CHAPTER II

LITERATURE REVIEW

In this chapter, the researcher first will try to explain and elaborate on the underpinning theories of the current research. Secondly, the foundations of the theoretical framework and its components will be described with sample references made to the related theoretical establishment and practical research finding.

However, the review of the related literature will primarily focus on the context of the study, namely the Iranian educational reform and particularly the need for introducing and implementing a pedagogical model of teaching the chemistry subject with the aid of computers.

In 2004, the famous report of ICT development in Iran, known as "The Iran's Road to knowledge-based Development Report" (Jahangard, 2004) was published. The report had criticized the implementation of ICT in he educational system in Iran, which was developed and implemented quite recently by the government. Based on this report, the most serious shortcoming was the lack of pedagogical models by using the computer in general education curriculum.

However, there are yet no plans by the government for implementing those pedagogical models that have been introduced by researchers in making changes to the current curriculum.

The increased use of computer in the teaching- learning processes at Iranian schools convinced the researcher to try these pedagogical models in the teaching of the chemistry subject as a potential factor for boosting the capabilities and the abilities of teachers and learners.

The most important element in these chemistry classes is an essential role of the pedagogical plan for reaching to a systematic plan. In a situation that is growing remarkably as far as computer skills are concerned, it will be difficult to control the growth unless a more systematic and formal approach is taken in the educational system by supervisors or the researchers at schools.

According to the available related literature, there is no published research on the use of computer-assisted guided inquiry in the teaching of the chemistry subject in Iran. Therefore, the present researcher has attempted to suggest and recommend the implementation of such a computer-based approach.

The observed lack of research and investigation in application and implementation of computers into the real context of classrooms in teaching chemistry had made the present researcher decide on the framework of such research in terms of: 1) identifying a theoretical framework based on existing evidence and literature review, 2) describing some pedagogical approaches and the pedagogical models in the teaching of the chemistry subject for further development of the proposed model, 3) conducting a review of research on similar issues in search of commonalities and establishing the research framework, and 4) identifying the gap among pedagogical models of chemistry teaching at Iranian high schools.

Theoretical Framework

The development of a pedagogical model depends on the chosen theoretical framework. Such framework must support the selected research design and form the foundation for implementation, evaluation, and conduct of further research.

For the current research, the theoretical framework was developed in three steps, namely defining constructivism, defining the ICT pedagogy based on practice, and determining the factors which contribute to success or failure of computer-based activities in the classroom.

Constructivism. The constructivist roots in philosophical tradition of (Von Glasersfeld, 1989), a direct pragmatism of Charles S. Pierce, William James and John Dewey (Terwel, 1999).

Constructivist learning theory is based on educational psychology derived from the work of developmental psychologists Jean Piaget (1973) and Lev Vygotsky (1978). Piaget describes knowledge development from a holistic and cognitive perspective, emphasizing on constructive understanding (e.g., reading, listening, exploring, and experiencing).

Vygotsky introduced the social and cultural influences on learning and emphasized their role in the construction of knowledge. He also stressed on learning in context which leads to comprehension through interactions with others in the social environments in which knowledge is to be applied. These educational psychological theories have been further developed by a number of constructivists (Jonassen, 1992; Papert, 1987) in recent years.

Furthermore, constructivism reflects a paradigm shift from a teacher-centered pedagogy based on behaviorism to a learner-centered educational approach based on cognitive theory (Ertmer & Newby, 1993). Moreover, behaviorist epistemology focuses on intelligence, domains of objectives, levels of knowledge, and reinforcement.

Constructivist epistemology assumes that learners construct their own knowledge on the basis of interaction with their environment. Although constructivism is an epistemic way of learning, it can also be understood as a theory of learning. Students actively construct knowledge in the process of learning through interactions with phenomena, and then they build up meaning of the phenomena through interactions within a social framework. Although the epistemological positions of constructivist theory are often challenged by philosophers and scientists, researchers generally agree that students learn by making sense of phenomena as they experience them, evaluate their qualities, and attempt to make sense of them within a socially acceptable context in light of prior knowledge (Linn & Bell, 2000).

The epistemology that is dominant in most educational settings today is similar to objectivism. That is to say, most researchers view knowledge as existing outside cognition, separate from cognizance and cognizant. Knowledge is “out there,” residing in books, independent of a thinking being. Science is then conceptualized as a search for truths, a means of discovering theories, laws, and principles associated with reality. Objectivity is a major component of the search for truths which underlie reality; learners are encouraged to view objects, events, and phenomenon with an objective mind, which is assumed to be separate from cognitive processes such as imagination, intuition, feelings, values, and beliefs.

Constructivist epistemology asserts that the only tools available to a cognizant individual are the senses. It is only through seeing, hearing, touching, smelling, and tasting that an individual interacts with the environment. With these messages from the senses the individual builds a picture of the world.

Constructivism emphasizes critical thinking, intellectual development, problem solving, "authentic" learning experiences, social negotiation of knowledge, and collaborative-pedagogical methods that change the role of the teacher from disseminator of information to learning facilitator, helping students as they actively engage with information and materials to construct their own understandings. That is to say, students learn how to learn, not just what to learn (Newman, Griffin, & Cole, 1989; Piaget, 1973). In this way teachers try to encourage students to become self-directed learners (Snowman & Biehler, 2000) and discover aspects of research, concepts or ideas on their own (Cruickshank, Bainer, & Metcalf, 1999). Therefore, teachers implement a curriculum to ensure that students cover relevant science content and have opportunities to learn truths which usually are documented in bulging textbooks.

In constructivism, teachers often use problem-solving as a learning strategy; where learning is defined as adaptations made to fit the world they experience (i.e., prior knowledge is used to make sense of data perceived by the senses). Other individuals are part of our experiential world, thus, others are important in the process of inferring meaning.

Cooperative learning strategy allows individuals to test the fit of their experiential world with a community of others. Others help to constrain our thinking. The interactions with others cause perturbations, and by resolving the perturbations individuals make adaptations to fit their new experiential world.

Experience involves an interaction of an individual with events, objects, or phenomena in the universe; an interaction of the senses with things, a personal construction which fits some of the external reality but does not provide a match. The senses are not conducted to the external world through which truths find their way into the body.

Objectivity is not possible for thinking beings. Accordingly, knowledge is a construction of how the world works, one that is viable in the sense that it allows an individual to pursue particular goals. Thus, from a constructivist perspective, science is not the search for truth. It is a process that assists us to make sense of our world. Teaching science through a constructivist perspective becomes more like science as scientists do it. It is an active, social process of making sense of experiences, as opposed to what we now call "school science." Indeed, actively engaging students in science is the goal of the most scientific educational reforms; we have all heard the call for "hands-on, minds-on science". By using a constructivist epistemology, teachers can become more sensitive to children's prior knowledge and the processes by which they make sense of phenomena. The constructivist theory of learning is very useful to be applied in the classroom, and thus the learning process will be a meaningful experience for the students.

Constructivism in teaching Chemistry. Constructivism is the most significant and dominant perspective in science education (Taber, 2001). According to Driver (1989a) constructivists attempt to foster active learning; they guide learners to create their own constructs using a process of peer and teacher-facilitated learning. He states that constructivist-based teaching allows students to become actively engaged in real-world relevant topics through a step by step process through which students use prior knowledge to achieve multiple solutions when solving science problems and share social significance through social interactions in the classroom. He adds that science is accessible to students at many levels and becomes fun and interesting for both students and teachers in the classroom. Driver believes that technology may be integrated in a meaningful way and science can be communicated to a wider audience when instruction emphasizes science as an inquiry and science process skills.

