn the dynamic aspect of spreadsheet which helps students search for patterns, construct algebraic expressions, simulate probabilistic situations, justify conjectures, generalize concepts, and graph and chart data (Paul, 1995). Consequently, this implies that spreadsheet is based on Bruner's and Piaget's principles in discovery and exploration approach. The following example, selected from the experience of some surveyed teachers, illustrates the point: some surveyed teachers have their students use the dynamic aspect of spreadsheet to find a decimal pattern for ninths.
Many teachers feel that spreadsheets make working with numbers more fun. Collis (1988) described spreadsheets as “sufficiently enjoyable and interesting in themselves that students can sometimes be experiencing the pleasure of exploring math at the same time as they are doing math” (p. 264). Students sometimes perceive mathematical concepts as dry and boring; spreadsheets can make these concepts so graphic that students express real delight with seeing how they work.

On the other hand, one of the few disagreements related to spreadsheets in education is whether to use them to keep grades or to rely instead on gradekeeping packages (gradebooks) designed especially for this purpose. Spreadsheets usually offer more flexibility in designing formats and allowing special-purpose calculation functions, while grade books are simpler to use and require little setup other than entering students’ names and assignment grades. Teachers appear to be about evenly divided on which is better; the choice comes down to personal preference. Studies show, however, that spreadsheets can be useful tools for teaching topics ranging from problem solving (Sutherland, 1993) to statistical analysis methods (Klass, 1988). The literature contains numerous testimonials by teachers who have used spreadsheets successfully in teaching topics ranging from mathematics (Baugh, 1995) to social studies (Voteline, 1992).

Having defined spreadsheet and provided its characteristics, let us now see how the surveyed teachers applied spreadsheet in their classrooms: the surveyed teachers can use spreadsheets to help them prepare classroom materials and complete calculations that they would otherwise have to do by hand or with a calculator. Moreover, spreadsheets help with many activities and products, the surveyed teachers add, in education, including: Gradekeeping to keep records and to prepare grade charts for posting, club and/or classroom budgets, computerized checkbooks for clubs or other organizations, attendance charts, performance assessment checklists. Increasingly, the literature reflects an increasing variety of applications for spreadsheets. Although their teaching role focuses primarily on mathematics lessons, spreadsheets have also effectively supported instruction in science, social studies, and even language and arts. The surveyed teachers can use spreadsheets in many ways to enhance learning:

First, whenever concepts involve numbers and concrete representation can clarify the idea, spreadsheets contribute to effective teaching demonstrations. Spreadsheets offer an efficient way of demonstrating numerical concepts such as multiplication and percentages and numerical applications. Second: Students can use spreadsheets to create neat timelines, charts,
and graphs as well as products that require them to store and calculate numbers. For example, a surveyed teacher has his students use a spreadsheet to generate charts and graphs of data they have gathered. The surveyed teacher introduces graphing concepts by having students interpret some commercially produced charts and graphs. Then they assign charts to do without benefit of spreadsheet software. (This gives concrete experience that teaches both the benefit of using a spreadsheet to produce these items and the procedures for generating them.) Then the teacher demonstrates how to use spreadsheet software to create charts and graphs. Students generate and conduct a brief class survey on a topic of interest. They use the spreadsheet to collect the data and display it in chart or graph form. The products are displayed on a bulletin board as “A Profile of the Class”. If additional surveys of other classes are done, the results can be posted on a bulletin board and compared across classes. Third, Spreadsheets take over the task of doing arithmetic functions so students can focus on higher level concepts (Ploger et al,1996). By answering “what if” questions, spreadsheets help the surveyed teachers encourage logical thinking, develop organizational skills, and promote problem solving. The following examples selected from the experience of some surveyed teachers illustrate the point:

The surveyed teachers have their students use a spreadsheet to help do numerical calculations involved in problem solving. “Primary school children think big” (Paul, 1995, p. 65). They talk about and attack many math-oriented problems that require arithmetic skills that they lack. Spreadsheets can help with the calculations involved in solving such problems and can support the conceptual development related to these activities.

With the first problem, students visit a pizza parlor with three different size pizzas (small, medium, and large) and divide them into 4, 6, and 8 portions. Students discuss whether individual portions are equal across all three sizes. They talk about whether it is more cost-effective to buy two small pizzas of four portions each, or one large pizza with eight portions. They make initial estimates and then measure the pizzas. After discussion of the best methods to use and after making some initial calculation, they form initial hypotheses, look at the kind of calculations necessary to solve the problems, and enter the data and formulas into the spreadsheet. After determining the solution to their problem, they change the pricing parameters to answer “what if?” questions. Then they change the radii of the pizzas until the cost for all sizes is equal.

Fourth, the surveyed teachers have their students use spreadsheet to help organize data obtained from classroom experiment and perform required descriptive statistical analyses.
Whenever students must keep track of data from classroom experiment, spreadsheets help organize these data and perform required descriptive statistical analyses. Fifth, The surveyed teachers teach their students to use spreadsheets to keep track of their own grades. They can do their own “what if?” questions to see what scores they need to make on their assignments to project desired class grades. This simple activity can play an important role in encouraging them to take responsibility for setting goals and achieving them.

On the other hand, it is important to note here the common mistakes and misconceptions encountered when using spreadsheets. First, students usually forget to highlight cells to be formatted. The computer cannot format a cell in the spreadsheet until the user highlights the affected cells first and then selects the option. If a chosen formatting option doesn't work for the cells you were formatting, be sure you first indicate the part of the worksheet where the format should apply. Second, perhaps the most common problems in spreadsheet use have to do with creating formulas. This results from failing to complete the first step in the procedure for creating formulas: placing the cursor in the correct cell. The next most common problem results from pressing the right arrow key (instead of the Return or Enter key) to leave the cell while creating a formula. Rather than moving the pointer, this action adds something to the formula. Many students become confused when they see a formula grow as they struggle to leave the cell. Another common problem with formulas is accidentally including the formula cell itself in the formula’s calculation, This is sometimes called a circular reference error. Even if an error message does not appear, this error usually is spotted quickly because the formula results in much larger numbers than expected.

II.I.4. Multimedia

Having discussed the use of spreadsheet as a constructivist tool, let us see whether multimedia and the internet could be considered also as constructivist tools:

II.I.4.a. Definition and characteristics

We live in a multimedia world, surrounded by complex images, movement, and sound. So perhaps it is not surprising that part of our human evolution has emphasized making our technology reflect the color and clamor of our surroundings. In educational technology, multimedia has been a steadily growing presence for some time. Computer-based multimedia learning stations have been used since 1966, and noncomputer multimedia methods have been around even longer. This section looks at current classroom uses of multimedia and its
companion concept, hypermedia. Let us start by stating the difference between Multimedia and Hypermedia.

Like other educational technology concepts, definitions for multimedia and hypermedia defy consensus (Moore et al, 1994; Tolhurst, 1995); people find the two concepts either too close to distinguish or too slippery to get words around. Tolhurst quoted one source as saying, "By its very nature, (multimedia) is invertebrate. You poke it and it slithers away" (p. 21). Definitions used in this thesis come to us from two paths that were separate initially but have converged over time.

Multimedia simply means “multiple media” or “a combination of media”. The media can be still pictures, sound, motion video, animation, and/or text items combined in a product whose purpose is communicating information. Hypermedia are “linked media” that have their roots in a concept developed by Vannevar Bush (1945) in his landmark article “As We May Think” (1945). Bush proposed a “memex” machine that would let people quickly access items of information whose meanings were connected but which were stored in different places (Bush, 1986). In the 1960s, Ted Nelson coined the term “hypertext” to describe a proposed database system called Xanadu based on Bush's idea (Boyle, 1997). In this system, items of information from all over the world were to be logically connected with “hypertext” links. For example, one could select “triangle” and get information on all related concepts such as isosceles, equilateral, and right angle triangle. The technology at that time was inadequate to produce Xanadu, but the idea was the forerunner of today's hypermedia systems in which information stored in various media are connected, thus the term hypermedia.

In current technologies such as browsers and authoring systems, most multimedia products also are hypermedia systems. That is, the combination of media elements are linked with buttons to click on or menus from which to select (Moore, et al, 1994). Clicking or selecting one item sends the user to other, related items. The combination of media makes this product multimedia; the ability to get from one media/information element to another makes it hypermedia. But what are the types of multimedia and hypermedia systems?

Multimedia and hypermedia systems come in a variety of hardware, software, and media configurations but usually are classified according to their primary storage equipment: interactive videodiscs (IVD), CD-ROMs (compact disc read only memory), digital versatile disc (DVD), and other technologies, including CD-I (compact disc-interactive). DVI (digital video interactive), and photo CDs (photographic compact discs). This section focuses on IVD
and CD-ROM technologies, since they have the most powerful current impact on education; these technologies all share a single core technology: laser beams heat light-sensitive material on a disc so that a chemical reaction causes the area to either remain opaque or reflect light, thus revealing encoded information. In contrast, magnetic storage units, such as hard disks and tape devices, store data as magnetic pulses, which are read or altered by the disk drive (Mathisen, 1991; Walkenbach, 1992).

II.I.4.b. The impact of multimedia on math education

Having defined multimedia, and hypermedia, let us now investigate the current and future impact of multimedia and hypermedia on education. The current widespread educational uses of multimedia and hypermedia systems foretell an even heavier reliance on these products in classrooms of the future. Educators recognize and use these systems when they see the strengths they offer (Moore et al., 1994). These systems offer some of the most powerful capabilities technology has to offer, including motivation, flexibility, development of creative and critical thinking skills, and improved writing and process skills. This means that multimedia and hypermedia are based on Bruner’s and Piaget’s principles (Scholten and Whitmer, 1996). Further, Hypermedia programs offer such varied options that most people seem to enjoy using them. Students who usually struggle to complete a projector term paper often will tackle a hypermedia project enthusiastically. McCarthy (1989) believes the most important characteristic of hypermedia is its ability to encourage students to be proactive learners (McCullen, 1998).

Hypermedia programs can draw on such diverse tools that they truly offer something for students who excel in any of what Gardner calls “intelligences”. Of all the learning and developmental theories embraced by constructivists, Gardner’s theory is the only one that attempts to define the role of intelligence in learning. His work is based on Guilford’s pioneering work on the structure of intellect (Eggen & Kauchak, 1999) and Strenberg’s view of intelligences as influenced by culture (Ormod, 2000). Gardner’s theory is that at least eight different and relatively independent types of intelligence exist. Gardner’s theory meshes well with the trend toward using technology to support group work. When educators assign students to groups to develop a multimedia product, they can assign students roles based on their type of intelligence (Eggen and Kauchak, 1999). For example, those with high interpersonal intelligence may be the project coordinators, those with high logical mathematical ability may be responsible for links and structure, and those with spatial ability may be responsible for aesthetic and graphics. For example, a student who may not be good at written expression but has visual aptitude can document things with sound or pictures. Hence,
such constructivist models of technology use the concept of scaffolding and developing each individual's potential. Many multimedia systems are under the assumption that they can help bring the students up from their level of understanding to a higher level by developing students to create appropriate multimedia products to enhance learning (Woodell, 2001). The International Society for Technology in Education suggests “prior to completion of grade two students will create developmentally appropriate multimedia with support from teachers, family members, or student partners” (p. 18).

The tremendous access to hypertext and hypermedia tools opens up a multitude of creative avenues for both students and teachers. Marchionini (1988) refers to hypermedia as a fluid environment that constantly requires the learner to make decisions and evaluate progress. He asserts that this process forces students to apply higher-order thinking skills. Turner and Dipinto (1992) report that the hypermedia environment encourages students to think in terms of metaphors, to be introspective, and to give free rein to their imaginations. Boyle (1997) suggests that technology has the potential of developing critical thinking since “educational multimedia design creates something that is dazzling new and deep familiar” (P. 164).

Turner and Dipinto (1992) also find that exposure to hypermedia authoring tools helps students by giving them a new and different perspective on how to organize and present information and a new insight into writing. Instead of viewing their writing as one long stream of text, students now see it as chunks of information to be linked together. Thus, the use of hypermedia tools in the learning process has important implications for schools. Dede (1994) sees that such uses offer new methods of structured discovery, address varied learning styles, motivate and empower students, and accommodate nonlinear exploration, allowing teachers to present information as a web of interconnections rather than a stream of facts.

Society's heavy reliance on hypertext/hypermedia to communicate information seems likely to expand in the future. The accelerating number of World Wide Web pages (to be discussed later) on the Internet is evidence that linking data together with hypertext and hypermedia is an effective way to present and add value to large bodies of information. Millions of people already publish hypermedia documents on the information highway in the hope of attracting listeners, readers, and viewers (Moore et al, 1994). Moreover, hypermedia tools also may permit sophisticated evaluations of learning. In the process of using hypermedia, people are said to “leave a track” (Simonson & Thompson, 1994), which may help analyze how students approach learning tasks. Future hypermedia systems might apply
pattern-recognition techniques from the field of artificial intelligence to help schools assess
student mastery of higher-order cognitive skills (Dede, 1994) which foster Piaget's, Vygotky's
and Bruner's principles. Bagui (1998) says multimedia "may have unique capabilities to
facilitate learning because of the parallels between multimedia and the natural way people
learn" (p. 4), that is, through visual information and imagery.

Having discussed the educational uses of multimedia and hypermedia, let us now
provide the educational uses of particular multimedia/hypermedia: Interactive videodisc
(IVD) and CD ROMs:

Videodiscs are optical storage media for random-access storage of high-quality audio
and analog information. Laser videodiscs store text, audio, video, and graphics data in analog
format. Interactive videodisc (IVD) technology was first released in the 1970s and now has
applications in both the education and business worlds. A videodisc resembles an audio CD
disc, except it is generally larger in diameter. Most videodiscs are 12 inches in diameter and
hold 54,000 still frames or the equivalent of 675 carousel slide trays. They represent a durable
medium for storing and displaying visual information. Videodiscs are read by a laser beam,
and the mechanism allows random access to any part of the disc. The random access feature is
important because it prevents the need to fast forward or rewind to find a particular image as
is necessary with a videotape (Gustafson and Smith, 1995).

Regular videodiscs give teachers a variety of types of products for classroom use:
perhapes the most ambitious use of videodisc technology in teaching comes from Optical Data
Corporation, which has developed an entire curriculum package. The company has followed
its Windows on Science program, now in wide use, with Windows on Math and Windows on
Social Studies. Some states now allow school districts to adopt these programs in place of
textbooks. D. C. Heath's Interactions program uses video technology to bring interactive
examples of math applications in real-world settings. Discs such as Videodiscovery's Science
Sleuths and Math Sleuths provide students with mysteries to solve (Frederickson, 1997). The
videodisc programs offer clues in the form of interviews, textual and numeric data,
photographs, and diagrams. The teacher plays an active role in guiding students via
questioning techniques and just-in-time teaching. For example, Apple Computer's TLT:
Teaching, Learning, and Technology is a videodisc intended to help schools work through the
school improvement process. The videodisc component provides interviews with experts in
the field and numerous examples of teachers and students in action. Further, Optical Data's
Adventures of Jasper Woodbury teaches middle-school math with a series of simulated
scenarios. Students solve real-world applied math problems by retrieving data embedded in the stories. Barcode technology comes in handy here, since it enables students to review segments from the story as needed. It is designed so that the teacher can stop the action and teach certain math techniques just when needed to solve techniques problems. By the way, users can scan bar codes to access chapters, individual frames, or segments of video. The barcode reader that interprets the patterns of stripes resembles the technology in many stores (Gustafson and Smith, 1995).

Other videodiscs are in the form of visual databases, movies and documentaries, and student presentation. Visual databases are collections of individual pictures and short video segments (Shields, 1994). Mathpedia was one of the earliest examples of this type of program. These databases are perhaps most useful in the areas of math, science, and art and provide a wealth of resources for both teacher presentations and student projects. Movies and documentaries can yield tremendous educational benefits. Through the search feature controlled by the remote control, a teacher can access any frame or segment of a disc almost instantly. The random access capability of the technology holds great promise for encouraging sound pedagogical uses of video as opposed to playing movies straight through. Student presentations videodiscs allow students to create their own illustrated presentations on topics they have researched or books they have read (Thorpe, 1993). This is a kind of repurposing, in which students present selected frames to support and enhance their reports. To illustrate, Some curriculum programs, like those in the ABC Interactive series and Mathpedia, have built-in tools that allow teachers and students to develop their own presentations by drawing on the videodisc resources.

Coming to CDROMs, they have become as commonplace in the lives of young people as phonograph records were to their parents and grandparents. But CD-ROMS have additional capabilities undreamed of in the days of record albums and turntables. Commonly called compact discs or CDs, CD-ROMs are made of the same material as videodiscs but are smaller in size, just 4.72 inches in diameter. CD-ROMs are known for their huge storage capacity, tip to 650 MB of data, which equates to the equivalent of 250,000 pages of text, or five hundred 500-page novels. Computer systems get access to CD-ROMs' through either internal or external CD-ROM players (Karlin, 1994).

The number of titles in the CD-ROM market has increased at a phenomenal rate over the past few years and will continue to grow. Eventually, CD-ROMs will store and display motion sequences, a role currently filled by IVD. At this time, IVD primarily is used for
applications that require video clips, while CD-ROMs are used more for database products such as encyclopedias. In the meantime, CD-ROM technology has adapted to allow users to store data on them as well as use them for pre-stored applications. Since CD-ROMs hold so much more information than disks, they are becoming valuable additions to schools' collections of storage devices, and readable/writable CD-ROM drives are becoming commonplace (Karlin, 1994). Consequently, there are several popular categories of classroom uses: First, a single CD-ROM can store the equivalent of 800 3½-inch microdisks, This makes CD-ROM a wonderful technology for distributing instructional software. Some companies have taken advantage of this added capacity by enhancing successful programs with new multimedia features, for example, The Oregon Trail by MECC and Broderbund's Adventures of Camzen Sandiego (Parham, 1995). Second, CD ROMs can be used as interactive math books. These on-screen stories have become extremely popular with primary teachers and students. On the audio tracks, narrators read pages as the words are highlighted on screen. If a student needs to hear a word again, just clicking on it with the mouse pointer will activate the audio.

Third, CD-ROM technology meets the needs of students and teachers in the area of reference materials more than any other. Plenty of reference materials are available at reasonable costs. To add still more value, these resources are accompanied by software that makes searching for information both easy and efficient (Truett, 1994). The following reference material CD ROMs which are incorporated by the surveyed math teachers illustrate the point: "Compton’s Encyclopedia”, “Encarta” by Microsoft, “The Aircraft Encyclopedia”, “Encyclopedia of Math and technology”, and “Encyclopedia of Science and Technology”. These categories could be used for carrying out research which means that CD ROMs are based on Piaget’s, Bruner’s and Vygotsky’s principles. Other CD ROMs can be used as collections of development resources. A wide variety of resources are now shipped on CD-ROM. These include collections of clip art, sound effects, photographs, video clips, fonts, and document templates(Truett, 1994). Some major conferences, like the National Educational Computing Conference (NECC), distribute to each registrant proceedings, presenter handouts, vendor samples, and shareware on CD-ROM.

