Chapter 2

REVIEW OF RELATED LITERATURE

Studies worldwide have shown that the use of computers have helped teachers upgrade and improve the quality of learning and teaching in their respective schools. The multiple abilities of the computers could be utilize to overcome the various weaknesses in the traditional mode of teaching and learning.

Meta-analyses conducted by Kulik, Kulik & Cohen (1980) on the overall effects of computer-based instructions (CBI) found that students performed better than their counterparts who learned using traditional instructions. These students also showed a more positive attitude toward learning using computers and toward the subject matter. The most significant finding in this meta-analysis was that students learned more quickly using computers than in conventional classes (Kulik, et al., 1980). Similar results were also obtained by Savenye (1990) during a study on the effectiveness of interactive videos where learners studied faster and have a more positive attitudes towards learning through interactive technologies.

In a related study, positive results have been obtained on the effects of computers in teaching and learning where the quality of teaching and learning conditions have been found to be improved (Kulik, Kulik and Cohen, 1980;O'Shea and

Self ,1983; Kulik, Bangert and Williams, 1983; Kulik, Kulik and Bangert-Downs, 1985; cited in Wainwright, 1989).

Computers in the Teaching and Learning of Chemistry

Computers in Chemistry teaching, in general, have been used since the 1960's in developed countries. Then, it was largely concentrated in higher education, after which it slowly spread its influence to the secondary schools. One of the first computer programmes to be used in undergraduate chemistry teaching was at the University of Illinois, North America. Some of the many claims for the advantages of using computers in teaching and learning are, the computer can;

1. increase students' motivation to learn
2. increase students' self-concepts
3. increase students' achievement over traditional instructional procedures
4. facilitates delivery and management of instruction, thereby allowing teachers more time to devote to individual instructions and remedition.

(Reith, Bahr, Okolo, Polsgrove, Eckert, 1988).

Other researchers(Bork, 1980; Steinberg, 1984; Schloss,Wisnews and Cartwright, 1988;Kinzie and Sullivan, 1992; Cox, 1992;Chan, 1993), have claimed that the use of computers can also:

1. promote perceptions of personal control
2. provide for continuing motivation
3. provide truly individualized learning
4. provide for a high level of interactivity

Computer-based teaching and learning can also, according to Bollough and Beatty (1991), encourage students to try new things without fear of making mistakes, have a powerful socializing effect on students and facilitate monitoring of students' progress in great detail and with precision.Yet other studies have shown that problem-solving skills could also be improved through computers in education where students learn more rapidly, their self-esteem increased, cooperative learning encouraged as well as learning be made less intimidating (Braun, Moursund & Zinn, 1992). Studies done by Culp and Castleberry (1981) have found that computers can be an effective tool in teaching Chemistry.

Computers it would seem, could provide and deliver some of the above advantages in the teaching and learning of Chemistry. This is because Chemistry is one of the most visual of sciences which is highly dependent on spatial-visual intelligence. Habraken (1996) believed that two of Gardner's *Multiple Intelligences,* spatial intelligence and bodily-kinesthetic intelligence are of particular importance to chemists. Bodily-kinesthetic intelligence is the ability to solve problems using one's whole body or parts of the body. Spatial intelligence, on the other hand, involve visual memory, visual imagination, and the mental processes of visual information (Habraken,1996). The spatial-visual approach is considered to be one of the most important aspect in communicating with non-chemists or for beginners in chemistry (Atkins,1987).

According to Habraken (1996), Chemistry has become a science in which ideas and information are communicated by pictures, that is via computer imaging. If the chemist's goal is to come to a deeper understanding of molecular structure and reactivity, then the use of imagery and visualization is indispensible. This view is supported by the fact that chemistry is a science that actually bridges the boundary between the visible and the invisible, the macroscopic properties of matter that we see, smell and touch, and the atoms, molecules, electrons, and bonds that we are unable to see directly. Thus it would appear that chemists work on both sides of this boundary (Beall, Trimbur and Weininger, 1994). Bridging between these two boundaries means taking the invisible and making it visible by utilizing what is known about both the macroscopic and the microscopic. Once this fact is recognized, then a more effective pedagogy can then be utilized. One of the main complaints of beginning students of chemistry is: how do chemists conceive the particular explanations that they offer for a particular phenomena (Beall *et al*, 1994).