In constructivism, the teacher's role is to engage learners to discover of knowledge and provide them with opportunities to reflect upon and test theories through real-world applications of knowledge. The constructivist approach to teaching and learning moves learners away from the rote memorization of facts to metacognition and self-evaluation (Ormrod, 1990). In a constructivist classroom, the role of the teacher is to organize the information and concepts using a variety of strategies such as questioning, examining, exploring, and developing new insights. In addition to these strategies, the teacher needs to break down concepts, and allow students to answer their own questions, conduct their own experiments, analyze their own results individually or in a group setting, and finally draw their own conclusions.

Critical thinking (Bloom's Taxonomy) in Chemistry. Bloom (1956) developed a classification of levels of intellectual behavior in learning. This taxonomy contained three overlapping domains: a) the cognitive mental skills (knowledge), b) psychomotor manual or physical skills (skills), and c) affective growth in feelings or emotional areas (attitude). Within the cognitive domain, he identified six levels, which are the six different levels of thinking. These levels are: knowledge, comprehension, application, analysis, synthesis, and evaluation. The levels are mentioned in a hierarchal manner meaning that a learner must start at the knowledge level and build on it to get to the comprehension level and progress on and on as elaborated in instructional objectives of the course of study. Classifying instructional objectives are used in this taxonomy to determine the levels of learning included in an instructional unit or lesson.

However, Anderson and Krathwohl (2001), who belonged to a new group of cognitive psychologists, had updated the taxonomy reflecting relevance to education in the 21st century. Interestingly, Bloom’s six major categories were changed from noun to verb forms. These changes are useful today for developing the critical thinking skills of learners. In this process, critical thinking activities arrange elements from the lowest to highest level. Finally, the lowest level of the original knowledge is renamed in order to understand and create the concepts.

Critical thinking involves logical thinking and reasoning including skills such as comparison, classification, sequencing, cause/effect, patterning, webbing, analogies, deductive and inductive reasoning, forecasting, planning, hypothesizing, and critiquing. On the other hand, creative thinking involves creating something new or original. It involves the skills of flexibility, originality, fluency, elaboration, brainstorming, modification, imagery, associative thinking, attribute listing, metaphorical thinking, and forced relationships (Johnson & Lamb, 2007).

However, in relation to this idea, it is believed that computers can develop creativity. Creativity as Boden says, "is the ability to come up with new ideas that are surprising yet intelligible, and also valuable in some way" (Boden, 2001). Therefore, creative thinking, as far as educating children is concerned, involves the representation in meaning derived from a dialogue between children and their work (Loveless, 2000). It deems as absolutely indispensable the realization of concepts behind creative thinking by deeply investigating the process of meta-cognition as it is meant by today's learning psychology.

Meta-cognitive knowledge reflects recent research on how students' knowledge about their cognition and control of their own cognition play important roles in learning (Bransford et al., 2000; Zimmerman & Schunk, 1998). It emphasizes making students more aware of and responsible for their own knowledge and thought. More importantly, meta-cognitive awareness is a key element in successful learning (Brown, Bransford, Ferrara, & Campione, 1983).

From the viewpoint of implementing technology in education, the idea of particular software tools being suited to particular tasks has important implications for the development of pupils' meta-cognitive awareness. For example, the software program Smartboard promotes quite a sophisticated level of meta-cognitive reflection (Goodison, 2002).

Encouraging children to think about their own thinking (meta-cognition) can enhance the ICT learning process (White & Shimoda, 1999). A major contribution of ICT to the teaching-learning process is found in the ease with which teachers can give students feedback and with which students can correct their own work. This stimulates students to reflect (Volman, 1997).

Therefore, meta-cognitive control and self-regulation involve the cognitive processes of Remember, Understand, Apply, Analyze, Evaluate, and Create (Anderson & Krathwohl, 2001). Meta-cognitive knowledge includes knowledge of the variety of strategies that students might use while they perform their inquiry. In practical work situations, students need meta-cognitive strategies, for example during their goal specification, planning their investigation, deciding on the strategies to take measurements, and to monitor and check their results in many stages.

Meta-cognitive knowledge also includes general strategies for problem solving, and deductive and inductive thinking (Anderson & Krathwohl, 2001). The goal of chemistry instruction is to promote and transfer the shift of focus to the other five cognitive processes, that is, from Understand to Create.

To understand is defined as constructing meaning from instructional messages in chemistry, including oral, written, and graphic communication and so on. Therefore, students can understand when they build connections between "new" knowledge to be gained and their prior knowledge. The incoming knowledge is integrated with existing mental models and cognitive frameworks. The Conceptual Knowledge (framework) provides a basis for understanding. There are seven sub-types of understanding: interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining (Anderson & Krathwohl, 2001).

Rutherford's atomic model is an example of using the computer in learning chemistry in this study. The experiment is about the gold foil. In this example of understanding process, the learner solves a problem and the creative process includes the following three phases: a) problem presentation, in which a student attempts to understand the problem and generate possible solutions, b) solution planning, in which a student examines the possibilities and devises a workable plan, and c) solution execution, in which a student successfully carries out the plan. This experiment includes three cognitive processes: a) generating, b) planning, and c) procedure (Anderson & Krathwohl, 2001). In this particular experiment, students' activities could be recognized as divided several distinguished themes: a) interpreting their observation in the negative films, b) remembering information to solve the problem, c) solution planning to solve the problem, d) applying their chemistry knowledge to solving this problem, e) to carry out the plan or a report , f) distinguishing relevant and irrelevant information of their measurements, g) to build a coherent representation of the key information of the problem, and h) to make sure that the solution "makes sense".

ICT pedagogy. As far as ICT implementation is concerned, learning theories suggest that teachers' perceptions of pedagogy in relation to ICT are often limited to controlled and directed learning. Among the proponents of this stand, Taylor (1980) stated that educational uses of ICT has categorized the modes of usage, for example, as tutor and/or as tool. Schulman (1987) had focused on the teaching processes, which involved the transformation of knowledge and the ways of teaching (pedagogical content knowledge).

Therefore, the teacher plays the main role in this experience. Alexander (1992) identified that teaching methods and pupil organization are the two facts of pedagogy. He illustrated that the pedagogy of ICT should be understood within a broader framework of educational practice. Lastly, Laurillard et al. (2000) have developed a 'conversational framework' on learning that demonstrated the productive and unproductive approaches to learning in different contexts by using various learning methods.

Recent research, however, suggests that the developers of ICT in education need to design a new 'integrated pedagogy' (Cornu, 1995). A theoretical framework for implementing ICT pedagogy is presented in Figure 2.1 in order to represent the presence of different elements at school level and to represent their interactions:

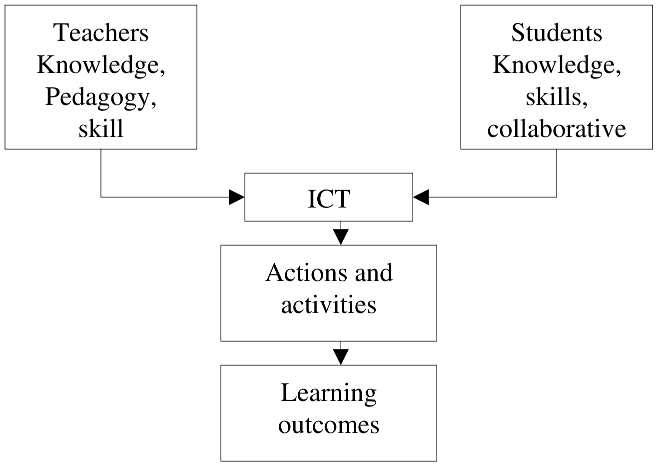

Figure 2.1. Overview of emerging framework.