In addition to the examples mentioned earlier about the use of hypermedia/multimedia in the surveyed schools, some classroom applications of multimedia and hypermedia in these schools are described as follows:
Instead of presenting book reports verbally or as written summaries, it is becoming increasingly common for students in the surveyed schools to report on their reading through multimedia slideshows or as hypermedia products. Teachers often design a standard format and students fill in the required information and add their own illustrations. Moreover, students use multimedia/hypermedia as an effective way to present research and to document field trips because they let others take virtual trips to the locations. Other surveyed math teachers require their students to make math interactive story book. Students document existing stories or write their own so they can be read interactively by others. Those reading these hypermedia stories can click on various places on screen to hear or see parts of a story. This format also lets students go beyond one basic sequence and create their own branches and endings to stories. Further, a surveyed interviewed math teacher said:

I asked my students to use multimedia software to design graphics for different types of daily weather. They used the graphics to record daily weather on an electronic calendar. Then, I had them print a copy and cut the calendar apart, by days. Finally I had them sort and organize the weather data to identify patterns. Note here that my students used the following multimedia software: logo, Super print, Hyper studio and web workshop.

Hence, it can be noticed that involving students in creating multimedia products enhances critical thinking by bringing the students up from their level of understanding to a higher level.

II.1.5. The internet

We have discussed that multimedia could be used as constructivist tools, but what about the internet?

II.1.5.a. Definition and characteristics

New technologies are often the impetus for innovation. Perhaps the greatest source of innovations during the past years has been the computer, particularly when combined with the use of the Internet. The internet burst on the scene in our society and in education only a few years ago, but quickly set fire to the interest and imagination of even the least technical teachers, students, and parents. Now, most computer based distance learning applications involve some internet resource or activity, and many rely exclusively on internet materials. Although these technologies chart the direction for change, it is the educators as innovators
within the schools that need to have the strength of vision to see how these technologies can be implemented (Houston, 1998). But where did the internet come from?

Today’s educational uses of the internet bear little resemblance to its original purpose. Yet learning something about its original design can help educators understand how the internet works today. The U.S. department of Defense (DOD) developed the first version of the internet during the 1970s to allow quick communication among researchers working on DOD projects in about 30 locations. The DOD also saw it as a way to continue communications among these important defense sites in the event of a worldwide catastrophe such as a nuclear attack. Since these projects were funded by the DOD’s Advanced Research Projects Agency (ARPA), the network was originally called ARPA net (Ross and Bailey, 1996).

In the 1980s, just as desktop computers were becoming common, The National Science Foundation (NSF) funded a high speed connection among university centers based on the ARPA net structure. By connecting their individual networks, universities could communicate and exchange information in the same way DOD’S projects had. However, these new connections had an additional, unexpected benefit. A person accessing a university network from home or school could also get access to any site connected to the network. This connection began to be called a gateway to all networks, and what we now call the internet was born (Ross and Bailey, 1996). Now, a question arises: what is the internet now?

Networks connect computers to allow users to share resources and exchange information easily. The internet has been called the ultimate network or the “mother of all networks” because it is a network of networks. It is a way for people in network sites all over the world to communicate with each other as though they were on the same local area network. The name means literally “between or among networks”. Though most people think of the internet as synonymous with the World Wide Web (WWW), the latter really is a subset of the internet system. The WWW is an internet service that links sites around the world through hypertext documents. By bringing up a hypertext or Web page document in a program called a web browser, one can click on texts or graphics linked to other pages in other sites. In this way, one “travels” around the internet from site to site (Cafolla and Knee, 1996).

The use of the internet depends on common procedures or protocols that allow computers to communicate with each other, despite differences in programs or operating
systems. Two important protocols are internet protocol (IP) addresses and uniform resource locators (URLs).

IP addresses: Internet exchanges are possible because everyone uses a common communication system called an Internet protocol, which assigns a number designation to each internet address. To navigate the internet, you may have an account on a computer connected to it. Most users connect their computers to the internet through large, high powered computer systems (servers) running the Unit operating system. An internet address is the combination of your account name (user id) and the internet registered name of the computer (host name). InterNIC (Internet Network Information Center), a cooperative service of the National Science Foundation and a Virginia company called Network Solutions, serves as a registry for internet addresses, ensuring that no two internet addresses or IP numbers are identical. Think of it as a database similar to that maintained by the Social Security Administration, which ensures that no two people have identical Social security numbers. In 1998, the U.S Congress provided funds allocated to improve this system and to help large universities who act as providers for educators to pay for high speed Internet connections (Biemiller, & Young 1998).

Uniform resource locators (URLs): Every web page or Web site has an address called a uniform resource locator (URL). A URL starts with the prefix HTTP, which stands for Hypertext transfer protocol— an internet standard that defines how messages are sent and what actions servers and browsers should take in response to commands. A URL entered into a browser sends a HTTP command to the Web server directing it to transmit the requested Web page (Cafolla and Knee, 1996-1997). Now, a question arises: why has the internet become so popular?

Educators, like just about everyone in the civilized world, either seem to be on the internet or trying to get on it. It has become a symbol for our era of technology’s power to shape our lives. A major benefit of the Internet is the comprehensive nature of its information and services. Once connected, educators and students can use the internet to exchange messages and files among themselves and with others anywhere in the world. Also, they can use it to locate information virtually from any place in the world. A person or site with desired information need only be connected to the internet and willing to provide an online listing of available resources (Ryders and Hughes, 1998). Starr (1997) refers to the Web as “easily the most glamorous” (p. 7) of the services provided by the Internet. The potential for this new medium has businesses, governments, athletes, educators, and private citizens around the world racing to realize the new opportunities available. But the internet popularity does not spring merely from its wealth of information, but from three characteristics that give
widespread appeal to technical and non technical people alike. It is widely available, easy to use, and highly visual and graphic (Starr, 1997).

First, anyone in the world can access the internet and use it to communicate with others. In this sense, it is as popular as the telephone and is, in fact, combining with telephone service to broaden the usefulness of both. Thus, it is widely available. Second, the internet is based on a simple and intuitive "point and click" activity. Anything on an internet page, such as a word or picture, can be a link to another location. One link may be to another place on the same web page; another link can connect to another place in the world. Both are equally easy to do. A brief demonstration has made many noncomputer users into internet enthusiasts. The term "surfing" and "browsing" indicate just how popular it has become to follow these links from site to site, gathering information along the way. Hence, the internet is easy to use. Third, When the internet was strictly a text based system, it was not nearly as popular with "nontechies". It was when images became a primary means of communication on web pages that the internet caught on. This graphic quality appealed to society's growing dependency on visual forms of communication fostered by television and videogames. In this sense, it is highly visual and graphic.

However, the introduction of this new technology is not enough in its own right to bring about innovation within the schools. "Society is designed to maintain existing conditions; the tensile strength of change must overcome the tendency to return to a previous status quo" (Houston, 1998, p. 208). Hence, let us provide an insight into how this technology can be used to support teaching and learning.

Many educators believe that the Web has a potential to transform the art of teaching and learning. Yet, similar refrains have been heard before. As far back as 1922, Thomas Edison expressed similar opinions about the potential of the motion picture when he stated, "the motion picture is destined to revolutionize our educational system" (as cited in Cuban, 1986, p.9). High expectations were also held for the introduction of the radio in the 1920s, slide projectors, filmstrips, records and tapes in the 1950s, television in the 1960s, and calculators in the 1970s. Although these technologies do have a role to play in today's schools, most people do not consider that their introduction caused a revolution in teaching and learning. Of all the new technologies, the overhead projector has been the most widely adopted for classroom use (Zhao, 1998). Why then is it that many new technologies do not live up to the reputation that precedes them? Educators suggest that the design and content of technological applications are most important in determining whether the material is adopted, rather than
the means by which we get the material to the learner (Kaufmann, 1998; Owston, 1997; Zhao, 1998). Further, Zhao (1998) suggests that one of the goals that designers need to focus on is designing content that promotes learning.

II.I.5.b. The use of the internet in teaching math

Nevertheless, Fetterman (1998) outlines a variety of internet resources for educational research and instruction. Describing numerous advantages of such resources, Fetterman mentions a serious limitation: “They are only as good as the data the user enters or retrieves” (Fetterman, 1998, p. 29). In what follows we discuss several popular applications of the Web in education: So many distance learning resources have been developed and are emerging every day that it is difficult to know how to start (Armstrong, 1995). This thesis offers a summary and examples for teachers to integrate various distance learning resources into teaching and other professional activities. Integration strategies are described for lesson activities, course delivery, support for teacher and student communications, and support for educators conducting or participating in research.

Some of the most exciting distance learning applications call for student collaboration via technology to address significant problems or issues or to communicate with people in other cultures throughout the world. In a series of articles written for Learning and Leading with Technology (formerly The Computing Teacher), Judi Harris refers to these as “educational telecomputing activities” (Harris, 1994, 1997-1998, 1998) and describes three general types of models: interpersonal exchanges (students communicating via technology with other students or with teachers/experts); information collection and analysis (using information collections that provide data and information on request); and problem solving (student-oriented, cooperative problem-solving projects). This implies that the internet activities are based on Vygotsky’s, Piaget’s and Bruner’s principles of cooperation, discovery, and exploration, to which ISTE (2000) add, prior to completion of primary grades students will “collaborate with peers, experts and others using telecommunications and collaborative tools to investigate curriculum related problems, issues, and information, and develop solutions or product for audience inside and outside the classroom.” (p.20). Harris (1998) lists different strategies, several under each model, referring to these as “wetware”, or activity structures that guide teachers’ actions in the project from planning through product development. Some examples of each are given here:
Electronic penpals: The simplest instructional activity in which distance technologies play a role is linking each student with a partner or penpal in a distant location to whom the student writes letters or diary-type entries. This kind of writing assignment has been shown to be very motivating to students (Cohen & Riel, 1989). Writing to communicate something to real people—rather than writing for teacher evaluations encourages students to write more and with better grammar, spelling, and usage. This makes electronic correspondence an ideal activity for English and/or writing classes, and enhances students' knowledge in other subject areas like mathematics and science. Networking in this way also eliminates social bias regarding gender, race, age, and physical appearance. Without social and cultural cues to color interactions, two people who may never have communicated to one another in person are able to build positive electronic relationships. Though not a substitute for face-to-face activities in multicultural education, e-mail is an important way to begin building awareness of and appreciation for other cultures. Electronic mail (e-mail) is the most common way to exchange personal, written messages between individual or small groups. It is possible to send e-mail via an internal network, rather than the internet, but most people with e-mail accounts also send e-mail outside their systems via the internet (D'Ignazio, 1996). Abilock (1996) discusses how powerful e-mail can be for communications among teachers, students and resource experts. Althaus (1997) stresses the importance of such communication by comparing it with classroom discussion. He states that when classes are involved in what is defined as discussion, teachers speak between 40 and 80 percent of the time, and most communication is between the teacher and a student rather than among students. Such discussions tend to draw in students who are good at developing quick responses and are able to gain the attention of the teacher and group within a time-dependent environment (Althaus, 1997). Quick responses are also rewarded because most teachers pause for less than 2 seconds after asking a question before speaking again to call on another student, rephrase the question, or provide an answer (Tobin, 1986, 1987).

Reviews of research with college students indicate that the properties of communication through the internet change some of these patterns of interaction. It appears that online discussions encourage greater and more diverse participation. A higher proportion of students tend to be involved when given the opportunity to contribute comments by e-mail. One research group found that student comments in the classroom averaged 12 words, but contributions to an e-mail discussion averaged 106 words. Students obviously have more time to construct an e-mail message, so it is not surprising that the messages are longer. Also, e-mail messages are more complex than classroom comments and range over several topics. As you might expect, message complexity in chat sessions is more similar to that found in face-
to-face classroom discussions (Althaus, 1997; Black et al, 1983; Olaniran et al, 1996). Two factors may contribute to these advantages. One is that in both chat and e-mail discussions, participating students can work on the preparation of their comments at the same time and can be assured that the comments will eventually be added to the discussion. The first student to click Send does not block out other participants. Also, communication through the internet reduces a variety of classroom cues (sounds and visual information) that may inhibit some students. Even the visible presence of the teacher as authority figure may cause some students to take less initiative.

Individual and cooperative research projects: Students can research a problem online working either by themselves or in groups, gathering information from electronic and paper-based sources. These research activities usually culminate in a presentation to the class and subsequent discussion of the findings (Harris, 1994a). For example, students may be asked to tap various online databases for articles and reports on contributions by the space program to math history. They may supplement this information with online conversations with experts they locate on the Internet. When the research is completed, the class report might include actual examples of these contributions as well as summaries delivered via multimedia or presentation software. Note here that such on line conversations are held in chat rooms. Chat rooms are internet locations that allow “live” real time communications between two or more users. As users in a chatroom type in their comments, what they type is seen by every one in the “room”. Chatrooms are considered more interactive than any other of the other written communications options. The chats held in them are sometimes known as “threaded discussions” (Armstrong, 1995).

Electronic mentoring (Telementoring): Dyrli (1994) refers to subject matter experts who volunteer to work closely with students online as “electronic mentors” (p.34). One source of aid in these activities, the Electronic Emissary Project at the University of Texas, links up classes across the country with mentors on topics ranging from Greek literature to life support in space (p. 35). The Center for Children and Technology (CCT, 1996) describes three kinds of telementoring activities it sets up to encourage young women to enter science, engineering, and other technology professions. However, they are useful strategies for all student mentoring activities and include guidance, discussion forums, and peer lounges. One kind of telementoring activities implemented in the surveyed schools is to encourage students to communicate mathematically.
**One-to-one guidance:** Young people have private, individual “discussions” via e-mail links with professionals who give advice and guidance related to a particular field. CCT says that before these discussions begin, mentors and students participate in separate online sessions to prepare for establishing these relationships. Mentors and students, for example, are asked to craft introductory biographies and set goals for their relationships.

Discussion forums: Students and mentors are linked in a mailing list that supports large group discussions on topics of mutual interest. These discussion groups are referred to as listservs. Listservs are discussion groups on the internet that feature ongoing “conversations” via e-mail between groups of people who share common interests. When e-mail is addressed to a listserv mailing list, it is automatically duplicated and sent to everyone on the list. These discussions are particularly useful in providing students with information and encouragement related to career pursuits (Armstrong, 1996). To illustrate, in a surveyed school, students and mentors are linked in a mailing list that provides students with information about professionals who use math at work.

Peer lounges: These are smaller mailing lists set up to share information and ideas for dealing with problems and issues during large projects. A “lounge” is set up for mentors, one for students, and one for teachers. Mentors use the lounges to talk among themselves about mentoring techniques and how to deal with common problems or issues. Students use the lounge to discuss their projects and classroom issues. Teachers use the lounge to discuss their programs with other teachers. Each is considered a type of peer mentoring. It is important to note here that students, teachers and mentors use a Bulletin board for communication. Bulletin Boards, like listservs, serve as electronic message centers but usually are used to post notices of interest rather than hold ongoing conversations. Most bulletin boards serve specific interest groups. They allow members to review messages left by others, and leave their own messages (Dyrli, 1994). The following example selected from the experience of some surveyed interviewed teachers illustrates the point:

**Lesson Purposes (interdisciplinary lesson plan, for grades 3 and 4).**

Students become aware of and comfortable with technology integrated into the curriculum; students develop intergenerational relationships.
**Instructional Activities.**

Students are paired with senior citizens for communication through telecommunications: messages are sent and received through local bulletin board systems. Students begin the activity by becoming familiar with the computer keyboard and certain key functions. They then begin working on questions to develop biographies that they subsequently share with other students as well as their older partners. Instructors prepare the senior citizens and assist them in logging on and off, entering passwords and user names, downloading messages, answering student questions, and sending and receiving files. Students use their questionnaires to interview the senior citizens to stimulate communication and obtain information needed to develop biographies. At the end of the activity, instructors arrange for students to meet their partners and present the biographies to them. Academic subjects are integrated into many parts of this activity. Students spend time on language arts, history, math, geography, and science skills. Intergenerational relationships developed through this activity are meaningful to both sets of partners. Teachers observe an increase in student's self esteem, leadership, cooperative learning skills, and academic achievement.

Electronic field trip: an electronic field trip in its simplest form fills classroom screens with visual images of a place considered to offer some educational value and to which students would not routinely be able to travel. Visual trips are designed to explore unique locations around the world, and, by involving learners at those sites, to share the experience with other learners at remote locations. Trips may use only video programs or may include prepared curriculum guides, suggested preparation and follow up activities, and discussion questions to help correlate experiences with specific objectives. Learners can interact with peers via telephone, computer, broadcast transmission, fax and mail (Dyrli,1994). Some typical examples of electronic field trips include a visit to different Egyptian places and an exploration of the history of geometry. Through electronic field trips, many students imagine themselves leaving their neighbourhoods and cities; they experience in some fashion the excitement and wonder of new places and faces and they learn from the experience.

Group development of products: teachers have developed many variations on group development of products. For example, students may use e-mail to solicit and offer feedback on an evolving literary project, sometimes involving advice from professional authors. Students may work independently toward an agreed-upon goal, each student or group adding a portion of the final product. This is sometimes called chain writing (Harris,1994a). For example, two surveyed schools linked electronically to write and videotape a play. At one school, students developed a list of characters and a general plot outline and wrote Scenes 1
and 2. Students at the other school selected a math topic for the play (to communicate mathematically): developed the personalities, physical characteristics, and backgrounds of the characters; and wrote Scenes 3 and 4. Together the students developed the final story line and produced the play, exchanging the videotaped portions that they produced independently.

Parallel problem solving: through technological links, students in a number of different locations can work on similar problems (Harris, 1994). They solve the problem independently and then compare their methods and results or build a database or other product with information gathered during the activity. For example, one sixth grade class in a surveyed school set up a web page to solicit data on the probability of heads or tails when flipping coins. Students received data from different schools and then shared the results with on line partners. Another example is the following (selected from the experience of a surveyed teacher):

Lesson purposes: students and teachers share math discovery projects via competition between classrooms in several schools with results shared on line and via broadcast as part of the regularly scheduled integrated math curriculum segment for a specific grade level. Networked teachers discuss challenges, resources, and results while the activities are in progress.

Instructional activities: Math projects are assigned via text and television broadcast and then tackled by individual students or groups of students. Teachers engage in discussion with other mathematics teachers using the curriculum and with projects developers to clarify activities, check results, and share data collected. Students projects are sometimes sent to project headquarters for exhibition or as part of regular competition among schools. Teachers are also supported on line with assessment materials and strategies, suggestions for further activities or alternate assignments, materials lists, and references for more information or research activity. Although students themselves are only beginning to use telecommunications technologies available to the integrated math project to gather or share information, the teacher connectivity and ongoing on line support make this project an exciting example of teacher collaboration and support using broadcast video and telecommunications technologies.