Learning chemistry actually requires that students relate chemical equations and other symbolic notation, both to molecular or atomic events and to macroscopic observations in the laboratory and data. Learning chemistry then requires the student to relate macroscopic observations, sub-microscopic interpretations, and symbols to one another (Brooks and Brooks, 1996). Learning to operate in these three worlds for the beginning students is difficult (Herron and Greenbowe,1986; Beall *et al.*,1994; Sanger and Greenbowe, 1997). In fact many chemical processes are difficult to communicate effectively because the concepts require individuals to visualize the movement of molecules, ions or electrons (Herron, & Greenbowe ,1986). At the same time, understanding chemistry, according to Kozma and Russel (1997), relies on making sense of the invisible and untouchable since much of what is chemistry exists at the molecular level and thus is not accessible to direct perceptions. Consequently, chemistry as a field of study is inherently representational or symbolic. Herron (1975) has described the world of chemists as operating in three worlds: the macroscopic world of everyday substances, the microscopic world of atoms and molecules, and the symbolic world of formulas and equations

It is important that instructors help students make the connections between the three levels of representation in chemistry, that is, at the macroscopic, microscopic and at the symbolic level (Greenbowe, 1994). The macroscopic level are the demonstrations and the laboratory activities which allow the students to directly observe the chemical reactions. The missing component, however, is the microscopic level of representation of the chemical reaction. Thus computers, specifically through the use of multimedia elements like graphics, animations and simulations can provide the link to bridge the apparent gap between the three levels of representations mentioned.

Difficult Topics in Chemistry

Studies have been conducted to identify specific topics within the science discipline areas (General Certificate of Education Advanced level) felt to be difficult by chemistry teachers and students alike (Fineley, Steward, Yarrock, 1982 and Welding, 1989). They are:

1. atomic structure
2. arrangement of electrons
3. stoichiometric reaction
4. the mole
5. chemical equation
6. writing chemical formula

Another topic which students also found difficult was the operation of cells (Finley, Stewart & Yarroch,1982; Butts & Smith, 1987). Researches have indicated that students found Electrochemistry difficult to master because they could not imagine or observe what happened at the microscopic level in an electrochemical reaction (Yochum & Lucona, 1995). It was also likely that electrochemical and electrolytic cells were topics that posed considerable conceptual difficulty for chemistry students due to the fact that an understanding of oxidation and reduction might be regarded as prerequisite for understanding these cells (Garnett & Treagust, 1992).

Another research findings by Grandey (1971) have found that the most difficult concepts for beginning chemistry students are those which involve the use of several steps or a combination of concepts. An understanding of each step in the problem-solving procedure usually require an understanding of each preceeding step. Electrochemistry is an example of a chemistry topic which requires a student to understand certain prerequisite concepts before learning the concepts in the topic. Some of these concepts include an understanding of atoms and ions, the inter-conversion between atoms and ions through the loss or acceptance of electrons, the writing of half equations, the concept of electricity , the chemical formula of chemical compounds and the writing of balanced chemical equations.

To date there has relatively been few in-depth studies done in Malaysia on the problems encountered by students in Electrochemistry either at the secondary level (Form Four), the upper secondary level (Form Six) or at the undergraduate level. A study by Chan (1990) on Form Four students revealed among others that the concept of mole, calculations in electrolysis, as well as chemical equations, were some of the difficult concepts to be learned. A third of the students in his survey have difficulty in understanding the concept of ion and chemical bond. It must be noted that prior to the *KBSM*, the chemistry syllabus had included Faraday's Law and its calculations in the topic Electrochemistry.

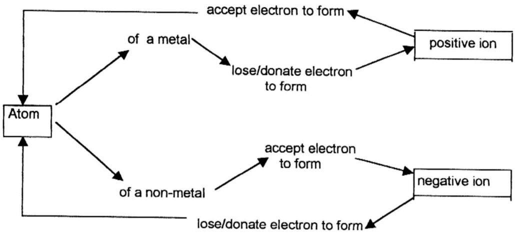
The concepts covered in Electrochemistry in the present *KBSM* syllabus, at the Form Four level however, only covers the concept of electrolysis and chemical or galvanic cells. It does not include oxidation and reduction nor does it include the calculation of Faraday's Law and the calculation of potential difference in chemical cells. The concepts of oxidation and reduction are only covered in Form Five whereas the calculations involved in the potential difference are covered in Form Six. Nevertheless, students still do not find Electrochemistry an easy topic to understand. These difficulties arise because, from the researcher's experience in teaching chemistry at the Form Four and Form Five level, students have difficulty in understanding the concept of atoms, ions, chemical formula, chemical bonds as well as writing balanced equations.