Factors contributing to the success of computer-based activities in the classroom. Many researchers have studied the factors that contribute to successful educational changes. Fullan (1998), for example, stated that a major influence in the adoption of change is the school principal.

Moreover, studies have found that the projects receiving the principal's support were more likely to succeed, since the principal's involvement indicates that the project is being taken seriously, and it helps in recruiting both material resources and psychological support (Marsh, 2001).

Venezky and Davis (2002), however, have shown that the most crucial factor contributing to the advancement of innovation is the availability of infrastructure resources. These resources could consist of hardware, in terms of the number of computers in the school available for students and teachers for educational purposes, and the quality and functioning of equipment (speed of processors, operating systems, peripherals and access to the Internet), as well as available software, general, and educational. It is believed that, the computer alone is insufficient and must be accompanied by technical and pedagogical supports (Pelgrum & Anderson, 1999).

In order to use ICT in education, the three-way interaction pattern between learners, teachers, and computers should be considered (Squires & McDougall, 1994), while considering the wider context in which teachers and learners work.

Many innovations fail because teachers do not have an understanding of the principles behind the innovations they are expected to carry out, and have not had sufficient training in the skills needed to use the technology. They often do not see a fit between the technology and their goals and intentions as teachers (Cuban, 1986).

Finally, it was found that infrastructure facilities and resources, the ICT team and teacher ICT skills would of course provide a learning climate and environment rich in authentic interaction (Impact 2, 2001).

Pedagogical practice. The focus of this study is the essential role of implementing computers in a pedagogical practice. The researcher tries to address previous similar researches of other subject matters and identify a possible framework to support the use of ICT in the teaching of the chemistry subject.

It is assumed that different types of pedagogical patterns may influence the interaction between teacher and students. For example, Thao Lê and Quynh Lê (2007) had defined teachers' role as facilitating the learning process, and not dictating it. The assumption here is that ICT use has changed the pedagogical roles of teachers and a compelling rationale for using ICT in schools is its potential to act as a catalyst in transforming the teaching and learning process (Hawkridge, 1990).

The use of computers to support constructivist pedagogy was shown to be effective by Dreyfus and Halevi (1991). They showed that the use of computer programs to provide an open learning environment allowed pupils to explore within a framework, and given that the teacher was working as a guide, even weak students were able to deal in depth with a difficult topic.

Biggs (1999) has argued that there is no single, all-purpose best method of teaching such as available resources, students' abilities, and individual strengths and weakness as a teacher. It depends on how the process of teaching using ICT to produce learning resources and provide successful learning experiences for students in the future was conceived. The office for standards in education (OFSTED, 2002) declared that good teaching in ICT includes clear objectives. This is to be followed by thoughtful planning and collaboration between teachers in integrating ICT into a scheme of work. Teacher intervention is required to ensure that pupils do not become distracted by the technology, and to let pupils know that teachers have high expectations.

OFSTED mentioned some weakness in this kind of teaching such as 1) unclear objective: ICT is used where other modes of learning would be inappropriate, 2) the potential of the application is not fulfilled, for example, individual work on a computer would be more appropriately conducted as a group discussion, or vice versa, 3) glossy computer graphics are used with no real purpose, 4) there is failure in use of the full potential of facilities, and 5) teachers fail to intervene in children's learning in this way.

Moseley et al. (1999), in their summary of previous research, identified five effective teaching behaviors: Lesson clarity, instructional variety, teacher task orientation, engagement in the learning process and pupil success rate. They considered that one of the most effective ways of creating variety is asking questions.

Moreover, most of the characteristics of computer-based teaching are context dependent, such as curriculum context, or the organizational set up in schools; therefore, they do not lie under the control of teachers. They are rather determined by school management and education policy frameworks. In the case of the present research, the researcher has used these findings from the literature on pedagogical practice to devise the interviews questions as well as classifying her class observations.

Teacher's ICT skills. The use of ICT and particularly the way it is used influence teachers' knowledge and skill in their teaching. Some researchers have clearly expressed the use and application of ICT and its elements in learning process are:

Some of these implementation drawbacks are difficulty of access, less control over learning and monitoring progress, different classroom organization, change of relationship from transmitter to enabler of knowledge, lack of proficiency in the use of ICT, less autonomy, change in work habits, pupils questioning of received knowledge which may undermine the traditional method, and the authoritarian role of the teacher (Cox, Cox & Preston, 1999; Handly & Aitken, 1986).

According to Cuban's investigation (1986), many innovations were rejected, since teachers lacked sufficient understanding of the principles behind the innovations and functions they were expected to carry out. Also, teachers did not have sufficient training in the skills requiring technology. More important, they often would not see compatibility between the technology and their aims and intentions as teachers.

In the context of the present research, the Iranian teachers are familiar with computers to some extent. In performing their task of teaching, some teachers know how to use a computer in teaching-learning activity and they know the basic functions of email and the Internet. Contrary to this, there are teachers who do not use computers in their classes at all. Indeed, the skills are heterogeneous.

However, some teachers have almost acquired the skills and have combined their learned skills with practice. Many of them have learnt the basic ICT skills during their teacher training (i.e., ICDL). Teachers have various abilities in using ICT, and their differences depend on the way they have combined their learned skills during the teaching-learning process. It can be reasonable to claim that teachers use different methods for using ICT as a tool, either in administrative program and planning activities, or in the classroom. In an independent investigation titled "The Impact of Roshd Network from the views of students, and teachers in the high school Tehran Urban" that was conducted by Satari (2005), it was found that ICT often did not fit in the existing teaching culture, and may even undermine the teacher's sense of efficacy. Satari stated that teachers using the technology tend to domesticate applications so that they conform to the prevalent practice. Such studies clearly showed that there is a gap in the literature on chemistry teaching through computers at international level. Inadequate information and lack of research based literature prompted initiation of the present research study.

Students' ICT skills. A thorough investigation of science and math books at Iranian schools showed that students have different ICT skills such as word processing, painting/drawing, and Internet searching for sources applicable to these subjects.

Although science students were unfamiliar with desktop publishing, programming and www-publishing, they try to acquire computer skills by themselves. These results showed that the students know some ICT skills, but many science students still lack a deeper understanding about the possibilities of ICT.

In 2004 the compulsory course syllabus scheme developed the inclusion of some special courses for teaching ICT basic skills to students at Iranian schools. Examples of the addressed grades are math students in the 8th and 9th grades. They were assigned a compulsory ICT course. By the end of the teaching syllabus, students were supposed to have learned how to use different applications of ICT from their teachers.

ICT infrastructure. The use of computers in teaching and learning processes is quite new. Hence, a crucial factor contributing to the development of the novel method is based on availability of infrastructure resources. These foundational resources consist of hardware, in terms of number of computers available for students and teachers for educational purposes, the quality and functionality of the equipment (speed of processors, operating systems, peripherals and access to Internet) as well as the availability of software (Venezky & Davis, 2002).