Simulated activities: in this type of problem-solving exercise, students participate in structured activities in which they carry out specific duties or responsibilities on which
depends some aspect of the project outcome (Harris, 1997-1998). One example is selected from a surveyed teacher. It is the following:

Lesson purpose (interdisciplinary lesson plan): to teach students about finding positions using a real situation, accessing information, geography, math, and lifestyles of people from different countries.

Instructional activities: students are assigned a specific yacht to participate in an annual race around the world. They are responsible for accessing computer databases of information giving latitude, longitude, elapsed time, and place. Each morning during the race, a student or group of students accesses a remote database and downloads information on the assigned yacht. Students keep daily records of their yacht’s progress from the beginning of the race until the boats arrive at a nearby harbor. Students ultimately present each real skipper with a map of that yacht’s progress and have the opportunity to discuss the race in person with some of the crew. The activity incorporated several curriculum areas. Students learn how to use distance technologies, how to locate positions using latitude and longitude, and how to calculate distance by comparing positions from one day to the next. In addition, students use the situation to develop writing assignments. Students devote at least 45 minutes to 1 hour a day to this activity.

Social action projects: online communication gives students access to people in other countries that can support social problem solving. In this type of project, students are responsible for learning about and addressing important global social, economic, political, or environmental conditions (Lamb et al, 1997). For example, students collaborating on a peace project write congressional representatives to voice concerns and present their viewpoints. The following example implemented by one of the surveyed teachers illustrates the point: the purposes of the lesson were to gather and compare data regarding the collection and dispersion of trash to see if one region conserves better than others and to assess grade level and day of the week differences. Students were involved in activities that require them to collect information on the number of ounces of paper trash collected each day in their classroom. In addition to collecting data on the trash, students record the number in attendance each day to analyze the relative proportion of trash to the number of students. The data collected are then electronically transmitted to a central classroom where the information is pooled for distribution. The students hypothesize about what the data might show and discuss local and collective data. Note here that this is an interdisciplinary lesson plan. Social studies were integrated into math.
Now, let us see how the websites support classroom projects: Harris (1997) gives an excellent description with examples of ways to use Web sites to support some types of distance learning activities. The following section summarizes Harris' work and shows that Web sites can serve any of several functions or combination of functions:

Sites can introduce the goals and purposes of a project and invite people to participate. A global project, Canadian Kids from Kantata, gives a description designed to "encourage communication among indigenous peoples and later immigrants" (Harris, 1997, p. 17). The page gives a history, an explanation of how the groups involved are organized, a list of organizations and people who support the project, and links to complete an application to become a participant. The British Chatback Project's "Memories from 1945" gives information on how to subscribe to an e-mail discussion list or listserv. Hence, websites can serve as project overview, announcement, and application. Further, a site gives participants actual instruction and information on how to do project activities, and this makes websites serve as project instruction. For example, the I*EARN Learning Circle global classroom project gives a "linked set of hypertextually rich Web pages that provide step-by-step instruction for project participation (Harris, 1997, p. 18). Some students use Web sites to add information to a collection that will be shared with others (Gelernter, 1998). KIDLINK's Multicultural Calendar database is a collection of descriptions written by students of holidays and festivals around the world. Students use the site to enter summaries and can search the resulting database by month, holiday, country, and author. This implies that websites could function as information repository and exchange.

On the other hand, students working with others in distant sites share a Web site to support their cooperative work. For example, a Colorado meteorologist posted a picture on a shared Web site of a device students could build to help them complete an experiment in radiative processes (Harris, 1997). These co-development Web sites can be even more helpful if they build in streaming video and/or videoconferencing. The term streaming video applies to movies that have been compressed and transmitted in the form of real time video via the internet. A streaming video player such as Real Video is needed to see streamed video. A streamed video file begins loading from a remote web site when the user clicks on it but does not wait until the video is downloaded; it starts almost immediately after the download begins. This is especially useful for large videos that take a long time to download. However, video quality is dependent on the quality and speed of the line connecting the computer to the internet (Jerram, 1995).
Coming to videoconferencing, the increasing availability of telephone switching technologies allows completely interactive communication among desktop computers. Today, computers adapted for complete two-way interaction are becoming common in schools and classrooms across the country. A typical desktop videoconferencing system has equipment like video camera, microphone, and speakers at each workstation or learning station that allows the learner to be seen and heard by the teacher or learner at the remote site. Signals are transmitted using modems and telephone lines. Teachers can use presentation technologies such as LCD projection panels connected to the computers to expand the number of persons who may observe the on-screen video. Learners may communicate directly with teachers, peers, and experts who use compatible systems. However, current applications of desktop videoconferencing are limited by several factors. First, the cost of transmitting video data over telephone lines is high because of the large amount of bandwidth those signals require. Second, current video transmissions must deal with analog signals, making them difficult to manipulate. However, video conferencing is on the increase, especially as equipment and line costs become cheaper and resources get easier to use (Jerram, 1995).

Other educational applications of websites link students to resources to support project activities and make gathering information for project work more efficient. Other websites display exemplary project activities and students work (Royer, 1997). To illustrate, “Chronology sites” exhibit an ongoing description of past, current, and planned project activities. In the GlobalLearn, project visitors to the site view artifacts found by explorers as they travel to various countries, “reporting” their findings on the Web site. Students usually make use of the exemplary project activities to show off the products of their learning activities in other sites (Ryder and Hughes, 1998). Many Internet Web sites show examples of students’ poems, stories, pictures, and multimedia products. Finally, Web sites sometimes are set up for the specific purpose of inviting new distance learning projects (Royer, 1997). Five current ones are: Global SchoolNet Foundation (http://www.gsh.org), the Intercultural E-mail Classroom Connection (http://www.stolaf.edu/network.iecc/), KIDPROJ (http://www.kidlink.nodak.edu), KIDSPHERE (kidsphere@vms.cis.pitt.edu), Pitsco's Ask an Expert site (http://www.askanexpert.com/askanexpert/ask.html).

Now, the following guidelines were deduced during the observation of some surveyed teachers who implemented the use of the internet into teaching:
The surveyed teachers have students begin by observing their environment in order to develop a purpose for their project. They ask them questions that lead them to think about Math related issues around them through brainstorming, discussing, and reflecting on their questions and ideas, students explore topics and focus on specific issues or concerns. For example, if the general topic is pollution, the teacher poses questions to narrow the topic, “Study the pollution caused by three types of fuels? What is the number of items of polluting substances produced by each type of fuel?”

They require students to use a variety of electronic resources such as Internet sites as well as print resources to locate information and connect ideas. To illustrate, students look for clues, ideas, and perspectives by evaluating the quality of the information they have found on the internet in order to consider whether each information source is authoritative, objective, reliable, and relevant.

Moreover, the surveyed teachers involve students in a high level of critical thinking as students begin to put together their ideas. First, students compare information from different sources, select information that seems most useful, organize the information into a solution, and decide on a way to express the results (a picture or chart). Second, students are asked to “wrap” or package the information and solutions in a format (video, Web site, or multimedia package) that will appeal to their intended audience. Third, students have to publicize their involvement in the project and decide how to carry out the solutions they have developed. For example, they might decide to help facilitate the computation process by making a presentation to a company board or volunteering in calculating the incomes and outcomes of a company. Finally, the surveyed teachers have their students reflect on how the project went and what they have learned. Students also analyze the impact of their work. For example, if they sent a report to a company manager, did they get a response?

What can be concluded from the above is that using the internet in classrooms has educational advantage of interacting when compared to meeting in the same classroom. Communicating through the internet is place independent—that is, individuals do not have to be in the same location to communicate. Some forms of communication through the internet, such as e-mail, are also time independent and do not require the participants to interact at the same point in time. Such communication through the internet may encourage more productive discussion by increasing the number of active student participants and extending the time available for discussion. It can help those who cannot think as quickly as others, may not be as proficient in using the language, or may be apprehensive of sharing when in the physical
presence of peers (Althaus, 1997). Even for those who have no difficulty expressing themselves in class, the writing activities involved in e-mail allow the time for reflection not available in a fast-paced classroom discussion. For these reasons, communication through the internet offers practical solutions to some very real educational problems relating to time and location. In sum, communication through the internet reflects Piaget's and Bruner's principles of discovery and exploration.
Chapter III: Methodology: Discussion of a survey as an appropriate methodology to carry out the research in the study of this thesis

Lebanon is a country with a good deal of diversity in its educational system. However, since 1997, there appears to be some uniformity and agreement on provision of basic educational opportunities for the primary math curriculum. It is recognized that the twenty first century has ushered in significant advances in math and technology. In that provision, technology and math education feature prominently in all the school curriculum. Now, let us describe the technology and math curriculum development in Lebanon.

Mathematics the world over has always been considered as a bridge not only between science and technology but also between all the subjects offered in a formal educational system. Anyone who is good in Mathematics is presumed to be able to cope with other school subjects. Happily that dictum has been accepted all over Lebanon and its effects are evident in the curriculum formulation found in many educational documents in Lebanon. The Lebanese National Center for educational research and development initiated the overall reform of the educational system in Lebanon. The center took up a new challenge for integrating educational technology tools into teaching mathematics. “The flashing advancement in technology has deeply marked modern society. We speak today of the era of “information” like we spoke a quarter of a century ago, of the industrial era” (The Lebanese New curricula, 1997, p.288). The state of curriculum development in Lebanon in terms of integrating technology into teaching math can today be described as healthy. That is the intended curriculum. But what goes on in Lebanon’s schools and beyond?

The success of any curriculum document is in the implementation. Implementing educational technology tools into mathematics successfully depends on well trained and well motivated teachers, adequate supply of relevant software, and development of a math technology culture (Sonn, 1993).

Reviewing studies in Lebanon over the last decade on the above factors shows that in most Lebanon schools, the state of attainment is dismally low. Even at the dawn of this new millennium, most Lebanon schools are classified as technologically under developed. Compared with technologically advanced countries, the rate of awareness and growth in math technology curriculum is still low. For instance, a Lebanese study made the following observation “At primary level, the quality of math education, particularly at official Lebanese
schools, is extremely poor, because the teaching of this subject is done by unqualified or under qualified teachers; the facilities are poor and the classes are often too large" (Science and technology for all in Lebanon, 2000, p.10).

Educational reform is a relatively slow process, particularly in terms of its visible and recognizable impact. Any reform needs to be comprehensive in addressing issues of curriculum, assessment, pedagogy, and progression. Such reform needs to be well supported both by initial and on going in service training of teachers and by the provision of different kinds of educational technology tools. It also means producing sufficient instructional technology qualified teachers in the first place or converting “existing qualified teachers into instructional technology ones through short, intensive training programmes”.

However, the availability and capacity of well trained and motivating teaching staff remain the single most difficult obstacle in instructional technology education even where nations are prepared to put resources into this capacity building. Other obstacles could be referred to the failure of the Lebanese Center for the Educational Research and Development to provide primary schools with hardware infrastructure (e.g. accessing students to computers, connecting student computers to the internet, connecting administrative offices to the internet).

Increasingly, twenty Lebanese schools principals have attributed the generally poor state of instructional technology in Lebanon to the mismatch between the intended and the implemented curriculum. Since the technological trend which dominates the 21st century with the call to capitalize on the integration of educational tools into math teaching to enhance the teaching and learning of math as opposed to the traditional view of adoring the textbooks as the source of information. These 20 schools integrated information technology into math in constructivist and direct manners.

Hence, these schools are jumping onto the technological bandwagon. To illustrate, they have embarked on a project of IT for all primary schools with the first phase being introduced in 1999 where teaching a computer literacy training programme has been implemented, and infrastructure for lab networking has been installed (computer lab, internet,...). The second stage was devoted to teacher training on the integration strategies where professional development activities to support the integration of technology and instruction have been implemented.
Educational technology is used in these schools as a tool to meet the individual instructional needs of all students. Integrated throughout a revisited curriculum and aligned with those schools frameworks, reform documents, and newly developed standards, educational technology is used to enhance the learning process. Students have access to a wide variety of media (such as print, video, audio, CD-ROM, quality software, laser discs, telecommunications, and distance learning) for accessing and retrieving information. Risk free environments encourage all students to become problem solvers, information managers, collaborators, team players, self-directed, and lifelong learners. The above schools' students perceive themselves as productive learners who are responsible for the depth and range of their own learning. Teachers act as facilitators in the learning process. Students are provided with basic technology skills to empower them as architects of their own learning, and give them real world instructional environments so that they will be prepared for higher education and the work place.

Educational technology in the above schools removes the school walls as barriers to learning. Access is provided to the world beyond the classroom. Students and teachers have access to the resources of learning outside the classroom walls and outside the time constraints of the typical school day. Through educational technology, students and staff are able to interact and converse with scientists and scholars, and participate in electronic field trips. Educational technology is used to accommodate diverse learners, improve teaching, enhance student achievement; and improve staff, parent, and community participation in the educational process. Parents become more actively involved in their child's education using telecommunications.

The use of IT in these schools had been advocated as an enabler to enhance the teaching/learning of mathematics. The above school curriculum experts illustrate that a laboratory functioning as a micro world of a mathematician's work place enables students to acquire the math skills and knowledge expected of them when they enter the real world. Computer assisted experimentation, besides providing accuracy and efficiency in collecting and manipulating data, also promotes a better management of time. And the time saved from tedious conventional ways of collecting, tabling, graphing and analyzing can be put to better use for reflection and problem solving.

Hence, according to the literature review and to the feedback obtained from the 20 Lebanese primary schools, integrating the educational technology tools into primary mathematics is very important. However, the other Lebanese primary schools are still
adapting the traditional teaching strategies in teaching math where technology is not implemented. How can we motivate the primary math teachers of such schools to integrate technology into math curriculum? How can we show them the importance of integrating technology into math curriculum and hence change their attitudes toward the integration strategies? This can be done by describing the attitudes and opinions of the Lebanese primary math teachers of the 20 schools already mentioned. Survey could be considered as an appropriate methodology to carry out the above research. Let us see why?

III.A. Why carry out a survey?

III.A.1 Definition of a Survey

It would be pleasant to be able to open this section with a straightforward definition of what is meant by a social survey. A survey may be designed to investigate a cause effect relationship or to throw fresh light on some aspects of sociological theory; or be occasioned simply by a need for administrative facts on some aspects of public life. When it comes to subject matter, all one can say is that surveys are concerned with the demographic characteristics, the social environment, the activities, or the attitudes and the opinions of some groups of people (Moser & Kalton, 93). Cohen and Manion (94) define survey as a descriptive method in educational research which gathers data at a particular point in time with the intention of describing the nature of existing conditions, or identifying standards against which existing conditions can be examined, or determining the relationships that exist between specific events. "It is the collection of a small amount of data in standardized form from a relatively large number of individuals; and the selection of samples of individuals from known population" (P. 124) Robson (93) suggested. Kerlinger (64) adds that survey research is represented by the collection of data from a population, or some sample drawn from it, to assess the relative incidence, distribution and interrelationships of naturally occurring phenomena (as cited in Robson 1993, p.124). Finally, Bryman (1989) attempts a more formal definition: "Survey research entails the collection of data on a number of units and usually at a single juncture in time, with a view to collecting systematically a body of quantifiable data in respect of a number of variables which are then examined to discern patterns of association" (P.104) (as cited in Robson 1993 P. 124). From the above wide range of definitions of survey, the kind of survey in this thesis is concerned with the attitudes and the opinions of primary Math teachers regarding integrating strategies.
III.A.2. Purpose of a survey

The purpose of many surveys is to provide someone with information. For example, someone wants to know how much people spend on food; a business concern is interested in finding out what detergents people are using. In each case, the researcher is well advised to want these facts, or to seek them through a survey. Interviewees are only concerned with noting that to them, the survey in this case has a clear descriptive purpose (Moser & Kalton, 1993). However, it must not be thought that the purpose of survey is always so straightforward. Many enquiries aim to explain rather than to describe. Their functions may be theoretical, to test some hypothesis suggested by sociological theory, or to assess the influence of various factors, which can be manipulated by public action, upon some phenomenon. But whichever be the case, the purpose is to explain the relationships between a number of variables (Moser & Kalton, 1993). Hence, what can be said here is that many surveys are carried out for descriptive purposes, they can provide information about the distribution of a wide range of people characteristics. Then, it is possible to go beyond the descriptive to the interpretive: that is, to use the survey to provide explanation of what is described, essentially to seek causal relationships (Robson, 1993). The purpose of the survey in this thesis is descriptive. It provides information about the attitudes of primary Math teachers in Lebanon concerning integration strategies, interprets and explains what is described.

III.A.3. Survey and other research strategies

Having defined a survey and its purposes, let’s prove that a survey is an appropriate method for the underlying research question.

The major divide between surveys and experiments lies in the presence of planned change in experiments and its absence from almost all surveys. The typical survey is passive in that it looks for describing and/or analyzing. However, the experiment is active since it asks: what happens if this changed? (Robson, 1993). As I mentioned earlier, the survey in this thesis is concerned with the attitudes and the opinions of the primary Math teachers concerning integration strategies in Lebanon which means that this topic is passive in that it is going to describe and analyze. Hence, the best methodology to implement such research is survey.

Furthermore, surveys and case studies also have clear fundamental differences from each other. Essentially, “the survey studies the sample not in its own right but as a means of understanding the population from which it is drawn. Case studies have a prime concern for understanding that particular case” (Robson 1993, p. 125). To illustrate, surveys may be
associated with more than one variable and the variations of their values. The study in this thesis is associated with more than one variable such as the technological educational tools, ways to implement such tools, and teaching strategies. It studies the sample as a means of understanding the population, which consists of Lebanese primary Math teachers, from which it is drawn. This means that this study doesn’t have a primary concern for understanding a particular case. Hence, survey can be considered to be the best method to carry out such research.

III.B. Survey method

III.B.1. The simple Survey (adhoc)

This survey involves collecting the same standardized data from an undifferentiated group of respondents (primary Math teachers) over a short period of time. The respondents are selected as a representative sample from a large population which is the primary Math teachers in Lebanon. “Such a survey is sometimes referred to as an adhoc sample survey” (Robson 1993, p. 130). Adhoc is perfectly adequate to the study in this paper since this study is not moving from description to establishing causations, to which Robson (1993) says “.... Moving from description to establishing causation is difficult with this design...” (P.131). The group of primary Math teachers teach different grades (G1,G2,G3,G4,G5,G6,G7). This means that “the group of respondents is likely to incorporate naturally occurring variables with several levels... it is also possible to view this as a comparison group survey” (Robson 1993, p.131). These comparison groups which cover variables can be built explicitly into the design, with appropriate sampling to ensure representativeness (Hakim, 1987).