In another short survey, teachers themselves felt that Electrochemistry was one of the topics that was not easy subject to teach. They also felt that their students found Electrochemistry to be a difficult topic to understand (Sa'adah, 1992). The findings in this short survey would appear to be similar to another study, previously done by Johnstone (1980) and Fineley, Steward and Yarroch (1982) where it was shown that both teachers and students surveyed suggested that students themselves found the topic Electrochemistry to be difficult.

Electrochemistry is the fourth topic taught in Form Four chemistry. The preceeding three topics are Matter, the Periodic Table and the Chemical Bond. In order to understand the Electrochemistry, students need to be able to grasp and comprehend the concepts found in the three topics mentioned. It could be possible that some teachers may not be aware that one of the reasons students found Electrochemistry difficult to understand was because students may not have mastered the pre-requisite concepts in the three topics mentioned.

One of the most important concepts that students need to understand is the difference between an atom and an ion. Ions are formed when an atom loses or accepts electron/electrons. Atoms of metal lose or donate electrons to form positive ions while atoms of non-metals accept electrons to form negative ions. When an ion accepts or donate electrons, an atom is formed once again. This inter-conversion of atoms and ions can be represented in Figure 1 as follows:

Figure 1:
Inter-conversion of an atom and an ion



From the researcher's experience, many students do not seem to appreciate this inter-conversion between atoms and ions, as partly evidenced by their difficulty in translating these two concepts into half or ionic equations. The failure to grasp these concepts could be one reason why students do not understand the process of electrochemical cells. In another related study, Griffith and Preston (1992) have generalized that all chemical educators agree that the understanding of the concept of atoms and molecules are fundamental in the learning of chemistry since such understanding is essential to the learning of other concepts like chemical bonding, chemical reaction, ions and states of matter.

In the second chapter of the Malaysian Chemistry syllabus, students have learned about the atomic structure and the electronic configuration of atoms. From the researcher's observation, most students found it difficult to relate between the movement of electrons to and from the outer-most orbital shell of an atom during the formation of an ion, with the actual writing of the half-equation to represent these processes. In other words, students found it difficult to relate the microscopic reaction at the molecular level with the symbolic representation of that particular process. This concept is again imperative to allow the students to interpret the processes occurring during discharge at both the electrodes in an electrochemical cell and finally to represent it symbolically through the writing of half-equations.

The researcher also observed that a number of students have a problem in writing the correct chemical formula of a compound. One of the ways to write the formula of a chemical compound is to determine the charge of the particle in a particular compound and then crossing the values of the charge to the opposite particle. However, in most cases, the researcher observed that students did not know how to determine the charge of a particular ion in the first place. The weaker students did not seem to relate to the fact that the loss of one electron from the outermost shell of a sodium atom will result in a net increase in the positive charge carried by the proton.

One reason for this problem could be due to the fact that students may not be aware that the sodium atom which has 11 protons and 11 electrons is neutral. Protons carry the positive charge whereas electrons carry the negative charge. Thus the loss of one electron from the atom will result in the sodium ion having 11 protons and 10 electrons, which means that the sodium ion has a positive charge of +1. Mathematically, this process can be represented by the following equation:

11protons + 10 electrons = 1 proton net
(+11) + (-10) = (+1)

Hence the formula of a sodium ion is Na^+. This concept is important for students to understand in order for them to write the correct half equations to represent the chemical process occurring at the electrodes during discharge in an electrolytic cell. For example during electrolysis, if a sodium ion (a metal cation) is discharged at the cathode, an electron is accepted to form the atom sodium. This process is represented by the following half equation :

$$Na^{+} + e \longrightarrow Na$$

If students do not know the charge of an ion and if students do not know that a positive ion can be transformed back to an atom by accepting an electron, (see Figure 1) then they would not know how to write the half equation at the electrode. Thus, it can be seen how the understanding of the concepts of atoms, ions, structure of atoms and chemical formula can help in the understanding of the concepts in Electrochemistry.