Among the observed Iranian schools in this study, it was realized that many of them have equipped themselves with various kinds of computers. In one school, there were ten Pentium Computers in a laboratory and about three computers were located elsewhere in the school, but they were in need of more facilities. All computers have Internet access through the local network. Each school had one TV monitor, one printer and a scanner. The network was managed through assigning students usernames and passwords for access.

However, this much penetration of technology seems inextricably insufficient for the purpose of relying on the available infrastructure in the context of the present research. The demand for more facilities and the urgent need of providing dependable infrastructure is obvious.

Conceptual Model to Develop Pedagogical Model on Teaching Chemistry through Computer-Assisted Guided Inquiry

Literature review shows rational use of computer in teaching chemistry (Clark et al., 2003; Henriques, 2002). The reason is that the computer enhances meaningful learning of chemistry (Dori & Barak, 2000), and develops the learning environment (Paul, 2002).

Studies indicate that the computer improves the traditional teaching and learning process. Access to new educational software and other tools of computer-mediated learning has changed instruction from teacher-centered teaching to student-centered learning. The ICT infrastructure resources are necessary for developing information capabilities, higher-order thinking, communication, collaboration, and other capabilities which could change learning goals and provide possibilities to develop new essential capabilities.

Indeed, ICT supports chemistry, and provides a more effective delivery of the chemistry curriculum. It also extends the curriculum-method and content -- product and process -- into new and useful territories which have not been possible in the past.

However, there are still deficiencies in our understanding of the principles behind the design and implementation of computers in learning chemistry environments and the development of the pedagogical model.

Andersoon and Weert (2002) describe four approaches to ICT-related teaching and learning. Firstly, ICT tools are taught as a discrete subject. Secondly, learning how to use ICT tools and development of ICT skills is integrated into a discrete subject. Thirdly, understanding how and when to use ICT tools to achieve particular purposes of ICT across the curriculum, and as a theme in all the subjects. Fourthly, specializing in the use of ICT tools (ICT is learned in specialized subjects or professional courses).

These approaches are parallel, and development in school is due to applying, infusing, and transforming. Each stage is characterized by indicators such as vision, learning pedagogy, development plans and policies, facilities and resources, understanding of curriculum, professional development for school staff, community, and assessment.

In order to reach a clear understanding of the use of computer in teaching chemistry, these indicators should be investigated. Therefore, the entire curriculum context for studying ICT pedagogical practices has to be studied within the three concentric contexts namely classroom, school, and community. These levels are mutually interacting and the boundaries are not clearly distinct (Kozma, 1999).

Pedagogical practices as an implementation of the school curriculum are necessarily affected by educational policies at the national level, which normally provide the framework for the intended curriculum. At the national level the pedagogical practice is often represented by curriculum planning experts, authors, and teachers who contribute to the formulation of school curriculum, as well as policies for enhancing technology infrastructure and support.

Changing attitude to leadership at the school level involves the factors associated with the entire curriculum process from intended to implemented curriculum in order to achieve curriculum goals. Such factors include school-based curriculum goals and resource development, ICT infrastructure, and methods as well as policies. Obviously, the change in strategy is largely influenced by the national plan/policy. The change in priorities thus influences key change factors.

Consequently, this study not only highlights practice in the classroom which is linked with school implementation and changing strategies, but it will also collect and analyze inside and outside school level data. Figure 2.2 shows the relationship amongst ICT, learning in the schools, and factors affecting the use of ICT in teaching chemistry.

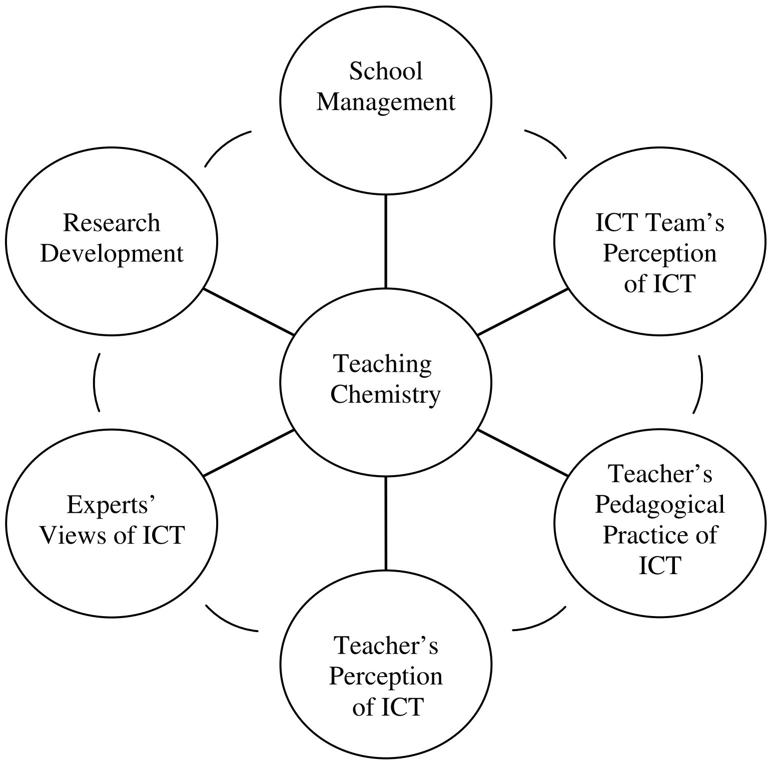

Figure 2.2. Factors affecting ICT use in Chemistry teaching in schools.

In this framework, ICT is technical competence to support pedagogical practice at the classroom level. In other words, technological confidence automatically leads to critical and skilful use of information and communications technology. Technical know-how by itself is inadequate; individuals must possess the cognitive skills needed to identify and address various information and communication technology needs.

Figure 2.2 clearly shows that, in this framework, ICT includes both cognitive and technical proficiency. Cognitive proficiency refers to the desired foundational skills of everyday life at school, at home, and at work. Technical proficiency, on the other hand, refers to the basic components of ICT literacy. It includes foundational knowledge of hardware, software applications, networks, and elements of digital technology.

As mentioned in *Curriculum Development*, a document published by the Curriculum Development Council in 1999, which acts as the basis for the curriculum reform, efforts are currently underway in secondary schools in Iran, indicating the overarching principle for the reform is to "help students Learn to Learn, which involves developing their independent learning capabilities leading to whole-person development and life-long learning". It recommends that learning and teaching in the schools should not only aim to bring about knowledge and understanding in the requisite subject matter, but also lead to the development of skills, as these are fundamental in helping students to learn to inquire, construct and apply knowledge to solve new problems; one of which is informational technology skills.

Furthermore, the same document recommends teachers to make use of tasks to "help students develop independent learning capabilities" across schools in Iran. One of these four tasks is "ICT for interactive learning". This key task plays an important role in supporting the achievement of the curriculum reform goals through helping students develop the ICT competences.