III.B.2. Panel Survey

It is, perfectly feasible to repeat a survey at different points in time. A repeated survey can make use of the same sample of respondents for each repetition. As with the simple survey, this can also be characterized as incorporating two or more comparison groups by virtue of the inclusion of naturally occurring variables. Such a survey is called panel or longitudinal Survey (Hakim, 1987). Since data are collected on the same set of respondents at two or more points in time, such a survey is likely to demand considerable resources of both time and effort, particularly when the phenomena of interest require substantial time intervals between the bouts of data collection. This leads to concluding that the study proposed in this thesis couldn’t be implemented with a panel survey because of the problems encountered in repeated measures experiments. Some members of the primary Math teachers may move away, or die or not respond for other reasons.
III.B.3. The rotating Survey

Coming to the rotating sample Survey, this is a hybrid somewhere between the repeated cross sectional simple survey and the panel survey. On each repetition of the survey, the sample will include some members from the previous survey and some new members (Hoinville et al, 1985). Such a design is not suitable for the study in this paper since such a design would provide a tool in interpreting relationships by including a clear temporal sequence of the data obtained, and this is beyond the study proposed in this paper.

III.C. Formal design for the simple survey

Having defined the survey’s objectives which explain why the survey is being done, what questions it means to cover, and what kinds of result are expected, let us now discuss the formal designs for survey.

III.C.1. Definition of the population

The first step is to define the population to be studied – its geographical, demographic and other boundaries. A population consists of a number of units of enquiry (Moser and Kalton, 1993), to which the enquiry is addressed (Cohen and Manion, 1994). It is what Robson (1993) refers to as “population refers to all the cases” (p. 135). It might be, for example, the adults living in Lebanon, or all children attending schools in Lebanon, or the official schools in Beirut. The last example illustrates that population is being used in a general sense, it is not limited to people. In the survey of this thesis, for example, I might specify the population as those primary Math teachers in Lebanon who are integrating technology into math curriculum. It consists of the 20 schools already mentioned. The geographical delineation of this population may comprise all of, say, Lebanon. Its characteristics, the aspects of the population we wish to measure (Barnett, 1991), are the opinions of Math teachers in Lebanon towards the integration strategies. This expresses some aggregate feature of the population in relation to how it varies from one teacher to another. Each teacher contributes his component (a number or qualitative description) for some measure of interest (his opinion), since this can vary from one individual to another, and this is termed the variable of interest. Barnett (1991), adds “the population characteristic will usually be a total, mean or proportion of this variable over the population” (p. 8).
III.C.2. Definition of the sample

We have seen how the object of our enquiries is a population consisting of a finite number of individuals, on each of whom some measure is observable. We want to characterize the population by some aggregate expressions of that measure, perhaps its mean, or total over the population to which Barnett asks "why not observe every individual in the population and thereby obtain the exact answer"? (p. 11).

Hence, the second step of the formal design for the simple survey is to decide whether the population should be fully or only partially covered. In the latter, and for most usual cases, the method of selecting the respondents has to be determined and this normally means a sample in the statistical sense (Moser and Kalton, 1993). In some cases, where the population is small and easily accessible, the question does not arise (Barnett, 1991). For example, suppose I want to determine how much loose change I have in my pocket, I am hardly inclined to take a sample of the coins and to try to estimate the total value. Alternatively, a full enumeration may take place for a very large population where there is a substantial social importance to justify the extensive expenditure (Barnett, 1991). This arises, for example, in national censuses of facts about every member of the country's population. But such cases are rare. Moreover, where the research is concerned with a very small and compact population like the children in a school, the inhabitants of a village, the employees in a company, it may be easy to cover all the members, so again the choice between complete and partial coverage barely arises. But for populations of intermediate size the choice could arise (Moser and Kalton, 1993). Suppose that one wanted the way 4000 families spend their money and that one had the resources to interview all the families. Would it be worth doing so? The answer would almost certainly be No. Hence, more commonly it really does make sense, for a variety of reasons, to limit our study of the population to the task of merely sampling some of its members and of using the information obtained in this way to infer the characteristics of the population as a whole. What are these reasons?

III.C.2.a. Why Sample?

The main obstacle to a complete enumeration of the population is the limit on the resources, in terms of money, time or effort, that we can apply (Barnett, 1991). It is one of the factors that decide the choice between a complete and a partial coverage, Kalton and Moser (1993) declare. They suggest ".... The populations being so large or dispersed that complete coverage is ruled out by shortage of money, time..." (p. 55). There is also the need to counter balance precision and expense. Quick inspection of a large number of individuals may result, in view of inaccuracies of measurement, in less precise information than that obtained from
more careful inspection of some judiciously chosen smaller sample (Barnett, 1991). For example, the use of alternative methods of medical testing provides a good illustration of this effect.

Since ambiguities can arise concerning how we obtain access to individuals in the study population, accessibility is considered to be an obstacle to a complete enumeration of the population. Frequently, there is different ease of access to different individuals in the study population. Some may not be even observable (Barnett, 1991). To illustrate, historical records may be incomplete. For example, temperature or rainfall readings over some period of interest may have been recorded sporadically; contemporary attitudes to some controversial issue may have been incompletely recorded, and we cannot recreate the circumstances for fuller study. Cohen and Manion (1994) agree with Barnett when they say: “populations, ..... vary considerably in their accessibility; pupils and student teachers are relatively easy to survey, gypsy children and head teachers are more elusive” (p. 85).

Hence, in the above cases we are compelled to accept only a sample from the population. In some instances the individuals of the study population may be destroyed in the process of sampling. Here a complete study of the population is sterile and no more useful even if we can afford it. There is often no point in knowing all about the population if it no longer exists for the exploitation of our knowledge (Barnett, 1991). Hence, a manufacturer of light bulbs, or matches, is not going to test the lifetime of each bulb, or strike each match, to prove the quality of his products. After such destructive testing, there would be nothing left to sell.

Coming to the study in this paper, it is easily seen that due to factors of expense, time and accessibility, it is not possible or practical to obtain measures from all primary Math teachers in Lebanon. Hence, what can be done is to collect information from a small group or subset (sample) of the population (primary math teachers) in such a way that the knowledge gained is representative of the total population under study.
**III.C.2.b. The sampling unit**

Having decided to take a sample of the population, ambiguities can arise regarding how we define the individuals in the study population (Barnett, 1991). Consider the following example: suppose we wish to conduct a survey of people’s income and the way they spend their money. Although the individuals in this study population are “people”, some conventional definition of “people” must be adopted before we can proceed. Even so, there is likely to be no easy means of identifying or sampling such “people” units. It would be far easier to sample addresses and to seek information on families at the chosen addresses. So, the addresses become the sampling units, even though the population of addresses is not of essential interest.

Coming to the study in this paper, the surveyor wishes to conduct a survey of primary Math teacher attitudes towards integration strategies in Lebanon. The surveyor might most easily obtain information by approaching a sample of primary schools and asking primary Math teachers about their attitudes towards the integration strategies in Lebanon. The primary schools constitute the primary sampling units, their Math teachers are sub units.

**III.D. Principles underlying sample design**

The questions which arises now is how should we sample? The resolution of the question, how should we sample, requires a more formal specification of the aims and objectives of a sample survey. The general aim must be to draw a sample which is an “honest representative” of the population, and which leads to estimates of population characteristics with as great a precision or accuracy as we can reasonably expect for the cost or effort we are able to expend (Barnett, 1991). Moser and Kalton (1993) suggest “two major principles underline all sample design. The first is the desire to avoid bias in the selection procedure, the second broadly to achieve the maximum precision for a given outlay of resources” (p. 79). To achieve the two principles mentioned above, the researcher in this study takes into consideration Moser and Kalton (1993) and Flower’s principles (1993) to avoid bias in the selection:

1- The sampling is done by a random method, which generally means that the selection is not consciously or unconsciously influenced by human choice. Each person has a known chance of selection set by the sampling procedure. If research discretion or respondent characteristics such as respondent availability or initiative affect the chances of selection, there is no statistical basis for evaluating how well or how poorly
the sample represents the population; commonly used approaches to avoid bias are not applicable.

2- The sampling frame covers the population adequately, completely or accurately.

3- All sections of the population are possible to find and able to cooperate.

Any deviations from these factors discussed above will cause systematic, non-compensating errors which are not eliminated or reduced by an increase in sample size. (Moser and Kalton, 1993). To illustrate, if the sample is taken from an inadequate list, no increase in size will correct its unrepresentativeness or eliminate the bias in the characteristic of an infinite number of samples so selected. Consider this example, suppose a mammoth sample of 9,000,000 individuals is selected to forecast the result of the U.S presidential election. Moreover, the sample is picked from telephone directories which do not adequately cover the poorer section of the electorate; and only 20% of the (mail) ballots which come predominantly from the more educated sections of the population are returned. Then, this forecast of the U.S. presidential election will go disastrously astray because the sampling frame doesn’t cover the population adequately, and some sections of the population are not able to cooperate.

As I noted earlier, the sampling frame is an important factor which should be taken into consideration in order to avoid bias in the selection. Hence, the first step in evaluating the quality of a sample is to define the sample frame. There are three characteristics of a sample frame that a researcher should evaluate:

1- Comprehensiveness: A sample can only be representative of the sample frame, that is the population that actually had a chance to be selected. Most sampling approaches leave out at least a few people from the population the researcher wants to study (Fowler, 1993). To illustrate, consider the following example:
Patient based samples exclude people who live in suburbs and mountains. Although these samples cover large segments of some populations, they also omit major segments with distinctive characteristics. As a specific example, published telephone directories omit those without telephones, those who have requested that their numbers not be published, and those who have been assigned a telephone number since the most recent directory was published. In the study of this paper, primary school samples will cover all Lebanese primary schools implementing a technology integrated math curriculum from the far north to the far south of Lebanon.

2- Probability of selection: Is it possible to calculate the probability of each person sampled? In the example discussed earlier concerning patient based samples, a
procedure that samples records of patient visits to a doctor over a year will give individuals who visit the doctor numerous times a higher chance of selection than those who see the doctor only once. It is not necessary that a sampling scheme allocate every member of the sampling frame the same chance of selection, as would be the case if each person appeared once and only once on a list. However, it is essential that the researcher be able to find out the probability of selection for each individual selected. This may be done at the time of sample selection by examination of the list. It also may be possible to find out the probability of the selection at the time of data collection (Henry, 1990).

In the above example of sampling patients by sampling doctor visits, if the researcher asks selected patients the number of visits to the physician they had in a year, it would be possible to adjust the data at the time of analysis to take into account the different chances of selection. Otherwise, it is not possible to estimate accurately the relationship between the sample statistics and the population from which it was drawn. It is important to note here that this doesn’t apply to the study of this paper since all teachers are selected equally.

3- Efficiency: In some cases, sampling frames include units that are not among those that this researcher wants to sample. Assuming that suitable persons can be identified at the point of data collection, being too comprehensive is not a problem (Groves, 1989). Hence a perfectly appropriate way to sample patients is to draw a sample of all patients in all hospitals, then exclude those employees who are working in those hospitals.

In the study of this thesis, a suitable way to sample primary Math teachers in Lebanon is to draw a sample of all primary Math teachers who are integrating technology into math curriculum in Lebanon excluding those teachers who are teaching other subject areas.

III.D. Sampling

Once the researcher in this study has defined the factors which should be considered in order to achieve the two major principles underlying all sample designs: avoiding bias and precision, now he is able to answer the next mentioned question: How should we sample? Our concern in this part is with bias arising through the sampling method. As I mentioned earlier, one way of avoiding this is to use a random method. Randomness lies at the base of all sound sample designs; these designs differ chiefly in the refinements introduced to minimize sampling errors for a given expenditure or conversely, to achieve a certain precision at minimum cost. (Moser and Kalton 93).
Since there is no list to constitute our sampling frame and from which we can choose at random the primary math teachers who are incorporating technology into math teaching, cluster sampling is the most appropriate kind of sampling in this study. The sampling frame often consists of a division of the study population into non-overlapping groups of population members (Barnett, 1991). Robson (1993) refers to such non-overlapping groups of population as clusters which are the primary schools in this study (20 schools), each of which contains individuals ie the primary math teacher having a range of characteristics. The clusters themselves ie the Lebanese primary schools are chosen on a random basis. 5 schools (clusters) are selected from a population of 20 schools. The sub population within the cluster, ie all the primary math teachers (grade 1 to grade 7), in these selected schools is then chosen. This sample includes 35 primary math teachers representing all the primary math teachers in the 5 surveyed schools. In other words, in each of the 5 surveyed schools, 7 primary math teachers are surveyed. These 7 primary math teachers represent all the primary math teachers in every surveyed school, and they teach 7 primary different grades ie each surveyed teacher teaches one grade. Note here that in every surveyed school, only one primary math teacher is available for each primary grade. This means that by using this strategy, the sample of this study consists of 35 primary math teachers chosen from 5 schools (American community school, International college, Qualaa school, Hariri school, and Adma school). The surveyed teachers teach different grades: 7 primary math teachers teach Grade 1, 7 primary math teachers teach Grade 2, 7 primary math teachers teach Grade 3, 7 primary math teachers teach Grade 4, 7 primary math teachers teach Grade 5, 7 primary math teachers teach Grade 6, and 7 primary math teachers teach Grade 7. Further, the surveyed schools represent different school systems, different socioeconomic areas, and geographic locations. Therefore, this sample reflects the relative number in the population as a whole.

It can be noticed here that the sampling frame provides a coverage of the population of interest, but its members (clusters) do not correspond to individual members of the population. Such loss of identification of individual is offset by the great convenience of having a tangible list of sampling units in which to define a sample and, frequently, by practical advantages of cost or access in contacting chosen sample members (clusters). To illustrate, consider the following example: a list of addresses might be a convenient basis of access to individual in households, but each address may correspond to several people. This choice of a sample of addresses is likely to be easier and less expensive than choice of individual in households (irrespective of whether or not a complete list of individuals in households exists).
III.D.2. Methods of data collection

In the last few sections we have been concerned with the coverage of surveys and particularly with methods of sampling. Now, we turn to the collection of the information. One of the most far reaching decisions a researcher must make is the way in which the data will be collected. Should an interviewer ask the questions and record the answers, or should the survey be self administered? If an interviewer is to be used, there is the further decision about whether the interview will take place in person or over the telephone. If the respondent is to read and answer questions without an interviewer, there are choices about how to present the questionnaire to the respondents. In some cases, questionnaires are handed to respondents, in groups or individually, and returned immediately (Fowler, 1993). Methods of obtaining data about the primary math teachers who are integrating technology into their teaching can be classified in the following way:

(i) Documentary Sources
(ii) Observation
(iii) Mail questionnaire (including e-mail)
(iv) Interviewing

III.D.2.a. Documentary Sources

Documentary sources can be used in planning surveys. The surveyor was warned not to hurry into the field without first consulting the necessary book and journal literature, past and present investigations of relevance, official reports and statistics, records of institutions and so forth (Moser and Kalton, 1993). The researcher in the study of this thesis begins by getting statistical data about the Math assessment results in Lebanese primary Schools adopting the integration strategies. These results are available in Schools or in the Lebanese Center for Educational Research and Development. The surveyor first considers carefully the suitability of such information for his purpose in terms of population coverage, accuracy and updating of information. The answer to such questions lead the surveyor to treat the finding as no more than rough studies.

III.D.2. Observation

Coming to observation, it implies the use of eyes rather than of the ears and the voice. The Concise Oxford Dictionary defines it as “accurate watching and noting of phenomena as they occur in nature with regard to cause and effect or mutual relations” (as cited in Moser
and Kalton 1993, p. 245). To illustrate, in the study of this thesis, the researcher plays the role of a participant observer by sharing in the life of primary Math teachers in classrooms, and observing their ways of teaching using technology. The researcher conducted naturalistic observation of the primary teachers and of the behaviors of the students in the surveyed schools. He noted their behaviors on the mathematical task encountered during the implementation of the integration strategies. Since the researcher intended to investigate the importance of integrating technology into math curriculum in terms of learning theories, it was important that the researcher gather what could be seen as a challenge to the conventional narrow teaching of primary mathematics.

An ethnographic approach, as described by Eisenhart (1988) was selected as being the most appropriate methodological choice that would allow exploring the issues the researcher had in mind. As a matter of fact, many of the principles of ethnography derive from the interpretivist philosophical viewpoint which focuses on the idea “all human activity is fundamentally a social and meaning making experience” (Eisenhart, 1988, p. 102). This idea agrees indeed with the constructivist viewpoint that people meaningfully construct their own mathematical knowledge through their actions.

Since ethnography is usually concerned with the development of a theory rather than with the testing of existing hypotheses (Millroy, 1992), an essential part of this research task was to discover what was significant and what was important to observe in the field. Hence, participant observation could be considered as a complementary method of collecting data.

With this method, the observer joins in the daily life of the primary math teachers. He watches what happens to the students and how they behave. He studies the life of the class as a whole, the interactions between students and teachers. During the observation, the researcher recorded his interactions with the surveyed teachers as well as students’ interactions with their teachers and with the software used. The researcher saw the following software in use: Pre Algebra CD, Super tutor Geometry, Grade Builder Algebra, Geometry, Sunburst, Mighty, Adding and Subtracting, E lab, Mathpedia, Jasper Woodbury, Supposer, Logo, Cabrigeometre, Compton’s Encyclopedia, Aircraft Encyclopedia, Encyclopedia of math and Technology, and Encyclopedia of Science and Technology. Note here that the researcher observed 7 technology math integrated lesson implemented in 7 grades (G1, G2, G3, G4, G5, G6, G7).
What can be concluded here is that in considering observations as a method of data
collection, its value is assessed in relation to that of the alternative method of collecting
information, that is asking primary teachers about the actions and behaviour of their students.
Direct observation can have a number of advantages over asking for information from
informants. If the primary math teachers are unable to provide the information about their
students or can give only very inexact answers, questioning must be ruled out and observation
is the only way to proceed.

III.D.2.c Mail questionnaires

The two sources of information already discussed are suitable for the study in this paper
and for certain survey situations. But if one wants to find out what a primary Math teacher
thinks about the purpose of integrating technology into math teaching or how much he knows
about kinds of the educational tools, one may use mail questionnaires.

Mail questionnaires can be used in this study due to the following reasons: first, without
doubt, the mail questionnaire is generally cheaper and this is described in the words of Sellitiz
and others (1959) "Questionnaire can be sent through the mail, interviewers cannot" (as cited
in Moser and Kalton, 1993 p. 257). Second, the population to be covered here is wide and the
funds available limited, so that the mail questionnaire is preferable. Third, some questions
demand a considered rather than an immediate answer. In particular, if the answer requires
consultation of documents, a questionnaire filled in by the respondent in his own time is
preferable (Moser and Kalton, 1993). Items of the questionnaire in this study require
consultation of software. Fourth, some primary Math teachers may answer certain questions
more willingly and accurately when not face to face with an interviewer who is a complete
stranger.

III.D.2.d. Interviewing

We have looked at the advantages of mail questionnaires, but looking at the limitations
of mail questionnaires is also important.

A mail questionnaire is most suited to surveys whose purpose is clear enough to be
explained in a few paragraphs of print; in which the scheme of questions is not over elaborate.
Ambiguity, vagueness, technical expressions and so forth must be avoided even more
perseveringly than when the questionnaire is filled in by an interviewer. Moreover, there is no
opportunity to probe beyond the given answer, to clarify an ambiguous one, to overcome
unwillingness to answer a particular question or to appraise the validity of what a respondent
said in the light of how he said it. In short the mail questionnaire is essentially an inflexible method (Flower, 1993).

Increasingly, the mail questionnaire is inappropriate where spontaneous answers are wanted; where it is important that the views of one person only are obtained, uninfluenced by discussion with others; and where questions testing a person’s knowledge are to be included. Besides, when the respondent fills in the questionnaire he can see all the questions before answering any of them, and the different answers can’t therefore be treated as independent (Moser and Kalton, 1993). In an interview in this study, an early question is: “can you name any classroom applications of drill function? And a later one “Do you ever use drill for preparation for tests ?” In a mail Survey, the previous question would be pointless. Finally, with a mail questionnaire the surveyor can’t be sure that the right person completes the questionnaire. Note here that some interviews are analyzed in the literature review.

It may be noted that some of the disadvantages of the mail questionnaire can be overcome by combining it with interviewing. Thus questionnaires can be sent by mail and collected by interviewers, who can clear up difficulties, check answers and ensure completeness. Thus, triangulation occurs here by confirming data from research observation, questionnaire and interviews. In this thesis, the interviews ranged from informal conservations to semi structured, to formal structured interviews.

Informal conversation: these conversations took place the first two weeks of the study. They consisted, essentially, of two types of questions. The first type was general and open ended questions that would make the teachers start talking about their teaching. The second type involved rather specific questions. The main purpose of these conversations was, simply ,to get to know the teachers more, to obtain information about their level of education, and years of experience. It was also necessary to know how much time they spent in the schools ie the numbers of hours taught per day, the number of computer labs, the availability of software, and school’s hardware infrastructure. This information was needed to schedule convenient time for other interviews. Furthermore, it was instructive to ask about the level of computer literacy of each teacher. From these conversations, the researcher was able to compile a profile for each teacher.

Also, informal conversation included talking to headteachers who helped the teachers in specific ways when they were engaged in workshops. Note here that the researcher conducted
35 informal interviews with the 35 surveyed teachers and 7 informal interviews with headteachers of the surveyed schools.

Semi structured interviews: The researcher asked successive questions about the use of the educational technological tools in teaching math. It is worth mentioning here that questions posed on these interviews were formulated following general guidelines, they were also generated in the natural setting and were not identified prior to interviewing. In other words, teachers' responses have been directed to a certain extent by the questions posed on the semi structured interviews. Note here that the researcher conducted semi structured interviews.

III.D.2.d.Designing the self completion questionnaire:

Let us now discuss the design of the self completion questionnaire: “It is clear, unambiguous and uniformly workable. Its design must minimize potential errors from respondents... and coders. And since people's participation in Surveys is voluntary, a questionnaire has to help in engaging their interest, encouraging their cooperation and eliciting answers as close as possible to the truth” (Davidson 1970 as cited in Cohen and Manion 1994, p. 93).

With these qualities in mind, we turn to the problem of designing a self-completion questionnaire. The researcher's task now involves the structure of the questionnaire itself in a such a way that it is clear, unambiguous and nonleading.

The questionnaire is the following:

I implement the technological educational tools in my classroom:

1. to give students practice exercises to practice the concept or skill being taught
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
2. to meet the individual pacing and remedial needs of each student
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
3. to enhance retention and recall
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
4. to motivate students to learn basic skills through reinforcement
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
5. to provide students with alternative learning strategies in teaching basic skills
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
6. as an assessment tool to inform myself about their strengths
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
7. as an assessment tool to inform myself about their weaknesses
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
8. to promote cooperative learning and interactions among students and thus foster critical thinking
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
9. to help students develop higher order thinking by generalizing from particular cases
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
10. to enable students to explore and recognize relationships between ideas and thus think critically
    a. very often  b. often  c. sometimes  d. seldom  e. almost never
11. to provide students with assistance to accomplish a complex task which requires higher order thinking skills.
    a. very often  b. often  c. sometimes  d. seldom  e. almost never
12. to have students employ higher order thinking skills by applying math skills in other subject areas.
    a. very often  b. often  c. sometimes  d. seldom  e. almost never
13. to enable students to employ higher order thinking skills by applying what they learn outside the school culture.
    a. very often  b. often  c. sometimes  d. seldom  e. almost never

III.D.2.f. Pilot study

Once the researcher has agonized over the construction of the questionnaire, writing, shredding and rewriting the question that he thinks is nearly ready to use, a pilot study should be done.

Piloting refers to a relatively informal exercise of trying out the questionnaire to see how it works and to get the bugs out of the questions. It involves getting a few people who are members of the target population but not of the researcher’s sample in order to work through the questionnaire in the presence of the researcher and talk it over with the researcher (Munn & Drever, 1999). In this sense, five schools which are members of the target population but not of the researcher’s sample are involved in the pilot study. The most appropriate sample in this pilot study is convenience sampling since it involves choosing the nearest individual to
serve as respondents and continuing that process until the required sample size has been obtained (Cohen and Manion, 1994).
Chapter IV: Analysis and results

The 13 item questionnaire was sent to 35 primary math teachers (grades 1-7) representing different grade levels: lower (G1,G2,G3), middle (G4,G5) and upper (G6,G7). The survey consists from two sections relating to (1) uses of the technological educational tools for enhancing basic skills, (2) uses of the educational technological tools for higher order thinking skills. Teachers are asked to indicate on a 5 point scale their frequency of use of the technological educational tools for the stated purposes.

IV.A. Data description, interpretation and tabulation

The following tables summarize the percentage of the frequency of use of the educational technological tools:

<table>
<thead>
<tr>
<th>Question</th>
<th>Very often</th>
<th>Often</th>
<th>Sometimes</th>
<th>Seldom</th>
<th>Almost never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>43%</td>
<td>14%</td>
<td>43%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Q2</td>
<td>43%</td>
<td>14%</td>
<td>43%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Q3</td>
<td>43%</td>
<td>14%</td>
<td>43%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Q4</td>
<td>43%</td>
<td>11%</td>
<td>46%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Q5</td>
<td>43%</td>
<td>14%</td>
<td>29%</td>
<td>14%</td>
<td>0%</td>
</tr>
<tr>
<td>Q6</td>
<td>0%</td>
<td>43%</td>
<td>57%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Q7</td>
<td>0%</td>
<td>57%</td>
<td>43%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Q8</td>
<td>57%</td>
<td>14%</td>
<td>29%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Q9</td>
<td>43%</td>
<td>29%</td>
<td>28%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Q10</td>
<td>43%</td>
<td>29%</td>
<td>28%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Q11</td>
<td>43%</td>
<td>29%</td>
<td>28%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Q12</td>
<td>43%</td>
<td>29%</td>
<td>28%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Q13</td>
<td>43%</td>
<td>29%</td>
<td>28%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

The results shown in table 1 indicate that the primary math teachers frequently use the technological educational tools to foster critical thinking through cooperative learning and interactions among students, generalizing form particular cases, exploring and recognizing relationships between ideas, providing students with assistance to accomplish a complex task, applying math in other subject areas, and applying what students learn outside the school.
culture. However, less frequent is the use of the educational technological tools to give students practice exercises to practice the concept or skill being taught, to meet the individual pacing and remedial needs of each student, to enhance retention and recall, to motivate students to learn basic skills through reinforcement, to provide students with alternative learning strategies in teaching basic skills, and to inform teachers about students' strengths and weaknesses.

**Trends in uses of the educational technological tools across grades 1-7**

To ascertain the grades across the schools the data are split into three levels, namely, lower (Grades 1, 2, and 3), middle (grades 4 and 5) and upper (grades 6 and 7). Table 2 summarizes the percentages of the frequency of use of the educational technological tools across grades 1-7. Note here that there are 15 lower primary math teachers, 10 middle primary math teachers, and 10 upper primary math teachers. Moreover, I got 100% responses ie all the surveyed teachers completed and returned their questionnaires.
As shown in Table 2, teachers at middle and upper grades rate the use of the educational technological tools to enhance higher order thinking skills higher than do the lower grade teachers. In summary, these teachers report that their most frequent use of the educational technological tools are to enhance higher order thinking, with a higher emphasis on promoting
cooperative learning (100% upper math teachers and 100% middle math teachers very often use such tools), and less emphasis on helping students generalize from particular cases (100% upper math teachers very often use them; 50% middle math teachers very often use them; and 50% middle math teachers often use them), enabling students to explore and recognize relationships between ideas (same percentages), providing students with assistance to accomplish a complex task, applying math skills in other subject areas and applying what students learn outside the school culture (same percentages). However, teachers at lower grades rate “enhancing basic skills” higher than do the middle and upper grade teachers. These teachers report that their most frequent uses of the educational technological tools are to enhance basic skills, with an equal emphasis on giving students practice exercises to practice the concept or skill being taught (100% lower math teachers very often use such tools; 50% middle math teachers often use them; 50% middle math teachers sometimes use them; and 100% upper math teachers sometimes use them), meeting the individual pacing and remedial needs of each student (same percentages), enhancing retention and recall (same percentages); and less emphasis on motivating students through reinforcement and providing students with alternative learning strategies.

Further, the lower grade math teachers rate “informing themselves about students’ strengths and weaknesses” higher than do the middle and upper grades. To illustrate, 100% lower grade math teachers often use the educational technological tools for such purpose whereas 100% middle math teachers and 100% upper math teachers sometimes use such tools to inform themselves about students strengths; 50% middle math teachers often use such tools to inform themselves about students’ weaknesses; 50% middle math teachers sometimes use such tools to inform themselves about students’ weaknesses; and 100% upper math teachers sometimes use such tools to inform themselves about student’s weaknesses.

IV.B. Discussion

It appears that the main use of the educational technological tools is to enhance higher order thinking skills. Furthermore, this becomes more predominant moving up the grades. However, the use of the educational technological tools to enhance basic skills decreased from lower grades to the middle and upper grades, but does not reach the level of “enhancing basic skills”. This result confirms one of the broad goals identified by NCTM (1989) that students must reason mathematically. NCTM states that American culture often treats math as a series of skills to memorize as opposed to a way of thinking. It seems that teachers use the educational technological tools to enhance higher order thinking skills in general, including
promoting cooperative learning, helping students generalize from particular cases, enabling students to explore and recognize relationships between ideas, and providing students with assistance to accomplish a complex task, applying math skills in other subject areas, and applying what students learn outside the school culture. Informing teachers about students’ weaknesses and strengths become more predominant moving down the grades. The fact that the emphasis on enhancing basic skills and assessment to inform teachers about students’ strengths and weaknesses does seem congruous to what Eggen and Kauchak (1995) say, “basic skills are necessary for lower primary students...”(p.93), and to what Snowman (1997) suggests, that identifying students’ strengths and weaknesses are necessary for planning activities appropriate for both skill development and intellectual development.

The fact that some software can be considered the best technological tools to foster basic skills refers to software’s capabilities in using mnemonics. Mnemonics are memory devices that help the learner remember information by making the material more meaningful. Research indicates that the more meaningful the information, the better our memory for it. Mnemonics should therefore be used whenever possible for memorization tasks. Mnemonics are usually given to the learner at the time the information is presented. If a mnemonic is used, the learner must practice the mnemonic until learned, prior to practicing the use of the mnemonic to recall the associated information. Such software helps the learners remember information or learn basic skills by developing a visual imagery mnemonic. In this sense, the software keeps the picture or drawing very simple and makes the image vivid and easy to recall from the item’s stimulus.

Influencing factors in the development of higher order thinking

As I mentioned earlier, it seems that primary math teachers implement the educational technological tools to enhance higher order thinking skills in general with an emphasis on middle and upper grades. Further, data from the interviews, observation, questionnaire items confirm such implementation. This can be referred to two facts. First, the intensive use of the constructivist educational technological tools in the middle and upper grades, since students at those levels are able to acquire higher order thinking skills. Piaget refers to such stages as concrete operational stages through which children become less influenced by perceptual centration, irreversibility, and egocentrism and are able to develop a greater understanding of logic based task. Second, a consistently high level of involvement and a satisfactory growth in various social, cognitive and psychosocial skills that are developed and reinforced within the implementation of such tools. There are two major interrelated reasons for the development of higher order thinking skills: (a) the educational software’s instructional design, (b)
cooperation and collaboration. Note here that the technological educational tools discussed here are those which support constructivist strategies ie problem solving software (caborigeometer, logo), spreadsheet, multimedia, procedural simulation, situational simulation, constructivist instructional games.

IV.B.1 The educational software's instructional design

Our questionnaire showed that 43% of the primary math teachers very often use the educational technological tools to help students develop higher order thinking skills by generalizing from particular cases”, exploring and recognizing relationships between ideas, providing students with assistance to accomplish a complex task, applying math skills in other subject areas, and applying what students learn outside the school culture. 29% of the primary math teachers often use the educational technological for the above purposes, whereas 28 % of the primary math teachers sometimes use the educational technological tools for the stated purposes. Combining such results with data obtained from observation and interviews, let us see how the instructional design of such tools develop higher order thinking skills .The user interface design of such tools is simple and user friendly with meaningful navigational icons. It fulfills the criteria identified as applicable to a Microworld simulation. Recall that a simulation attempts to mimic an imaginary or real environment and content that cannot be experienced directly, for such reasons as cost, danger, accessibility, and time (Perkins et al,1995). Thus, a Microworld simulation presents the learner with the simplest case of the domain so that little training is necessary to begin using it usefully (Rieber, 1996). A Micro world simulation also, and importantly for cognitive growth, allows the learner to reshape the Microworld simulation to explore and manipulate increasingly more complex processes and concepts (Riebber ,1996 ; Thurman,1993) at different levels of expertise .

The data obtained from interviewing can add to our understanding of the responses to the questionnaire items: “to enable students to explore and recognize relationships between ideas and thus think critically”, “to have students employ higher order thinking skills by applying math in other subject areas”, and “ to employ higher order thinking skills by applying what they lean outside the school culture”. According to Rieber (1996) and Pellegrini (1995) Microworld simulations can provide learning environments consistent with serious play which they defined as an activity demanding those learning situations that require creative higher order thinking and a strong sense of personal commitment and engagement. One teacher in our study supported the notion of serious play for such tools by saying that “really a child's work is his play and his play is his work . So I don’t truly have a problem with that"
(teacher interview). To exemplify, he quoted that the children were saying that logo was fun and, in the next breath, commenting that "I am a real artist or architect (drawing geometrical graphics)". Such tools contain that "careful blending of attributes .... Where structure and motivation are optimized without subverting personal discovery, exploration, and ownership of knowledge" (Rieber, 96, p.44). Another surveyed interviewed teacher already reported (application of multimedia p.73) that multimedia enabled students to apply math in other subject areas. When he asked his students to use multimedia software to design graphics for different types of daily weather and then to record daily weather on an electronic calendar, the teacher applied the concept of numbers in language arts. Such connection enhances the development of higher order thinking skills. It constitutes an activity of the mind which takes the dimensions of a big human adventure. It is a fertile field for the development of critical thinking. It offers to students the necessary knowledge and efficient means to understand and explore the real world whatever the domain is: physical, chemical, biological, astronomical, social, psychological, etc. (Lebanese New Curricula, 1997).

It is the learner interface which has contributed to the higher order thinking skills. The "learner interface" as opposed to the "user interface", contains the pedagogic elements of interactive multimedia instructional design (Reeves, 1993). Such tools incorporate a pedagogy that adopts a cognitive apprenticeship approach utilizing authentic problems and interdisciplinary approach contexts. Cognitive apprenticeship attempts to enculturate learners into authentic practices in similar ways to craft apprenticeship, it supports learning in a domain by enabling students to acquire, develop, and use computer tools in authentic and interdisciplinary domain activities (Brown et al, 1989). Authentic problems and contexts do not have to be those that are part of the child's everyday experience but they do have to have a reality that is legitimate. For instance, art or architecture (drawing houses by Logo) is not part of the primary grades children's lives but artists or architects belong to the world in which the children live. As well, problems based on creating designs and making graphics (e.g. tiling) utilized by artists or architects are both integral to Logo and the children's personal and school life. These tools are "realistic or virtual surrogate of the actual work environment" (Mclellan, 1994, p.30). This means that the children in the surveyed classrooms were involved in legitimate authentic art activities when learning to gather, interpret, and communicate evidence to solve artistic mysteries that assist in their understanding of the art of architecture and thus foster critical thinking.

The importance of authentic activities could be referred to the compatibility of such activities with the general instructional goals of any subject areas which means that such
activities deal with information and skills that are used throughout life in a variety of contexts. Such information and skills are commonly associated with the world of work. Marzano (1996) refers to such instructional goals as life long learning standards. But why do students need such standards?

Employers are often dissatisfied with the graduates of our schools. Rapid change in workplace technology demands that all workers must be adaptable, continuing to learn and do new jobs in new ways throughout their lives. In 1989, a report by a government commission on work-force quality concluded that immediate changes in U.S. schools were needed if America was to compete in global markets (Marzano, 1996).

Government studies also report serious problems of schooling in America. A Nation at Risk, published in 1983 by the National Commission on Excellence in Education, reported that U.S. students were not studying the right subjects, were not working hard enough, and were not learning enough. Others define the crisis in education as one of stagnation rather than decline. The major problem is that schools have not kept pace with society's expectations and needs for the rapidly changing world of the twenty-first century (Marzano, 1996).

The idea of preparing people for a rapidly changing world is daunting challenge. Rapid change requires lifelong learning, and this means that people who enter the work force must be prepared to learn on their own. The skills required for effective work following high school graduation are now essentially equivalent to those that were required for college-bound students in the 1980s (Marzano, 1996). It is not sufficient merely to memorize a body of knowledge. Given today's information explosion, it is not even possible to do so! People need to be able to reason with and about that knowledge. They need to make decisions about what they know and what they need to learn.

This means that when students acquire new information in the process of solving meaningful problems, they are more likely to see its potential usefulness then when we ask them to memorize isolated facts. Meaningful problems also help students overcome the "inert knowledge" problem, defined as knowledge previously learned but not remembered in situations where it would be potentially useful. Seeing the relevance of information to everyday problems helps students understand when and how the information may be useful.

When students see the usefulness of information, they are motivated to learn. Research on the relationship between interest and learning indicates that personal interest in a topic or
domain positively affects academic learning in that domain (Eggen and Kauchak, 1995). New approaches to motivation emphasize authentic tasks that students perceive as real work of real audiences.

We have seen how learner interface is able to develop problems that are rich and complex enough to engage students in the kinds of sustained inquiry that will allow them to deeply understand important new concepts. Bringing complex problems into the classroom is an important function of technology. Unlike problems that occur in the real world, problems that are created with graphics, video, and animation can be explored again and again. These multimedia formats capture children’s interest and provide information in the form of sound and moving images that is not available in text based problems and stories. Multimedia formats are more easily understood and allow the learner to concentrate on high-level processes such as identifying problem-solving goals or making important inferences.