The curriculum reform document provides audio/video aids for difficult concepts, searches information from various sources, encourages interaction among the learners, resources and teachers, promotes collaboration between learners and teachers, and facilitates access to information, development of critical thinking and knowledge building. In addition, factors that would impact on students' use of ICT in their learning are presented in Figure 2.2. These factors are important in strategic development. The objectives in this study are to consider the current situation of ICT in empowering students' learning of chemistry at secondary school level which directly addresses "empowering learners with ICT" in the Strategic development plan. As can be seen in Figure 2.2, the two factors of "teachers' pedagogical practices with ICT" and "teachers' ICT competency and perceptions of ICT" are exploring issues concerning the strategy of "empowering teachers with ICT". The "school management" factor is related to the strategy of "enhancing school strategy for the knowledge age". The "digital resources" and "improving ICT infrastructure and pedagogical model" factors are related to the research goal.

Besides, the study itself is a research on experts who will contribute knowledge and experience on the effectiveness of the strategy as well as impact of ICT on students' learning outcomes. In other words, the strategy of "providing continuous research and development" will be emphasized and will provide useful information on "school building". Moreover, chemistry education will be included in this study. To conclude, ICT is an important aspect in the learning outcomes arising from student learning in schools which is important to the preparation of students' lifelong learning abilities.

Chemistry Instruction

As mentioned before, this study focuses on the development of a pedagogical model for teaching chemistry to students in the tertiary school through computer-assisted inquiry. Focuses on pedagogical approaches were presented in the first section to provide the grounds for better understanding of the results of this study.

Moreover, the nature of chemistry was presented in the second section to justify how to design a pedagogical model for teaching the chemistry subject.

In this chapter, features of pedagogical models would be discussed following this brief introduction.

Pedagogical approaches. Among the targets of the present study is to examine experiences of some schools that have made advances in the use of ICT in chemistry classrooms. The researcher decided to observe the implementation of ICT as it is in use in chemistry classrooms; she observed ten classes across the selected schools.

Chemistry lessons were observed in terms of how ICT was used, while the specific roles of the teachers and students in the teaching and learning process were observed and analyzed carefully. Based on the grounded theory approach, it was found that the most notable variations were closely related to the kinds of pedagogical approaches adopted in the lesson.

In fact, the lesson was subsequently categorized under three different pedagogical approaches, namely:

Expository Approach: The expository approach to learning refers to the transmission of information from expert to novice (Ormrod, 1990). In expository instruction “the teacher is the source and the owner of knowledge” (Martin, 2003).

Instructors using expository methods dominate the presentation of lessons, and use strategies that include lectures, demonstrations, and computers (De Jong, 2005). The whole lesson follows a pre-structured sequence of steps. The teacher initiates each step by providing information and/or posing questions. The student responds, and the teacher will then provide evaluative feedback and follow up on the student’s response. The teacher exercises strong control over the development of the classroom discourse through such cycles of Initiation-Response-Evaluation (IRE).

The functions performed by ICT during the teaching and learning process would include: 1) to display notes and drawings to supplement the teacher’s oral presentation, 2) to locate the topic of learning in an interesting context, 3) to supply stimulus materials to elicit ideas from students for discussion, and 4) to provide visualization for the understanding of dynamic processes. The teachers also provided the names of web sites so that the students could do follow-up reading after the teachers’ exposition.

Although ICT was used in teaching the lesson, there were often other types of activities such as paper and pencil work. An example of ICT adoption in expository teaching is shown in Table 2.1.

Table 2.1

A Summary of Expository Teaching

Lesson	Topic	Teacher's role	Student roles	Use of ICT
Chemistry	Ionic	Shows PowerPoint slides containing notes, equations, and diagrams for supplementing electronic whiteboard explanation	Group work	-Presenting information (e.g. PowerPoint slides, -Demonstration and visualization (e.g., simulation, animation multimedia).

Task-Based Approach to learning: Historically, Task-Based Learning (TBL) seems to be used mainly in language learning. According to Willis (1996), "the task is a goal-oriented activity in which learners use language to achieve a real outcome…learners use whatever target language resources they have, in order to solve a problem, do a puzzle, play a game, or share and compare experiences".

Some educators have also put ideas similar to task-based learning activities forward quite strongly. This includes those who advocate theories of constructivism and apprenticeship learning (Kafai & Resnick, 1996). These views raise fundamental doubts about the validity of conventional learning of declarative knowledge, which is distanced from the actual physical and social context.

At the beginning of the lesson, the teacher usually takes an active role in providing the background of the task (reviewing related knowledge, introducing the purpose of the task, and so on) and in teaching students the use of the technology.

In a task-based lesson, a substantial part of the time is allocated to students for working on the task, either individually or in groups. In the process, the students are playing an active role in their work. Here, the teacher's control is exercised indirectly through the definition of the task goal and directly through the discussion with students during their work.

In discussions between the teacher and the students, the teachers typically play a less prescriptive role. They often coach reactively, in the sense that their directions or assistance is given based on what the students want. They give their advice only after they have solicited and understood the ideas of the students, and try as much as possible to follow the students' line of thinking. In some cases, the teacher works as a technical support person for the students. The students tell the teacher what they want to do (but cannot do), and the teacher tells them what technical steps could be taken.

Some teachers would conduct an interim or final review of the task products by the whole class. In these review sessions, the teachers would play a facilitating role. They highlight key questions and invite comments from the students. An example of ICT in a task-based approach is shown in Table 2.2.

Table 2.2

A Summary of the Task-Based Approach

Lesson	Topic	Teacher's Role	Place Task	Use of Technology
Chemistry	Atom	- highlights relevant previous learning; - assigns the task, explains the purpose, and key expectations; - explain use of the IT tools; - work in small groups, and discusses in class.	Computer laboratory	Electronic version of an atom

Problem-Based Approach to learning: The early applications of PBL were in medical schools in the 1960s. It is now widely used in the field of education. The PBL instruction addresses the ability to: 1) think critically and be able to analyze and solve complex, real-world problems, 2) work cooperatively in teams and small groups, and 3) demonstrate versatile and effective communication skills, both verbal and written (Duch, Groh, & Allen, 2001).

In PBL, learning begins with facing a messy, unstructured real world problem. The problem triggers the learning by having students define the problem, analyze the problem, generate hypotheses, and identify learning issues. Students then work in small groups to discuss the problem scenario. They ask themselves questions, such as what they know from the problem scenario presented, what they need to know and what ideas come to mind to solve the problem (Aspy, Aspy, & Quimby, 1993).

Problem-Based Learning includes students' abilities: a) to pose questions and/or answer questions about a suitable issue intelligently by formulating strategies/plans and conducting investigations, b) to collect data, c) to analyze data mechanically, d) to use the computer and spreadsheet programs (Excel) as a tool for statistical calculation, e) to represent data graphically using Excel, and f) to interpret data and draw conclusions. An example of ICT in the problem-based approach is shown in Table 2.3.

Table 2.3
A Summary of a Problem-Based Approach

Lesson	Topic	Instructional Objectives	Teaching Objectives	Classroom Activities
Chemistry	Covalence	- motivation and test students; - group work; and to reinforce the concepts learned	Students' abilities to: - analyze questions posed, plan conduct of investigation; - collect data; - apply measure of average; - use computer and spreadsheet; - represent data graphically using Excel; and - interpret data and draw conclusions.	- brainstorming; - questions posed; - method, investigation, and data collection; and - review, revise, collected data.

Nature of Chemistry. According to Erduran and Scerri (2002), the philosophy of chemistry describes the nature of chemistry, for example, how different classifications schemes help explain qualitative aspects of matter.