Although technology-based problem environments come in many forms, an important characteristic is that they are under the learner’s control. Students can review stories on an interactive videodisc many times and freeze specific frames or pictures in order to study them. Problems presented on the World Wide Web or in hypermedia allow students to search easily for the parts that interest them most. Simulations or exploratory environments allow students to carry out actions, immediately observe the results, and attempt to discover the rules that govern the system’s behavior. No matter what form of technology is involved, the student is primarily responsible for deciding how to investigate the problem, and the technology creates an environment in which flexible exploration is possible. To illustrate, we have already seen how the instructional game “Jasper woodbury” implemented by a surveyed teacher (p.53) presents authentic challenges that require students to understand and use important concepts in mathematics. Let us take this example from my observational data: in “Rescue at Boone’s Maedow”, Larry is teaching Emily to fly an ultralight airplane. During the lessons, he helps Emily learn about the basic principles of flight and the specific details of the ultralight she is flying, such as its speed, fuel consumption, fuel capacity, and how much weight it can carry. Not long after Emily’s first solo flight, her friend Jasper goes fishing in a remote area called Boone’s Meadow. Hearing a gunshot, he discovers a wounded bald eagle and radios Emily for help in getting the eagle to a veterinarian. Emily consults a map to determine the closest roads to Boone’s Meadow, then calls Larry to find out about the weather and to see if his ultralight is available. Students are challenged to use all the information in the video to determine the fastest way to rescue the eagle.
After viewing the video, students review the story and discuss the setting, characters, and any unfamiliar concepts and vocabulary introduced. After they have a clear understanding of the problem situation, small groups of students work together to break the problem into subgoals, scan the video for information, and set up the calculations necessary to solve each part of the problem. Once they have a solution, they compare it with those that other groups generate and try to choose the optimum plan. Like most real-world problems, Jasper problems have multiple correct solutions. Determining the optimum solution involves weighing factors such as safety and reliability as well as making the necessary calculations.

The Jasper series focuses on providing opportunities for problem solving and problem finding. It is not intended to replace the entire mathematics curriculum. Frequently, while attempting to solve these complex problems, students discover that they do not have the necessary basic skills. Teachers use these occasions as opportunities to conduct lessons in which they review the necessary concepts and procedures.

Now, let us consider other observational data in relation to the questionnaire item “to provide students with assistance to accomplish a complex task which requires higher” Our observational data during the implementation of the software “E lab” which is already discussed in simulation reveal that the children love the central character, Mr. solver, or guider, or helper of this software. They modeled his scientific methodology, along with the chant, “Mr. Solver’s or guider’s or helper’s plan”. He was the “helper” the guide who intervenes and provides scaffolding tips, reminders, and suggestions that provide opportunities for self directed decision making such as the coach in cognitive apprenticeship (McLellan, 1994) or the “more capable other” in socio constructivist pedagogy (Gallimore and Tharp, 1990; Henderson, 1996). Mr Helper or solver gives feedback and constantly use professional scientific language. Deconstruction of one statement highlights these apprenticeship characteristics. To illustrate, let us consider the following feedback: “The formula you typed contains an error, for information about fixing common formula problems, click Help” (from an observation concerning the effects of spreadsheet). “You did not apply the data correctly to the rate of speed” (from an observation concerning the effect of procedural simulation). Through the production of this character, the instructional designers guarantee that students gain scaffolded support, appropriate language usage, and recognition of their learning achievement, that is, ingredients found in a cognitive apprenticeship.

Other aspects of scaffolding could be achieved by teachers incorporating the educational technological constructivist tools into their classrooms. From my observational data, it can be
said that Vygotsky’s ZPD was obvious in one situation where a few children became interested in following the kit directions for building a Lego structure. Even though the directions were pictorial and contained no words, the first time around children needed an adult’s assistance to learn how to follow the step by step construction directions. It was something that none of the children in the class could do independently. However, it was within their ZPD, because they could accomplish the task with assistance. After success in following one set of directions, two or three children in the class could attempt the task independently. Therefore, the teacher withdrew scaffolding by offering assistance to them on this task only when it was sought. In addition, the children who could now accomplish the task independently became more competent peers who could assist their classmates in developing this new skill.

What can be said is that although students benefit greatly from the opportunity and responsibility of exploring complex problems on their own, the mere presence of these opportunities does not lead to learning with understanding. Because of the complexity of the problems and the inexperience of the students, scaffolds must be provided to help students carry out the parts of the tasks that they cannot yet manage on their own.

Cognitive scaffolding assumes that individuals learn through interactions with others who are more knowledgeable, just as children learn through adult–child interactions. Adults model good thinking, provide hints, and prompt children who cannot “get it” on their own. Children eventually adopt the patterns of thinking reflected by the adults. Cognitive scaffolding can be realized in a number of ways, including modeling and coaching by experts, and providing guides and reminders about the procedures and steps that are important for the task.

Teachers can also use technologies to scaffold the solution of complex problems and projects by providing resources such as visualization tools, reference materials, and hints. Multimedia databases on CD-ROMs, videodiscs, or the World Wide Web provide important resources for students who are doing research. Technology-based reference materials provide several advantages over those in book format. Most importantly, they allow the presentation of information in audio or video format. In many cases, students can see an actual event and create their own analysis rather than reading someone else’s description. Electronic references are easy to search and they provide information quickly, while students are in the midst of problem solving. For example, definitions of words and their pronunciations are readily available while a student is reading or writing a story. A student who is stuck while setting up
a math problem can effortlessly access hints and examples. Students will highly value and easily remember the knowledge acquired in these "just in time learning" situations because they understand why it is useful to them.

Technology can help learners visualize processes and relationships that are normally invisible or difficult to understand. For example, students might use spreadsheets to create a graph that demonstrates a trend or shows whether one result is out of line with the rest. These graphs are useful in initial interpretations of numerical data and also valuable for reporting it to others. Charts, maps, and other graphic representations can be created by students or automatically generated by simulation programs to depict the changes brought about by student actions.

The learner interface also provides the necessary intrinsic motivational ingredients for an effective simulation: challenge, curiosity, fantasy, and control (Rieber, 1996). One of the students in the study commented that the same graphics were "challenging because we didn't know much about creating design or making graphics" and, thus their curiosity was motivated as they had to find out the correct instructions to create an accurate picture. Other students argued that, because of the increased expectations, it was appropriate to commence at the beginner level and progress through advanced to expert level. They could articulate the increased cognitive demands of the expert level and their enjoyment with meeting the challenge. What can be said here is that the children in this study were actually in control; they had so much ownership of their work.

**IV.B.1.a. The role of logo and Cabrigeometer in facilitating children’s abstract reasoning about geometric problems**

Other observational data, combined with the response of the questionnaire item "to help students develop higher order thinking by generalizing from particular cases", reveal that the educational instructional design of such tools reflect Piaget’s principles of generalization which enhance the development of higher order thinking skills. We can consider, for example, how the educational instructional design of Cabrigeometer and Logo reflects Piaget’s principles of generalization.

Traditional theories of cognitive development suggest that learning may not occur unless instruction is appropriate to children’s level of cognitive development (Piaget, 1936; van Hiele, 1986). Thus, in geometry learning, which requires abstract thinking abilities, children
theoretically should not be able to understand certain geometric principles until their cognitive development is at the formal, abstract level. According to van Hiele's geometric thinking hierarchy, children's learning and thinking about geometry changes as they advance through three levels (Hiele, 1986, 1997; Fuy et al, 1988):

1. Visual level
2. Descriptive/analytic level
3. Abstract/relational level

At Level 1, the visual level, children identify and think about geometric shapes based on the visual appearance of shapes and according to their similarities to real-world objects (van Hiele, 1999). For example, children will recognize a shape as a circle because it looks like a round plate. At level 2, the descriptive/analytic level, children think about geometric shapes according to their concrete characteristics (Liu & Cummings, 1997; van Hiele, 1999). At this stage, for instance, a shape is a rectangle, not because it looks like a door, but because it has two long sides, two short sides, and four right angles. At Level 3, the abstract/relational level, children are able to integrate the visual information gained in Level 1 and their understanding of the characteristics of shapes gained in Level 2 to construct an abstract concept of geometric principles (Liu & Cummings, 1997; Hiele, 1999). Thus, children at this level of thinking understand and can explain why the sum of the angles of any triangle must be 180 degrees.

Although the van Hiele model describes the progression of children's thinking from one level to the next, the model does not describe the processes that are involved in advancing thinking through the three levels (Liu, 1999). It is important, therefore, to understand how a child's thinking progresses from one level to the next and to identify the thinking processes that must be in place before the transition can occur.

The processes involved in advancing geometric thinking require both concrete thinking and abstract thinking. In much of the cognitive development literature, concrete thinking and abstract thinking are described as two separate stages of thinking (Swan, 1993), similar to van Hiele's three discrete levels. For example, in his classical theory of cognitive development, Piaget (1971) makes a distinction between concrete thinking and formal thinking. Concrete-thinking children can think logically and solve mathematical problems. However, concrete thought can only solve problems that exist in the present and that can be represented through manipulation of physical objects (Hiele, 1999). For example, the concrete-thinking child cannot solve an abstract verbal problem, such as "Nabil is taller than Fadi, and Fadi is taller than Samir. Who is the tallest of the three?" However, when concrete materials are used, such
as blocks of different sizes and colors, the child can easily solve a similar problem such as; 
"the red pen is bigger than the green pen, and the green pen is bigger than the blue pen. 
Which is the biggest pen?" In comparison, formal abstract thinking stems from mental rather 
than physical manipulations, and problem solving skills do not depend on concrete 
experiences.

Liu and Cummings (1997) have described two thinking processes that are essential for 
geometry learning and that advance movement through van Hiele's hierarchy:

1. Concrete-abstract process (CA)
2. Abstract-concrete process (AC)

The CA process accounts for advancement through the three levels of the van Hiele 
hierarchy. The CA process begins with children's initial sensation of concrete objects and 
experiences in the physical world (Liu & Cummings, 1997). Once these physical stimuli have 
been detected by the sensory system, their particular qualities and characteristics are identified 
and interpreted through perception. This process ends as the individual formulates concepts, 
ideas, or laws about what was sensed and perceived, extracting an abstract concept of the 
concrete experience. The CA process also can be conceived of as a process of inductive 
thinking-reasoning from particular facts (geometric shapes, measurements, etc.) to a general 
conclusion about concepts, ideas, or laws (geometric concepts or rules). In geometric 
learning, the CA process leads thinking through the van Hiele hierarchy and stimulates 
transitions between each of the three levels. Once children go through the concrete-abstract 
thinking process, their thinking about geometry progresses to the third level of van Hiele's 
hierarchy, the abstract/relational level. According to Liu and Cummings (1997):

Once children have developed these concepts, they have developed a geometry schema 
that contains all of the rules and relationships that have been learned during the process. 
Moreover, once children develop these concepts, they can think about geometry in more com­ 
plex ways than if they simply had memorized rules about the characteristic qualities of 
geometric shapes and figures (p. 101).

In contrast to van Hiele's scheme, the abstract/relational level is not the highest level at 
which children can think about geometry. Once they reach this level, children are ready to 
move to an even higher level of thinking, that of abstract-concrete (AC) thinking, which 
allows them to apply their newly learned concepts (Liu & Cummings, 1997). The process of
abstract-concrete (AC) thinking is not simply the reverse of concrete-abstract thinking. Instead, it is a higher form of thinking that depends on more advanced abstract and logical reasoning abilities but is grounded in the concepts and rules derived from concrete-abstract learning (Liu & Cummings, 1997). In other words, it is not enough just to think abstractly about geometric principles; the individual must be able to apply this thinking to solve actual problems.

The AC process also can be conceived of as a process of deductive thinking reasoning from general to specific. In geometry learning, the application of deductive reasoning in the problem-solving process may occur through a sequence of steps. One model that describes this process is the six-step problem solving model proposed by Hayes (1989). The six steps include:

1. Identifying the problem
2. Representing the problem
3. Planning the problem
4. Executing the plan
5. Evaluating the plan
6. Evaluating the solution

The Hayes sequence depicts the way information is handled during the problem-solving process and requires children to divide a single geometric problem into a number of smaller, more basic problems. Children use steps one through four to solve each smaller problem. Then, after evaluating the answers to each smaller problem, they configure their solutions into a final solution to the larger problem in steps 5 and 6.

In summary, concrete-abstract (CA) processes are involved as children's geometric thinking advances from the visual level to the abstract/relational level in van Hiele's hierarchy. Once they reach the abstract thinking level, children apply abstract-concrete (AC) thinking processes to solve concrete geometric problems. Application of CA and AC processes results in inductive and deductive reasoning skills, respectively.

As previously noted, the surveyed primary mathematics teachers integrate the educational technological constructivist tools into teaching to enhance students' higher order thinking skills. Two technology tools that are useful for accomplishing this purpose are PC logo, and Cabrigeometre.
As mentioned earlier, Logo provides users with the capability to create attractive graphic images, perform calculations, maintain and update data, and even create sounds and play music. In a Logo environment, even children can perform these tasks and have fun at the same time. A number of studies have investigated the effectiveness of Logo as a concrete context for facilitating children's abstract reasoning about geometric problems (Geddes, 1992; Weaver, 1991). These studies suggest that Logo can be effective in motivating children to learn through exploration and discovery. Through these processes, children come to understand that there may be several solutions to any problem. As children experiment and look for different solutions to a task, they use different thinking skills and construct knowledge in different ways. By observing children as they experiment with Logo commands, and develop procedures for solving geometric problems, it is possible to gain insight into their thinking and learning processes.

Cabrigeometre is a useful tool for advancing children’s thinking through van Hiele's hierarchy because it allows them to investigate geometric concepts and discover relationships among these concepts (Key Curriculum, 1999; Pokay & Tayeh, 1997). Cabrigeometre provides users with the capability to draw, measure, calculate, and script geometric shapes and figures. Thus, it is a powerful tool for visually presenting geometric concepts to children and for allowing them to construct points, lines, and circles using constraints. To illustrate from my observational data, a student can constrain a point to be the midpoint of a line segment, set one line to be parallel to another, fix a circle’s radius equal to a given length, and construct a graph of geometric relationships. Moreover, if any part of a geometric shape is transformed, all related parts change accordingly, allowing immediate observation of geometric relationships. These visual effects provide the concrete information that, when children sense it repeatedly, can be generalized into abstract geometric principles.

IV.B.1.b. Reflection of Erikson’s stages of psychosocial development

Now, let us consider the questionnaire items stated above and the observational data in order to see whether the educational instructional design of the constructivist educational technological tools reflect Erikson’s stages of psychosocial development, which deal with the development of higher order thinking skills, and Gardner’s theory of multiple intelligences.

Erikson described the opportunity or challenge of a four to five-year old as a tension between initiative and guilt and that of a six to eleven year old as a tension between industry and inferiority. Erikson sought a healthy balance between the two competing outcomes. He suggests that in some appropriate situations children may develop with a healthy sense of
guilt and with a realistic sense of inferiority. However, his favored outcomes in the preschool age emphasized initiative, so that a child developed a sense of direction and purpose in his/her activities. In the elementary age range, Erikson favored outcomes emphasizing industry so that a child could develop a sense of mastery and competence (Snowman, 1997).

When the surveyed teachers involve their students in the use of such tools (Logo, Cabrigeometer,....), their progress through Erikson’s stages of development is greatly helped. Children in the initiative versus guilt stage (four to five years old) are given ample opportunity to explore and manipulate objects. They are encouraged, and not made to feel guilty about their curiosity. Building, constructing, and Logo programming fit well into this stage. These uses of computer technology not only lend themselves, but actually require children to take initiative and to explore the materials. The materials themselves are merely starting points for whatever children choose to create with them.

Children in the industry versus inferiority stage (six to eleven years old) are becoming aware of how things work and how they are made, they need opportunities to become masterful and competent (Snowman, 1997). Again, building, constructing, and logo programming fit well into this stage. Because children use the materials in such self directed ways, children can experience mastery and competence at many different levels, as they become more adept at building and programming. The following episodes from my observational data (Qualaa schools) illustrate the point: I observed children’s performances in grades 3 and 6. Their teachers required them to accomplish the following tasks:

Task One: Given the Logo code “repeat 4 [forward 100 right 90], the surveyed teacher asked the students to:

1. Use PCLogo to produce the shape (explain that this shape is a “square”)
2. Use the logo code to replace side length 100 with three different numbers, and produce the three shapes.
3. Summarize the definition of “square.”

Task Two (logo with AC process): Given a “rectangle” shape with 100 as the short side and 150 as the long side, the surveyed teacher asked the students to:

1. Compare this shape with a square in terms of its sides and angles
2. Write the Logo code to produce the rectangle, and then produce two other rectangle shapes with different lengths and widths
3. Summarize the definition of “rectangle”
Task One requires concrete-abstract thinking, and Task Two requires abstract-concrete thinking. The following criteria were used to evaluate the participants' performance on each of these tasks:

1. The definitions or conclusions should be correctly described.
2. The logo code should be correct and specific to the tasks.
3. The measurements and calculations should be accurate.
4. The procedures should be in a logical sequence.

In grade 3, the teacher required his students to accomplish task 1. In grade 6, the teacher asked her students to accomplish task 2. In each grade, there were 15 students and 5 computers. Three students were working at each computer. Hence, in each grade, there were three groups. The teachers grouped their students in mixed ability groups, and they chose names and color coded them (blue group, yellow group,..). On the other hand, the teachers set up rules about what students can do and can not do to the computers and posted them on the computer. For example: “Be kind to the equipment”, “Eating and drinking should be done away from the computer”, “Respect the work of others”. Then, the students started working out the assigned tasks.

In grade 3, the participants were curious about and interested in learning logo. The teacher had already demonstrated the software to them and showed them how to work through each step in the program. The students followed the steps correctly and learned the necessary skills for solving the task.

In task one, the students successfully produced the square shape with the given code. Next, the surveyed teacher instructed the students to change side length 100 to side lengths 150, 200, and 300, respectively. For each change in side length, the students wrote the code correctly and produced the three squares. However the students had difficulty performing step 3, summarizing the definition of “square”. To help them with this, the teachers constructed a worksheet in which they could write down the numbers referring to the sides and angles of each of the four shapes. When they looked at the side lengths and angle degrees for each shape, they were able to summarize correctly that all four shapes had “four equal-length sides and four 90 degree angles.” Thus, the students took initiatives and demonstrated exploration.

In grade 6, The students first compared the shape of the given rectangle with four squares produced in a previous task, and then correctly wrote the Logo code as “forward 100
right 90, forward 150 right 90, forward 100 right 90, forward 150 right 90" without using the "repeat" command. Their successful completion of this task indicated that they could apply their new understanding of the concept of square to the construction of a rectangle. They produced another two rectangles and then used worksheets without assistance to correctly summarize the characteristics of rectangle. The students here exclaimed "look what I made" or gleefully and proudly shouted "It works". Hence, the students here experienced mastery and competence.

On the other hand, one way of viewing individual skills and abilities is to refer to Howard Gardner's theory of multiple intelligences (1983,1991) (as cited in Snowman,1997). This theory holds that there are multiple ways of knowing, including linguistic, musical, logical, mathematical, spatial, bodily-kinesthetic, inter and intra personal, and naturalistic. Gardner asserts that although we should play to children's strengths, children will learn best if they are exposed to the school curriculum through a variety of intelligences (Snowman,1997). The logo computer programs that are used in the surveyed classrooms use a number of these multiple intelligences. Logo is a computer language. When children learn logo, they develop their linguistic skills in the same way that they might if they were introduced to another foreign language. Calculating how to move objects where you want them to go (the command: "forward any number, then right 90 four times" makes a square) use the logic of mathematical intelligence. Microworlds contains a musical feature in which children can create tunes and play them back. Building with legos and animating graphics in Microworlds are spatial activities. Children use their bodies to type, use a touch pad or mouse, click, build and deconstruct. Interpersonal skills are used when children ask for, receive, and give help among peers. They are often observed creating an object, then showing it to a peer. For instance, in one classrooms, two boys constructed very similar programmable cars in about 40 minutes of their Logo hour. They then played cooperatively with the cars for the remainder of the hour (data collected from observation). Interpersonal intelligence is used when children decide how they are going to spend their logo time. They know how they are feeling that day, whether they want to work on the computers or with the legos, and if they want to work alone or with others. Teachers assist this process by employing a plan-do-review approach where children are queried about their plans for the day and then either write (or draw) in the journals as review, or share what they did in a large group meeting at the end of logo time. Perhaps the only multiple intelligence not addressed by programming with logo is the newest intelligence acknowledged by Gardner, that of naturalistic intelligence. Technology is almost by definition not of nature, and therefore opportunities to utilize the naturalistic intelligence must be found else where during a child's day.
Gardner's theory could be applied to other constructivist educational technological tools to foster higher order thinking skills. When the surveyed teachers involve students in activities to develop a multimedia product, they apply Gardner's theory of multiple intelligences. To illustrate from my observational data about multimedia, the surveyed teacher asked his students to use multimedia software to design graphics for different types of daily weather. They used the graphics to record daily weather on an electronic calendar. Then, he had them print a copy and cut the calendar apart, by days. Finally he had them sort and organize the weather data to identify patterns. The teacher assigned the students with high logical mathematical abilities to be responsible for links and structure, those with spatial ability to be responsible for aesthetic and graphics.

What can be concluded here is that by mixing the three methods of collection (observation, interviews, questionnaires) we have reached validity since in this sense any bias inherent in particular data sources, investigator and method could be neutralized when used in conjunction with other data source, investigators and methods.

**IV.B.2. Cooperation and collaboration**

As mentioned earlier, 50% of the surveyed teachers often use the educational technological tools “to promote cooperative learning and interactions among students and thus foster critical thinking”. Let us look at our observational data to add to this result.

At a theoretical level the educational world has long accepted the inadequacy of a model of teaching, which is essentially one of transmitting a body of knowledge from teacher to pupil. In practice, however, the HMI publication “Education observed”(DES, 1984) reports that “teachers need to have higher expectations of their pupils, to take greater account of pupils’ individual differences and generally to make lessons less teacher dominated”. (as cited in MIT Epistemology and Learning Group,2000,p.2). This report also goes on to comment that most school classrooms do not encourage pupils to develop arguments; to formulate, as well as to answer questions, and to articulate their ideas through more open discussion. Eggen and Kauchak (1995) add “Research on this process indicates that students who explain and elaborate learn more than students who just listen to explanations” (p.282). In the world of mathematics, mathematics educators since the publication of the Cockcroft report are also aware of the potential role of discussion in the mathematics classroom. As the Cockcroft report stated “language plays an essential part in the formation and expression of mathematical
ideas. School children should be encouraged to discuss and explain the mathematics which they are doing” (Cockcroft, 1982 as cited in MIT, 2000, P.10). Contexts are therefore being sought which provoke pupils to talk about mathematics and articulate their perspectives on mathematical activities. Changing the emphasis in the mathematics classroom from a teacher centered to a more pupil-centered approach to learning is not however an easy task as it involves change in the teacher’s role. Individualized learning schemes have started to shift the balance of control in classrooms but it is still the case that most pupils do not expect to discuss, collaborate and take responsibility for their own learning. The use of the computers, in an interactive way, could provide the catalyst for further progress. The motivation of the graphical feedback and the public character of the screen would seem likely to stimulate investigative, pupil centered work which could quite naturally be shared (Hoyles & Noss, 1989).

Mathematics educators have also turned their attention to the process by which discussion and peer collaboration can serve as aids to pupil learning. It is reasonable to conjecture that “talking”, in both its cognitive and communicative functions, and listening generate increased understanding, facilitate integration of previously fragmented context specific knowledge, and provide a bridge between the mathematics embedded in activities and its formalization in standard mathematical notation. Research on peer collaboration effects has, however, been sparse. Such evidence that does exist which supports the notions of group work and discussion, tends to be within a Vygotskian framework. The work of Vygotsky offers insights into the intellectual value of inter peer support, particularly with regard to scaffolding the learning task (Wood, Bruner and Ross, 1976, as cited in Hoyles and Noss, 1989) in order that a partner might achieve a level of potential development rather than a level of actual development (Vygotsky 1978 as cited in Hoyles and Noss, 1989). The following episodes from my own observation illustrate the three way interactions between two pupils and the educational technological constructivist tools feed back and the positive side to collaborative working which fosters higher order thinking skills.

**Case 1**

In a surveyed classroom, I observed two students. The first was an outgoing, friendly talkative boy with a tendency to be impulsive and easily distracted. The second, on the other hand, was quiet, reserved and thoughtful. He had an important role in bringing the first back to the work when his attention wandered and encouraging him to reflect and be more systematic. For this part, he enjoyed working with the first and benefited from his stream of exciting ideas. By the end of the class both students were able to demonstrate a remarkable
ability to question each other and try to explain their ideas when their partner was confused. This is illustrated by the following excerpt in which the pair were defining procedures for regular polygons. The first student then confidently defined a procedure to draw a hexagon in the editor:

\[
\text{REPEAT 6 (FD 40 RT 120)}
\]
\[
\text{END}
\]

(Note here that REPEAT is an instruction in logo. It makes the turtle execute the same list of instructions a certain number of times. This process is called a loop. RT turns turtle in degrees clockwise. FD moves turtle forward n steps.)

The second student was not convinced that this would work: "I would laugh if it didn’t work” the first student then remarked: “So would I… Well I wouldn’t actually laugh”.

The second student was certain that he had known that it would not work: “I knew it”. The first student was baffled and asked the second to help out: “well where did we go wrong?” the second student tried to explain but was really only at the stage of trying to sort out his own ideas: “you went wrong with the… what was it?”

The second student needed to look back at the procedure definition. He did this and tried again to explain in a rather halting fashion, making reference to the total turtle theorem: “It can’t be 120 you know…. That’s 720 six 120’s are 720….not 360”. The first student still did not understand the second student’s reasoning but this discussion made him realize that he needed to return to direct interaction with the turtle rather than working in the editor, that is change the form of representation of the activity. The first student said “we’ve got to do it slowly”. He started to draw a hexagon in direct drive thinking aloud as he did it: “120……120……..it is 120, I’m sure because I remember hexagons are 120 degrees……..

He did not recognize at this stage how the turtle drew an equilateral triangle and was simply recalling some facts he knew about equilateral triangles. The second student, however wanted to try out his ideas: “can I just try 60?” the first student was willing to let him try, although he was not convinced: “yeah…….I don’t know if it will work..” The second student typed in

\[
\text{REPEAT 6 [FD40 RT 60]} \text{ (RT turns the turtle n degrees clockwise)}
\]

and as the correct image emerged, the second student said “It does…” the first student was impressed but still wanted to know why “….how did that?” The second student could now
confidently and clearly explain: It is 60.....look it is 360....it is 360 around a point and you've got to....so it is 60....." The interaction assisted both boys ; the second student became more articulate in his ideas and the first student began to identify the bug in his original argument "that he has to consider the exterior angle of the hexagon."

**Case2:**

Let us consider the second case in which two students were involved (observation taken from another classroom). The first student was an exceptionally shy pupil who lacked confidence in her own ability, but was bright. The second student was a bubbly, outgoing girl, about average in class for mathematics and loved using the computer. The two students were friends in and out of school. They both valued their collaborative Logo work. I found that the first student benefited from the collaboration because the second student provoked her into elaborating her ideas, thus helping her to think them through more clearly. The second student also provided a continuous source of suggestions, ideas and comments and thus kept the computer activity going particularly as she became very proficient in Logo syntax. I think that the second student benefited from the collaboration because the first student was able to make decisions at a conceptual level about mathematical issues and explain her decisions to the second student: this helped the second student's understanding of the issues involved as well as complementing her conceptual approach with a more analytic perspective.

These findings are illustrated in the following extract: the two students wanted to make the turtle draw two circles using the ARCR command. The second student wanted to enter:

```
ARCR 40 360
ARCR 40 360 (ARCR draws an arc to the right with radius 40 and size 360 degrees)
```

However, the first student wanted to combine these commands into:

```
ACRC 40 720
```

The second student did not understand what the first student was doing. So she questioned her: "what are you doing ?" the first student started to explain : "that will take it round to there." The second student did not want to take the risk of trying something which she was not sure about. "No, just do 360....that will take it to there". The first student was insistent. "Yes, I know, but....". Again, the second student disagreed: that's where we need it....". This provoked the first student to elaborate her argument: "Yeah, I know, but instead of doing two "commandments" ,you can just do one "commandment". The second student asked her to elaborate more: How ? The first student replied without any general explanation just
giving the command required. This formalization was important to clarify her thinking for herself and for the second student. The first student said, “ARCR 700”. The second student corrected the first student’s arithmetic indicating that she was at least following the argument: “What 700 or 720?” the first student then tried to explain again: “oh,720....that will take it round to there without having to do that....because if you add that to that you get that....”. The second student, because she did not understand, was prepared to question again : “No, but...”. The first student now replied with a carefully reasoned explanation provoked by the second student’s persistence: “Say if you told me to walk five steps and I walked five steps …then you told me to walk another five steps ....so I walked another five steps....you might as well tell me to walk another ten steps...that’s what I am on about...”. The issue was resolved by the first student typing in ARCR 40 720.

As stated earlier, it seems that lower primary math teachers implement the educational technological tools to enhance basic skills. This could be referred to the intensive use of the direct educational technological tools in the lower grades since students at those levels require basic skills. Piaget refers to such stages as preoperational stages when children forms many new schemes but do not think logically. Perceptual centration, irreversibility and egocentrism are considered barriers to logical thought.

Our questionnaire showed that 100% of the lower primary math teachers very often use the educational technological tools to give students practice exercises to practice the concept or skill being taught, to meet the individual pacing and remedial needs of each student, to enhance retention and recall, to motivate students to learn basic skills through reinforcement, and to provide students with alternative learning strategies in teaching basic skills. On the other hand, 100% of the lower primary math teachers often use the educational technological tools to inform themselves about students’ strengths and weaknesses. Let us consider the data obtained from my observation and interviews in order to add to our understanding of the responses to the above questionnaire items.

From my interviews, it can be concluded that drill and practice, tutorials, process simulation and physical simulation can be used as alternative learning strategies for teaching basic skills. Moreover, other observational data in grade 1 reveal that the concept of addition, subtraction, multiplication and division were taught in meaningful ways. Students used pictures to describe addition, subtraction, multiplication, and division situation (Mighty Math software). For example, in order to divide 9 by 3, the students had to snap the correct numbers of clowns on 3 boxes (in an interactive way). Students were easily able to understand the
concept of addition, subtraction, multiplication, and division because of the interactive capabilities of the software which provided the students with meaningful learning. Hence, learning with technology supports models of instruction that emphasize learning with understanding and more active involvement on the part of the students. When I interviewed the teacher of this class, he said that such learning strategy was more than memorizing information. It involved understanding the significance of information so that it could be used as a tool to solve problems in the future and enable students to become independent learners. Without the use of technology, the interviewed teacher added “my students can memorize facts, but they can’t tell you why these facts are significant. They haven’t had to make in facts and try to assimilate or synthesize and spit it back out into some form that has meaning. They are not used to having to attach meaning to what they are doing”.

What can be inferred here is that such learning strategy is based on information processing theories by encoding information in meaningful ways.

According to the above result, the major use of technology in lower grades involved opportunities for extended practice of basic skills. But why do the lower math teachers use the two kinds of software (drill and practice, tutorial) for enabling the students to practice the skill?

It is important to distinguish between two types of stages of basic skill development, acquisition and fluency. Acquisition refers to the initial learning of a skill, and fluency refers to being able to access this skill in a quick and effortless manner (such as math facts). If students do not develop basic skills to fluent levels, then the learning process is incomplete and they will not be able to function well in the real world.

Although there is no question that the nature of a drill and practice application makes it ideal for providing endless practice in almost any curricular area, when a student is in the acquisition phase of learning the use of drill and practice is inappropriate. As the name implies, computer based drill and practice is designed to reinforce previously learned information rather than provide direct instruction in new skills. If technology is to be used during the acquisition phase of a new skill or concept, the tutorial is more appropriate than drill and practice. A technology based tutorial differs from a drill and practice application in that a tutorial attempts to play the role of a teacher and to provide direct instruction on a new skill or concept. The tutorial presents the students with new or previously unlearned material in an individualized manner, providing frequent corrective feedback and reinforcement.
Coming to the result of the following questionnaire item: 100% of the primary math teachers often use the educational technological tools as an assessment tool to inform themselves about students' weaknesses and strengths, it appears that the lower primary math teachers implemented such an approach in order to explore whether students have fallen behind because they have not acquired the specific knowledge and skills necessary to profit from upcoming instruction. Among the approaches relying on identification of learning prerequisites is Gagne's learning hierarchies.

The first step in creating a hierarchy is to analyse one learning target the student must be able to perform. The next steps involve identifying which performances a student must learn as prerequisites to it. For each prerequisite performance identified, the teachers repeat the same analysis, generating a hierarchy of prerequisite performances. This backward analytic procedure identifies critical prior learning, the lack of which could cause students problems in subsequent learning. From my observational data, we have seen a number of instructional software that have incorporated such learning hierarchies and used assessment to diagnose students' knowledge. Examples include Algebra CD (tutorial).
V- Conclusion

The integration strategies are the educational approaches that integrate technology, connectivity, content and people. When implemented correctly, the integration strategies build on the unique, dynamic characteristics of digital content to foster productive and engaging learning. This in turn both supports and promotes the essential skills students will need in education, life and work in tomorrow's world.

When integrated effectively into the curriculum by skilled teachers, technology enables students to seek and manipulate digital information in collaborative, creative and engaging ways that make digital learning possible. In a digital learning environment, just as in a traditional learning environment, content is anything used to teach or learn. It includes text-books, films and worksheets but can also be a blueberry pie cut into pieces to illustrate fractions or baking soda and vinegar to explain the properties of a gas. Digital content is not just computer-based. It includes video on demand, software, CD-ROMs, web sites, e-mail, on-line learning management systems, computer simulations, and streamed discussions. When applied appropriately by teachers and students in a productive, project-centered learning environment, digital content makes a vast reservoir of information, ideas, resources and experts accessible at any time. The strength of the digital content in education stems from its dynamic characteristics that allow students to both locate and construct information. Digital content can be:

Randomly accessed.

The limitations of time, location, delivery and presentation no longer preclude students from accessing high-quality information. Information is transmitted, received, shared, organized and stored using a variety of delivery platforms and accessible through a range of devices.

Relevant, up-to-date and authentic.

Educators and students can augment curriculum with current, real-world information. This reality-based investigation encourages students to discover and understand real world implications.

Explored on many levels.
The dynamic nature of digital content allows teachers and students to explore subjects according to their needs, abilities and interests.

**Interactive and engaging.**

While traditional forms of content furnish information, digital content can stimulate and involve students.

**Manipulatable.**

Digital content can be evaluated, revised and produced, which allows students and teachers to apply information in increasingly complex ways.

**Instantaneous.**

With optimal bandwidth, information becomes immediately accessible according to student and teacher needs.

**Creative.**

Digital content enables learners to be active participants in the learning process. Rather than passively accepting information, students can direct and choose their educational outcomes in new and sophisticated ways. The productive characteristics of digital content both inspire and allow greater creativity.

The creative use of digital content allows teachers and students to transform the learning environment into a more dynamic, demanding, vibrant and interactive exchange. These environments combine the best of traditional learning with the unprecedented opportunities created by technology. Once digital content is integrated into the curriculum, the learning process becomes:

**Problem and Project Centered.**

Less concerned with one right answer, problem and project centered digital learning prepares students to answer questions and support arguments. When connected to real world information, students and teachers become more active in local and global community efforts.

**Student-centered.**
Students actively participate in defining their individual learning objectives and the plan to achieve them. Teachers take on the more sophisticated role of facilitators, while remaining the cornerstone of a student’s learning team that also includes the student, parent, peers and outside experts. By providing the framework, goals, guidance and advice, teachers help manage and encourage students as they pursue their own learning.

Collaborative.

Students engage in multi-age, interdisciplinary projects in teams within the school or at a distance. Learning becomes an interactive experience as teachers and students access content, exchange ideas and consult with experts at anytime from anywhere. As students pursue self-directed projects, teachers and students often exchange roles so that students teach their teacher.

Communicative.

Students, teachers and community members communicate and give feedback through e-mail, videoconferences, threaded discussions, bulletin boards, and chat rooms. Peer review exercises and local and global community efforts provide guidance, interaction and an increased sense of relevance and accountability. In addition, this interaction fosters a greater appreciation of various cultural perspectives.

Customized.

Digital learning conveys a new capacity for tailoring information to meet individual student needs, learning styles, and abilities. Tools such as tutorial and “drill and practice” software can facilitate data-driven decision-making that supports individual student needs.

Productive.

Innovative projects and digital tools encourage students and teachers to become content producers (creating multimedia projects). Consequently, the quality of projects is elevated as students and teachers connect and receive feedback from the wider local and global community.

Not only does digital learning make education more engaging and relevant, but it also develops the skills necessary for students to succeed in life and eventually work. Integration strategies do not change the fundamental purposes of education. However, in the rapidly
evolving global digital economy, the shifting objectives of society and needs of students demand a corresponding adaptation of our education environments.

In the digital economy, technology dramatically alters the options for inquiry, analysis and expression. Today, the ability to find information quickly and efficiently, manipulate it and apply it to solve problems and inform decisions has become a primary asset. The ability to learn, even for an organization, is a precursor to success. Traditional educational environments and methods do not prepare students with the necessary skills to thrive in today’s society, nor do they train them to prosper in tomorrow’s workplace.

For almost a decade, national attention has focused on a new set of skills necessary to prepare students for life and work in a world moving from the industrial age to the digital age. The necessary knowledge identified by the United States Secretary of Labor’s Commission on Achieving Necessary Skills (SCANS) includes five workplace competencies and a three-part foundation of skills and personal qualities necessary for solid job performance. These competencies are: the ability to use resources productively, master interpersonal skills, locate and manipulate information, understand systems thinking and operate technologies. According to SCANS, the foundation for these competencies rests with basic skills as well as the ability to think creatively, make decisions, solve problems and know how to learn (Marzano, 1996).