Furthermore, exploration of the nature of chemistry involves how different class concepts, for example acid and salt, are used as a means of representation, and how some concepts play very specific roles in chemistry explanations such as chemical composition, molecular structure and bonding, and how electrons in a particular orbit are employed in "level specific" explanations.

This project is a pedagogical model development for chemistry teaching-learning computer-assisted guided inquiry that is designed to support and integrate into the traditional high school chemistry classes. According to the same rationale, various kinds of models and representations such as mental, expressional, consensual, scientific, historical, curricular, educational, pedagogical, and hybrid could be used in chemistry and/or chemistry education.

Their modes of representation can usually be concrete, verbal, symbolic, visual and/or gestured at macroscopic, (sub)-microscopic and/or symbolic levels which chemists exhibit with high fluency through their scientific thinking (Russell et al., 1997). Macro refers to the phenomenological modes or what can be perceived by the senses without the aid of instruments; this is usually concrete. The micro refers to the mode which can only be perceived with the aid of instruments or the one which is abstracted by inference from chemical processes; this is often abstract. The symbolic mode refers to symbols, models and equations which are often representational. The micro and the symbolic enable one to interpret the macro. These interact with each other and have to be manipulated skilfully for understanding to occur.

The novice learner has great difficulty in working at three levels at the same time, almost certainly because of overloaded information (Mbajiorgu & Reid, 2006). Since the 1960s the emphasis in chemistry teaching is much more on the symbolic level of representation than on the macroscopic level (Gabel, 1998).

There is not, however, one effective teaching model that leads to conceptual understanding; rather, understanding is achieved by linking models together in an appropriate fashion (Gabel, 1998). The details of the pedagogical model used in this study for chemistry teaching are explained in the next part.

Pedagogical model in Chemistry teaching. Since the late 1980s, inquiry based learning has been one of the new approaches in scientific education. Students at all grades and at any scientific domain should have an opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry (National Research Council, 1996). This point of view requires students to combine processes and scientific knowledge to develop their understanding in chemistry.

Inquiry is a term used in teaching science that refers to a way of questioning, seeking knowledge and information or finding out about phenomena. Moreover, it is believed that inquiry is a combination of behaviors involved in the struggle of human beings for reasonable explanations of phenomena about which they are curious (Novak, 1964). From a pedagogical perspective, inquiry-oriented teaching is often contrasted with traditional expository methods and reflects the constructivist model of learning, often referred to as active learning. It has been believed that learning is the result of ongoing changes in our mental frameworks as we attempt to make meaning out of our experiences (Osborne & Freyberg, 1985). Thus, in classrooms where students are encouraged to make meaning, they are generally involved in developing and restructuring their knowledge schemes through experiences with phenomena, through exploratory talk and teacher intervention (Driver, 1989b).

Therefore, we could define scientific inquiry as the ways in which scientists study the natural world and propose explanations based on evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of the scientific study of the natural world. Generally, the inquiry-based science instruction engages students in the processes of formulating predictions, organizing and interpreting data, and communicating results using science terminology. In this model the teacher is the main facilitator and is the resource who guides students toward instructional goals, a process known as scaffolding (Vygotsky, 1978). There are various pedagogical models for inquiry to support meaningful learning, for example, structured inquiry, guided inquiry, and open inquiry as depicted in Table 2.4.

Table 2.4

A Summary of Pedagogical Model Inquiry

Open Inquiry	Guided Inquiry	Structured Inquiry
Students follow precise teacher instructions to complete a hands-on activity.	Students develop the procedure to investigate a teacher-selected question.	Students generate questions about a teacher-selected topic and design their own investigations.

In this structured inquiry, teachers provide students with a question and the process to help them to find answers. Teachers lead students step by step through the scientific process. In open inquiry, teachers furnish the materials for students' learning to investigate, but students must come up with the question and method for investigation. Teachers vary considerably in how they attempt to engage students in the active search for knowledge. Some teachers advocate structured methods of guided inquiry (Igelsrud & Leonard, 1988), others promote the use of heuristic devices to aid skill development (Germann, 1991).

However, inquiry has also been mentioned as an approach to high school chemistry instruction in the Iran national curriculum framework (Curriculum Council, 1998). The pedagogical model of this study is based on Guided Inquiry. Guided Inquiry is found on the belief that learning is a process of personal and social construction. A view of learning as a process of social and personal construction is deeply embedded in the American educational tradition and has been developed by influential 20th century thinkers such as Vygotsky (1978), Bruner (1960), Piaget (1973). Constructivist learning emphasizes an active search for meaning and understanding by learners. It believes that: 1) learners must construct deep knowledge and deep understanding rather than passively receiving it, 2) learners are directly involved and engaged in the discovery of new knowledge, 3) learners encounter alternative perspectives and conflicting ideas so that they are able to transform prior knowledge and alter it into deep understandings, 4) learners transfer new knowledge and skills to new circumstances, 5) learners take ownership and responsibility for their ongoing learning and mastery of curriculum content and skills, and 6) learners contribute to social well-being, the growth of democracy, and the development of a knowledgeable society.

Concluding the above discussion, it can be stated that, the Inquiry approach in chemistry teaching refers to a way of questioning, seeking knowledge or information, and finding out about phenomena. The Process-Oriented Guided Inquiry Learning is based on a learning environment where students are actively engaged in mastering course content and in developing essential skills by working in self-managed teams on guided inquiry activities. In addition to learning, understanding, and applying new concepts, students also develop important process skills in the areas of information processing, critical thinking, problem solving, teamwork, communication, management, and assessment. The instructor facilitates student learning by appropriately guiding and questioning the teams as they work through the specially designed activities.

Also, guided inquiry requires the ability to use technological tools such as spreadsheet, word processor, database and so on.

Mind Tools. Jonassen (1992) describes mind tools, or cognitive learning tools, as "computer-based tools which facilitate generative processes of information by learners" and tools which "facilitate critical thinking and higher-order learning".

However, there are both theoretical and educational justifications as well as practical reasons for the inclusion of Mind Tools into any curriculum development attempts. There are various theoretical justifications for deployment of mind tools in the current model development. Firstly, they allow for the construction of knowledge. Secondly, according to constructivist theory, knowledge is built by the learner and not supplied by the teacher. So, when teachers engage learners in reflective thinking, this leads to knowledge construction. Thirdly, they allow learners to reduce the cognitive load of some of the basic, lower level operations, thus enabling the learner to spend more time with higher level thinking processes. Lastly, they are efficient, and can be used across the curriculum and are rather inexpensive (Jonassen et al., 1998).

On the other hand, the educational justifications for the inclusion of mind tools are also different. They are cognitive processing tools which help the learner to become a more self-reliant thinker and problem-solver. They are also unintelligent tools that provide learners with the intelligence, not the computer. These are cognitive partnership tools that help learners transcend mental limitations such as memory, and are used for other practical reasons such as the lack of software, the cost, and the efficiency concern. Eventually, one of the most useful mind tools, with a strong theoretical and research background, is Concept Mapping which belongs to a category of computer tools that is designed especially for learning (Jonassen, 1992).

Finally, the practical reasons for using mind tools are stated as the lack of software and availability of computer-assisted instruction materials only covers a fraction of the curricula, the high cost of purchasing even a few CAI programs, and even a small set of mind tools which can be used efficiently across the curricula. Moreover, this is also believed to be more time efficient because lesser time is spent on learning to use different programs. This by itself is the skill which lasts long and is deposited for future reference (Jonassen, 1996).

***Cooperative learning*.** Cooperative learning is a successful teaching strategy in which small teams, each with students of different levels of ability, use a variety of learning activities to improve their understanding of a subject. Each member of a team is responsible not only for learning what is taught but also for helping team-mates learn, thus creating an atmosphere of achievement. Students work through the assignment until all group members successfully understand and complete it. Research has shown that cooperative learning techniques promote student learning and academic achievement, increase student retention, enhance student satisfaction with their learning experience, help students develop skills in oral communication, develop students' social skills, promote student self-esteem, and help to promote positive race relations. As stated by Johnson and Johnson (1994), a cooperative learning situation can be structured using five elements: the positive interdependence of group members, individual accountability, face-to-face interaction, the development of social skills (e.g., communication, trust, leadership, decision-making and conflict management), and assessment of collaborative efforts by group members.

However, the deployment of cooperative learning involves several important steps including explaining the task and cooperative structure of the lesson, monitoring all learning groups and intervening when necessary, assessing students' achievement of learning goals and teamwork, and processing students' achievement of learning goals and teamwork.

Learning cycle. A model for infusing inquiry into the curriculum is the use of the Learning Cycle units. The Learning Cycle approach first engages student interest, usually through a hands-on mini-lab or demonstration, as well as through a pre-assessment activity such as concept map. Second, the unit allows students to explore through a lab activity or hands-on exploration, through which students gain concrete experience with the subject matter, with lab procedures, and with basic lab skills (such as data collection and data analysis). The Explore phase is also used to generate student questions, such as: "Why did that happen?", and "How does this work?" In this phase, students' questions are used as the basis for a study of the content and specific unit concepts. This phase might include readings, lectures, discussions, visits by or consultation with experts, web quests, or other information sources. As new questions arise, they are added to the list of unit questions.

Thirdly, In the Elaborate phase, students apply their lab skills, content knowledge, and process skills to deeper exploration of the subject. Finally, the Evaluation phase may include new information (a return to concept map, a test or quiz, a student reflection), but should also include information from the previous phases (lab reports, posters, or presentations, web quests or homework assignments, student reflections, peer and/or self ratings for group work, etc.). However, it can be concluded that the Learning Cycle helps to balance and enhance both the understanding of concepts and the development of process skills.

Role of ICT in Chemistry Instruction

The implementation of ICT in the teaching of the chemistry subject around the world has stimulated numerous initiatives and has been subjected to controversies on the utilitarian purposes which less experienced chemistry instructors might be able to conceive. However, the following implementations support the inclusion of ICT into the chemistry class. Firstly, ICT can support chemistry learning through simulations and modeling systems, multimedia, microcomputer-based laboratories, basic tools (e.g., word processors, spreadsheets, graphic software), communication applications (e.g., e-mail, videoconferences, newsgroups, course management systems), and databases (Voogt & Van den Akker, 2002).

Secondly, as stated by Webb (2005), the ICT-rich learning environments support learning through four main effects including promoting cognitive acceleration, enabling a wider range of experience so that students can relate scientific activities to their own and other real-world experiences, increasing students' self management, and facilitating data collection and presentation.

Finally, the role of the World Wide Web (WWW) in developing patterns of usage for ICT application in chemistry instruction is vital. In the virtual environment learners can imagine unimaginable chemical formulas and composites. The role of the Internet in such development is elaborated in the next section. It can be traced back and proved that ICT has become known rapidly via the Internet. Tsai (2005) states that the Internet can be used to create learning environments where students are allowed to explain and defend their thinking, opinions and decisions in order to cultivate critical thinking and meta-cognition. Studies have shown that it is the penetration of Internet which is influencing the familiarity of learners with class-applicable software. An example of this software is the Mind Mapping Software.

However, the use of Concept Mapping software as a meta-cognitive tool to facilitate activities involving the structuring of knowledge is undeniable. The Microcomputer-Based Laboratory (MBL),—a good representative of these Internet-based mind mapping software— has been used in chemistry education since the 1980s (e.g., Nakhleh, Polles, & Malina, 2002). The instructional effectiveness of MBL is linked to the pedagogical approach employed (Linn, 1995). However, it is recommended that the students' activities must be carefully structured. An MBL activity cannot teach anything, or enhance student learning in chemistry, unless it is used with a curriculum, a school, and a social context (Newton, 1997; Tinker, 1996).

Moreover, the students' interactions with the teacher are important in maximizing potential benefits from MBL use (Barton, 1997). It is also recommended that, whenever possible, teachers should engage students in discussions on the meaning of graphical data (Barton, 1997). Talking to students about their graphs improves their ability to describe them, and encourages them to reflect on their meaning. Yet from another aspect, ICT can be used as a tool such as word processors, spreadsheets, graphics, packages, scanners, digital and video cameras, presentation applications, and databases or as an agent for interaction with an information source. For example, the computer can provide versatile opportunities to support teaching (Kozma, 1991). In particular, it provides new opportunities for chemistry learning (Lagowski, 1998), and provides opportunities for interaction and communication (Smith et al., 2005).

According to Donovan (2001), students found it useful, especially when they are accessing materials and information, needing help, and intending to gain a better understanding of chemistry. The Web can provide new opportunities, for example, to support learning in chemistry by easily bringing together various visualizations of media: video, audio, graphics, and text to help in students' knowledge integration. It can help students to integrate information in chemistry by using various visualization technologies, for example, molecular modeling and drawing programs to study their experimental results for a proper understanding of phenomena (Russell et al., 1997).

Waddington (2001) states that technological innovation in chemical education has become an integral part of the learning environment once it is used as a tool to seek and process information, and reflect on one's understandings, beliefs, and thinking processes. Applied in this way, technology is "empty" as it allows the learner to enter information and explore new content relationships. Ordinary software applications, such as word processing, spreadsheet, graphics presentation, and database software, problem solving software, simulations, electronic mail, and the Internet are technology tools that fit into this category. These applications help the user to control almost everything that happens, including the interaction between the user and the machine. Rather than rote memorization of facts, these applications encourage creative, higher level tasks. From the perspective of human roles change, technology can change the role of the teacher and also alter the interaction in the classroom. Learning becomes a public and highly visible activity by using technology. It can support students as they build shared meaning through a collective transformation of their learning experiences (Roschelle, 1996). "In our observations of technology–using classrooms, observations showed the numerous examples of students acting as peer coaches to each other, and offered advice when a peer had trouble; such advice-giving was continual when students were working individually on computers (Means & Olson, 1997). Concluding the above discussion, one must not imagine the application of ICT for the purpose of diffusing technology into the real practice within the classrooms without recognizing the role of the Internet which can be supportive and widening the software deployment.

Recent research relating to ICT in Chemistry classes. Information and Communication Technology has an important role in scientific teaching. Rapid development in hardware and software means a great deal of unfeasible technological opportunities is now possible, yet there remains a considerable gap in pedagogical modeling for teaching chemistry in the classrooms. An integrated study of ICT in teaching science consists of some obstacles, including insufficient material resources, inadequate new information and communications technologies, inappropriate technologies in the scientific fields and specific areas, and misconceptions, especially where teachers would be considered less important, and the idea that the use of ICT is a waste of time (Gomes, 2005).