Integration strategies give students a firm foundation in all these skills. They facilitate students in explorations that can invigorate in-depth analytical thinking, inspire creativity, stimulate curiosity and develop skills of innovation. The challenge of teachers is to integrate its reach into all curriculums and to deliver its global opportunities to all learners. Its beauty will be found in the powerful development of remarkable, authentic learning achievements, innovative demonstrated understanding of curricular content and intellectual vigor in lifelong learners.

Such strategies can help us reach across the nation and tap into the vast educational resources countries offer. The dynamic learning environment created with new tools and digital resources will give hope and encouragement to our students so that all children can benefit from technology and achieve at the highest levels possible.

In particular we have seen how the instructional use of the constructivist educational technological tools is consistent with professional standards for teaching mathematics and
with current research on student learning of mathematics in general. In the spirit of problem solving and inquiry, students working with these tools develop rich mental models (producing the rectangle) that enable them to reason in increasingly sophisticated ways. They gradually come to know the mathematical properties of shapes, not as empty verbal statements to be memorized, but as powerful conceptualizations that enable students to sharpen their analyses of mathematical phenomena. In this way, students' work with these tools helps them develop one of the most important goals of the NCTM Standards, “mathematical power”, a term denoting students' ability “to explore, conjecture, and reason logically, as well as the ability to use a variety of mathematical methods effectively to solve nonroutine problems. This notion is based on the recognition of mathematics as more than a collection of concepts and skills to be mastered; it includes methods of investigating and reasoning” (1989, p. 5).

Thus, these tools are extremely powerful technological tools both for teaching a number of critical mathematical ideas and for cultivating reasoning techniques that increase students' overall mathematical power. Unlike ubiquitous computer drill and-practice programs, using these tools actually involves students in doing mathematics with technology in a way that anticipates their later use of dynamic computer graphing and visualization tools as sophisticated adults. (For instance, I used the CabriGeometre to model the construction of buildings in my neighborhood. I wanted to analyze the effects of building construction and spacing on the views from various windows in the house.) Thus, these tools not only enhance students' learning of important mathematical ideas, they involve students in using a powerful technological tool that they can utilize throughout their mathematical careers.

Further, these tools utilize a cognitive apprenticeship approach. They demonstrate valuing the social constructivist idea that knowledge is constructed by the learner but mediated by more capable others, such as the teacher and peers (Gallimore and Tharp, 1990). The approach thus guided the presentation of scaffolded learning experiences that took into account the learners' role in making knowledge their own (Shapiro, 1994).

Thus, the use of these tools in the classroom has brought with it new challenges, ideas and ways of thinking and has revitalized the education debate. They have generated enthusiasm and a new involvement in learning from pupils and teachers. In particular, the upsurge in the use of Logo is seen as a way of providing opportunities for mathematical investigations, encouraging discussion and project work, and making mathematics more open and practical, accessible and popular to a greater number of pupils. It is by no means certain that pupils made learning gains in specific circumstances after collaborative work or
discussion. They have gained something from their partnership in terms of presenting each other with challenges and encouraging persistence and variety in approach. They have also learned some independence from the teacher and the way to collaborate together during their Logo work spread to their “other” mathematical work (art) and affected the level of discussion of mathematical issues within the mathematics classroom generally.

However, one must not underestimate the use of the direct educational technological tools (drill, tutorial, ...) since they help students master basic skills which are considered as prerequisites to higher order thinking skills. Hence, which strategy is suitable for classrooms: the direct strategy or the constructivist strategy. I think that proficient technology oriented teachers must learn to combine directed instruction and constructivist approaches. To implement each of these strategies, teachers select technology resources and integration methods that are best suited to carry them out.

Together, the two different views of reality may merge to form a new and powerful approach to solving some of the major problems of the educational system, each contributing an essential element of the new instructional formula. Some practitioners believe that constructivism will eventually dominate overall educational goals and objectives such as learning to apply scientific methods, while systematic approaches will assure specific prerequisite skills. Tennyson (1990) has suggested, for example that about 30 percent of learning time be spent on what he terms acquiring knowledge, verbal information and procedural knowledge. The remaining 70 percent should be spent on the employment of knowledge ie contextual skills, cognitive strategies and creative processes (Educational technology, 1991). Hence, a link between the two strategies must be forged so that students may travel freely from one to the other, depending on the characteristics of the topics at hand and individual learning needs. Sfard (1998) agree that “one metaphor is not enough” to explain how all learning takes places or to address all problems inherent in learning (P. 10).

Consequently directed and constructivist models each address specific classroom needs and problems and both will continue to be useful. Neither model in itself can meet the needs of all students in a classroom. Teachers must merge directed and constructivists activities to form a new and more useful school curriculum, Even Gagne, a leader in promoting systematic, directed methods, proposes that effective, useful instruction sometimes calls for integration of objectives in the context of a complex, motivational learning activity that he refers to as an enterprise (Gagne, 1985). His description of the nature of this enterprise sounds
much like the kinds of activities often proposed by constructivists. In fact, one of his three kinds of enterprises calls for a discovering schema.

Overall, it is evident that the educational technological tools discussed in this study can provide a rich environment in which pupils can engage together in mathematical activity, but the influence of the atmosphere in the mathematics classroom on pupil outcomes can not be underestimated. The potential of some of these tools such as Logo or Cabri-geometry will only be realized if the pupils are able to work collaboratively with an emphasis on process rather than competitively with an emphasis on product. Pupils must be allowed the space to develop confidence to try things out for themselves in an experimental manner. We recognize that the development of such a mathematical environment is not straightforward given the complexities of teaching and learning and the social relationships expected within school mathematics classrooms. I believe after analyzing the result of this study that the effort needed to incorporate the above tools into mathematics classrooms will be worthwhile. I believe that the computer can't change a poor learning environment into a good one but with open minds it can be a catalyst for change in pupil-teacher relations with pupils more likely to make decisions and, to some extent, set their own learning agendas. As Weir (1987) claimed (in the context of Logo programming) "the most exciting part of the educational computing enterprise will be its effect on classroom culture: the attitudes and atmosphere and the patterns of intervention, and on the location of control in the classroom" (p.246). Computers are not, however, a panacea. It is all too easy to merely fit their use into existing practice or hive them off into a separate compartment leaving the curriculum essentially unchanged.
VI. Implications

In this sense, the significant implications of the results of this study are important for professional development of teachers. They include the importance of addressing teachers’ belief about the use of the educational technological tools, along with exposure to a wide variety of related educational tools and examples. Further, they provide math teachers with practical suggestions for meeting NCTM standards that emphasize the integration of educational technology into teaching, so that they can be able to justify their teaching strategies to parents and the wider community.
VII. Recommendations

Based on the result of this study, I propose three suggestions for education. The first suggestion is that more attention should be paid to combining direct and constructivist approaches and integration strategies into a single curriculum. This can be referred to the importance of combining the psychological theories discussed earlier and to the result of my research: lower primary math teachers support the use of the educational technological tool to enhance basic skills whereas middle and upper primary math teachers support the use of the educational technological to foster higher order thinking skills. Moreover, it is based on the fact that the basic skills developed through direct integration strategies are considered prerequisites to the development of higher order thinking skills which are achieved through constructivist integration strategies. Thus, combining the two approaches (direct and constructivist) is considered important in the teaching process. A suggested lesson plan based on the combination of the mentioned theories is the following:

Lesson Title: "A Number a Day"

Subject: Mathematics

Grades: 1 and 2

Purpose: The activity is designed to help students understand

- The concept of number and its relationship to the calendar
- What a calendar is and how it can be used to keep track of time
- On to one correspondence and sequencing numbers

Additional understandings include that

- Mathematics is a symbolic language common to all cultures
- Mathematics is everywhere
- Knowledge of numbers enhance students' understanding of the world around them
- Technology can add to students' knowledge by allowing them to electronically retrieve information
- Technology can help students communicate local, original ideas to a large audience

Description: Most primary grade classrooms begin the day with a discussion about the day, date, weather, and so on, setting the tone and context for the activities that follow. As students study the current day, its name, and its number, they develop mathematical ways to express the number (e.g. equations, birthdays, number of boys or girls in the class, number of teeth lost so far this month, etc).
Using information found on websites, students create a more complete record of their representations of the day’s number. This record can be created using drawing or painting software, videotaped for school announcements, published in a classroom newsletter, or inserted on a classroom web page.

Note: the complexity of this activity is determined by the students’ current mathematical understandings. The websites provided in tools and resources should be explored thoroughly for information that will best help students. In addition, using weather related literature significantly enhances the study of the day, the date, the season, and so on.

Activities:

1- As part of opening activities, students complete sentences such as: “Today is ----, Yesterday was----, Tomorrow will be----, The day before yesterday was----, the day after tomorrow will be”. Use numerals with each date as well as the word: for example, “Today is Monday, 7th”. Notice here that this activity is based on direct integration strategies which help students recognize numbers and review prerequisite skills. Through such activity, students achieve the following math objective: “use one to one correspondence to count objects to 100” and the following NETS performance indicator “Use a variety of media and technology resources for directed and independent learning activities” (p.18)

2- A simulation software is incorporated which facilitates a discussion about the number that represents the date, shows students how to express the number in many different ways and relate it to the things in the classroom (e.g., number sentences and equations, a birth date, the dates on money, etc....). This simulation software reflects the type of physical simulation discussed earlier. This simulation is based on direct integration strategies to teach the skills of expressing the numbers in many different ways and relating it to things in the classroom. The surveyed math teachers incorporate this software to have students achieve the NETS performance indicator stated above “Use a variety of media and technology resources for directed and independent learning activities” (p.18). Further, this software show students how “to represent real world application of whole numbers to 100 using concrete materials, drawings, and symbols” (a math objective as cited in the Lebanese math curriculum”.

3- Have students visit a website that explores the number ie shows the day’s number from different perspectives. Then, students have to find ways to express numbers that are similar to their own. What cab be said is that this internet activity helps students
achieve the following NETS performance indicator: “use developmentally appropriate multimedia resources (e.g. the internet) to support learning” (p.18). As mentioned earlier, the internet is based on constructivism. Hence, such activity enables students to achieve the following math objective “represent real world application of whole numbers to 100 using concrete materials, drawings, and symbols” (a math objective as cited in the Lebanese math curriculum”. Notice here how the simulation activity incorporated in activity 2 guides students to achieve the stated math objective and how the internet activity enables students to achieve this stated math objective which means that the internet complements the simulation software.

4- The surveyed teacher makes connection to other curriculum areas, including history. To illustrate, although primary grade students have not studied Egyptian culture, the mathematical connection to the contributions made by this and other cultures can be simplistically introduced to build understanding about the rich contributions many people have made to mathematical understanding. The surveyed teacher has students display their findings about numbers, and history by drawing pictures, creating multimedia presentations, and any other method or activity that is appropriate for the developmental level of the students. Through this activity, students achieve the following math objective “students will be able to communicate mathematically” and since it is based on a constructivist approach, this activity help students achieve the following NETS performance indicator “prior to completion of grade 2, create developmentally appropriate multimedia products with support from teachers, family members or student partners” (p.18)

What can be concluded here is that each technological educational tool has its own function in achieving math and NETS objectives and thus fostering more than one discipline. In this sense, the technological educational tools described in this paper enable students to cover all aspects of Bloom’s taxonomy.

The second suggestion is that all Lebanese primary schools should model the integration strategies implemented by the surveyed schools. Such model is practical since the importance of IT is no longer the subject of debate in the Lebanese Center for Educational Research and Development. Several initiatives are presently being put in place to enhance IT in official Lebanese schools. The Decade of Education In Lebanon declared recently by the Center for Educational Research and Development has as part of its Agenda, successful implementation of educational technological tools into math education where a project IT for all Lebanese
schools will be embarked on, through which computer literacy training program and teacher training on the integration strategies will be implemented and infrastructure for lab networking will be installed. A plan of action which was adopted by the Lebanese Minister of Education has been endorsed at the conference on math, science, and technological literacy of the ICASE held in March 2001 (Science, math, and technology for all in Lebanon, 2001). Let us therefore look to the future with some optimism about the state of technology and mathematics in Lebanon. The third suggestion is that the results of this study have generated a question that is worthy for research. Perhaps the most significant question is the way in which teachers interact with special need students, particularly students with learning disabilities. It may be interesting to carry out such research on the basis of current issues and problems in special education, the integration of technology into special education, and exemplary lesson plan for a variety of integration strategies in special education.
VIII. Limitations of the research

This study investigates the importance of implementing the educational technological tools into teaching mathematics in terms of development of higher order thinking skills. This result is obtained by carrying out a survey. It is argued that a survey can be considered as an appropriate methodology to carry out the research in the study of this paper. This refers to two facts. The first fact is that survey is based on nonlaboratory situations where experiments are often neither feasible nor ethically defensible. In this case, survey can give that reassuring scientific ring of confidence. The second fact is that the study of this paper is about an important topic "integration strategies". Many teachers use a variety of teaching strategies to teach their students. In the course of any period, teachers form judgments about teaching strategies and make choices about when and how to proceed. Many teachers can not, however, clearly describe the teaching strategies and processes they use and the beliefs they bring as they form these judgments. What kinds of evidence are these judgments based on? What criteria are used in interpreting that evidence? What constitutes mathematical understanding? How systematically is evidence collected? Answering these kinds of questions, which would not only deepen teachers' understanding of integration strategies but also would have important effects on instructional practice and curriculum choices, can't be implemented without devising questionnaires.

However, surveys could be considered as generating large amounts of data of dubious value. Their findings are seen as a product of largely uninvolved respondents whose answers owe more to some unknown mixture of politeness, boredom, desire to be seen in a good light rather than their true feelings, beliefs or behavior and this of course affects validity. In this thesis, the validity of questionnaires and interviews could be referred to what the respondents said. However, there is some validation from the observational data but this is limited.

Such weaknesses of the survey are based on the fact that the trustworthiness of the data depends to a considerable extent on the technical proficiency of those running the survey. Since the questionnaire in this study should be comprehensible and unambiguous, the exercise is obviously not a waste of time where we are obtaining valid information about the respondents and what they are thinking, feeling or whatever. Further these weaknesses would be overcome by the use of observation and interviews. Mixing methods of data collection neutralize any bias inherent in particular data resources.
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Appendix I

The Cover Letter

The following questionnaire is part of a survey under study I am conducting in partial fulfillment of the requirements for the degree of EdD at the university of Leicester. This study is about integrating technology into primary mathematics. Since you have integrated information technology into primary mathematics, I am relying on your attitudes, experience, and judgment to contribute toward a deeper understanding of integrating technology into primary mathematics. The validity of the results will depend on your accurate responses.

Thank you for attention and assistance

Sincerely,
Nehme Safa
Appendix II

Questionnaire

This questionnaire contains items representing your attitudes and opinions towards integrating technology into primary mathematics.

Name (optional):------------------
Name of the school (optional):-------------
Grade level you teach:---------------------
Sex:-----Male, ------Female

I implement the technological educational tools in my classroom:

1. to give students practice exercises to practice the concept or skill being taught
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
2. to meet the individual pacing and remedial needs of each student
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
3. to enhance retention and recall
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
4. to motivate students to learn basic skills through reinforcement
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
5. to provide students with alternative learning strategies in teaching basic skills
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
6. as an assessment tool to inform myself about their strengths
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
7. as an assessment tool to inform myself about their weaknesses
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
8. to promote cooperative learning and interactions among students and thus foster critical thinking
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
9. to help students develop higher order thinking by generalizing from particular cases
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
10. to enable students to explore and recognize relationships between ideas and thus think critically
    a. very often  b. often  c. sometimes  d. seldom  e. almost never
11. to provide students with assistance to accomplish a complex task which requires higher order thinking skills.
12. To have students employ higher order thinking skills by applying math skills in other subject areas.
   a. very often  b. often  c. sometimes  d. seldom  e. almost never

13. To enable students to employ higher order thinking skills by applying what they learn outside the school culture.
   a. very often  b. often  c. sometimes  d. seldom  e. almost never
### Appendix III
The Emergence of Questionnaires from the Literature Review

<table>
<thead>
<tr>
<th>Questions</th>
<th>Emerged from</th>
</tr>
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<tbody>
<tr>
<td>Question #1</td>
<td>Section II.G.1.a: Definition and Characteristics of Tutorials</td>
</tr>
<tr>
<td>Question #2</td>
<td>Section II.G.1.b: The Use of Tutorials in Teaching Mathematics + Section II.G.2.b: The use of Drill and Practice in Teaching Mathematics</td>
</tr>
<tr>
<td>Question #3</td>
<td>Section II.G.1.a: Definition and Characteristics of Tutorials + Section II.G.2.a: Definition and Characteristics of Drill and Practice</td>
</tr>
<tr>
<td>Question #4</td>
<td>Section II.G.4.a: Definition and Characteristics of Instructional Games + Section II.G.2.b: The use of Drill and Practice in Teaching Mathematics</td>
</tr>
<tr>
<td>Question #5</td>
<td>Section II.G.1.b: The Use of Tutorials in Teaching Mathematics + Section II.G.3.a: Definition and Characteristics of Simulation</td>
</tr>
<tr>
<td>Question #6</td>
<td>Section II.G.1.a: Definition and Characteristics of Tutorials + Section II.G.2.a: Definition and Characteristics of Drill and Practice</td>
</tr>
<tr>
<td>Question #7</td>
<td>Section II.G.1.a: Definition and Characteristics of Tutorials + Section II.G.2.a: Definition and Characteristics of Drill and Practice</td>
</tr>
<tr>
<td>Question #8</td>
<td>Section II.I.5.b: The use of the internet in teaching Mathematics</td>
</tr>
<tr>
<td>Question #9</td>
<td>Section II.I.2.b: The use of Problem Solving Software in Teaching Mathematics + Section II.I.3.b: The impact of Spreadsheet on Mathematics Education</td>
</tr>
<tr>
<td>Question #10</td>
<td>Section II.I.2.b: The use of Problem Solving Software in Teaching Mathematics + Section II.I.3.b: The impact of Spreadsheet on Mathematics Education</td>
</tr>
<tr>
<td>Question #11</td>
<td>Section II.I.2.b: The use of Problem Solving Software in Teaching Mathematics + Section II.I.1: An overview of the role of the other types of Simulation and Instructional Games in Fostering Constructivism</td>
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<tr>
<td>Question #12</td>
<td>Section II.I.4.b: The Impact of Multimedia on Mathematics Education + Section II.I.2.b: The Use of Problem Solving Software in Teaching Mathematics</td>
</tr>
<tr>
<td>Question #13</td>
<td>Section II.I.1: An overview of the role of the other types of Simulation and Instructional Games in Fostering Constructivism + Section II.I.2.b: The use of Problem Solving Software in Teaching Mathematics</td>
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