However, ICT includes some restrictions such as lack of pedagogic and didactic information about the use of ICT in classrooms, lack of appropriate infrastructure, resistance to the change from teachers concerning the use of new strategies and methodologies justified by the didactic research in sciences, and lack of technical support to organize the ICT area. Indeed, what chemistry should teach to the majority of students, is still very problematic (Gilbert et al., 2004). Schank and Kozma (2005) illustrated that many students have misunderstanding about the nature of matter, chemical processes, and chemical systems. In other words, the challenge at this time concerns the design, implementation, and assessment of computer-aided teaching methods (e.g. Wu & Glaser, 2004).

On the other hand, there are still many unsolved problems, despite the advances made in software development and design innovations. Therefore, there is a need to explore the issues that a teacher faces when implementing computer-based activities into the chemistry classroom and to provide teachers with information that may ease the transition of technology into instructional praxis in science classrooms throughout Iran. However, a naturalistic study provides an appropriate means for conducting such explorations; the present research could be an initialization of it.

ICT Use in Teaching of Chemistry in Iran

As mentioned before, the use of computer in the teaching-learning process has been developed in Iranian schools since 1998, and it was particularly used in chemistry classes since then. At first, the educational systems faced some questions such as: “What should be taught?”, or “How should it be taught?”, “How to assess if it is taught well?”, “Who should be taught?”, “Who should teach?”, and many more. Therefore, the Iranian Chemical Society publication “Recommendations for the Education of Chemistry” presented some guidelines to prepare high school chemistry teachers prior to the introduction of the procedure.

In Iran, the chemistry curriculum at high schools focuses on the understanding and application of concepts, skills, procedures and processes in different situations, such as real world problems faced in daily lives, and developing attitude towards learning chemistry and science (National Curriculum, 1998). In chemistry, the curriculum uses an inquiry-based framework, where it foresees students acquiring concepts, processes and thinking skills, attitudes and values through inquiry activities that relate to the roles played by science in daily life, society, and the environment. The science curriculum provides students from the primary to the middle and high levels with a firm foundation in the fundamental knowledge and understanding of scientific facts and concepts, with hands-on experience of science that builds upon their natural interest and curiosity in the environment around them. The science curriculum builds upon the foundation of knowledge, skills and attitudes in at least two of the three sciences, namely, Biology, Chemistry and Physics. The appropriate use of ICT can assist in making knowledge come "alive" by making visible the metacognitive or thinking processes of both teachers and students. Figure 2.3 presents a basic framework of pedagogical teaching of chemistry in Iranian schools.

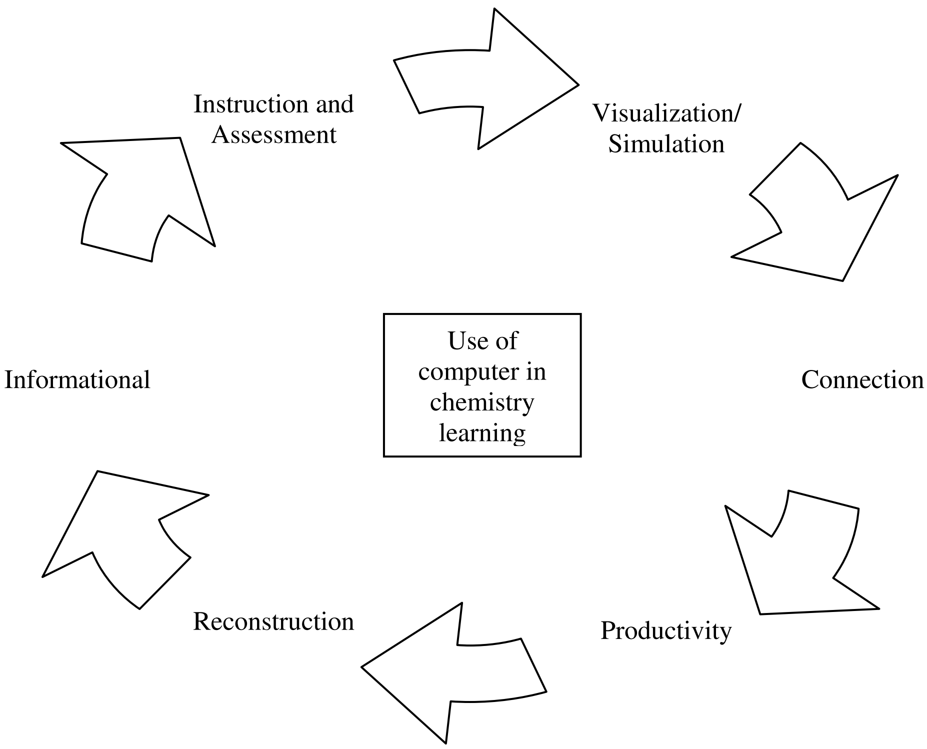

Figure 2.3. Diagrammatic representation of the framework for conceptualizing and analyzing a pedagogical model for teaching chemistry in school settings.

In early 1998, the Ministry of Education explored the use of computers in the educational system. This provided a series of drill-and-practice in classroom exercise on a range of scientific topics in the high schools, and gave immediate feedback to the learners as well as provided the appropriate scaffolding to guide learners in their problem-solving tasks. Although the computer was not integrated into the curriculum by then, a significant number of high school teachers made the very first attempts at using ICT in significant ways in their teaching.

In 1998, the Ministry of Education (MOE) provided some schools with the basic ICT infrastructure such as computers and Internet access. MOE also mass-acquired courseware, both developed by MOE and by commercial publishers for high schools, and provided basic ICT training for all teachers. These strategies prompted a shift in the range of ICT tools utilized, which resulted in a more widespread use of ICT in the chemistry curriculum in schools. Over the past 10 years, an obvious shift has occurred from teachers using ICT tools to prepare lessons, to designing lessons where students are engaged in using ICT tools for learning.

The use of ICT in chemistry involves a range of ICT tools, namely productivity tools such as Microsoft Word and Microsoft PowerPoint which are used to prepare lessons and lesson materials such as activity sheets, and the Internet which is commonly used by teachers to search for interesting information for incorporation into lessons to enhance learning. While we see that more teaching and learning now incorporates ICT, the pedagogies used by teachers are still predominantly teacher-centered. It is imperative to change this and shift teachers from teacher-centered to learner-centered pedagogies. The majority of teachers are still not comfortable with using ICT as a connection and reconstruction tool to expand students' learning opportunities. As mentioned before, there is increasing evidence that the beliefs of teachers strongly influence their pedagogical practices in the classroom. As a result, the High School Chemistry Curriculum requires them to develop a pedagogical model through computer-assisted guided inquiry for teaching.

Summary and Conclusion

The future classroom would operate in different ways than in the past with the use of ICT in the classroom. Teachers try to motivate and develop their interaction with their students by using technology. There is a large and growing body of knowledge about the role of technology-enhanced instruction. However, there is insufficient published research concerning the teachers' roles, students' roles, technology roles, and interaction among them when incorporating ICT into classroom activities. The current researcher attempted to provide an ideal setting for studying the incorporation of technology into chemistry instruction in Chapter **Two.** Such a study will also contribute to valuable scientific knowledge, since at this time; there are no published studies dealing with the efforts and issues of a pedagogical model through computer use for teaching chemistry in Iran. The present researcher strongly believes that there are potential benefits for utilizing and implementing ICT into the current learning and teaching practice of the chemistry subject nationwide. Therefore, she would like to insist on the fact that such a study is considered still rudimentary and eye opening, and richer research is urgently recommended.