Students also need to recognize from the second topic, that metals are usually found on the left side of the Periodic Table whereas non-metals are usually found on the right side. They also need to recognize which elements are metals and which are non-metals. This recognition is important to help students identify whether a compound is an ionic compound or otherwise based on the concept that an ionic compound is basically formed from a metal and a non-metal.

In many cases, the researcher observed that some Form Four students, after three to four months of studying chemistry, still could not recognize a metal from a non-metal. Thus they would fail to identify an electrolyte, which is essentially an ionic compound and a non-electrolyte which is a covalent compound. Students, it would appear, do not relate what they have studied in the second and third chapter with that in the fourth chapter. As an example, students do not recognize that sulphur monochloride is a non-electrolyte. This may be due to their failure in identifying that suphur is a Group VI element while chlorine is a Group VII element, both of which are non-metals. When two non-metals form a compound, the compound formed is covalent thus would not conduct electricity. Although they have learned, in the third chapter, that one of the properties of a covalent compound is its inability to conduct electricity, they still fail to relate that sulphur monochloride do not conduct electricity because the compound is made up of molecules; there are no free-moving ions to conduct electricity in the compound.

Another important concept usually overlooked by students is the presence of ions in an ionic compound both in the solid and in the aqueous state. In the first chapter, students have learned that particles in the solid state are closely-packed, thus movement of particles are restricted. When heat is applied to the solid, the forces between the particles can be overcome and the particles can then move freely. However, the researcher found that in many cases, students believed atoms or molecules exist in the solid ionic compound while ions are only present in the molten or aqueous state. The important difference between ions in the solid state and in the aqueous state has not been understood by most students. Thus questions regarding the reason for the inability of solid ionic compounds to conduct electricity could not be answered correctly by most students. In a related study, Ogude and Bradley (1996) have revealed that students thought free electrons are found in electrolytes. They also thought that without electric current, ions are not formed.

In addition, in the third chapter students learn that ionic bonds are formed when there is a transfer of electrons from an atom of a metal to an atom of a non-metal. The resulting ionic compound formed has a very high melting point and boiling point due to electrostatic forces between the two oppositely-charged ions within the crystalline structure of the solid ionic compound. These electrostatic forces in the ionic compound can be overcome by supplying a large amount of energy into the system or by the hydration process. As a result, the ions are now free-moving and the ionic compound is now said to be in the molten or aqueous state. The resulting free-moving ions will then allow electricity to be conducted through the compound. Many students, however, may not be aware of the described phenomenon.

Based on informal and formal questioning on students tutored for the last twelve years, both at the Form Four and Form Five level, it was found that most students were not able to relate electrical conductivity of a molten or aqueous ionic compound with the free moving ions. Most students merely know for a fact that ionic compounds in both the aqueous or molten state can conduct electricity without understanding the concept of electricity in solution.

Another area of difficulty found in this topic was that students do not know what happens during electrolysis itself. Based on the researcher's observation, students are usually confused about the movement of cations and anions in the electrolyte. This was perhaps compounded by the many terminologies used in the topic where cathodes refer to the negatively charged electrode while anodes refer to the positively-charged electrode. In addition, a positive ion is called cations while negative ions are called anions. This confusion regarding the use of the terms cathode, anode and positive and negative ions has also been found in studies done by Ogude and Bradley (1996) which can lead to misinterpretation of electrode events. In addition, students usually fail to realize that when electricity is conducted into an electrolyte during electrolysis, the free-moving anions and cations become polarized and move towards the oppositely charged electrodes. Some of these free-moving ions then become discharged at the electrodes by accepting or donating electrons to form atoms or molecules.

Since Electrochemistry involves chemistry and electricity, it is imperative that students understand the latter concept as well. Students need to know that the flow of electricity in aqueous solutions is due to the free-moving ions whereas electricity which flows along the wires is actually the flow of electrons. The confusion about this concept of electricity could be one of the reasons why students found the topic to be difficult. It would appear that the researcher's observations would concur with a related study by Garnett and Treagust (1992) who have found that nearly 40% of the students interviewed were confused about the nature of electric current in metallic conductors. In the same study, the nature of electric currents in electrolytes was also poorly understood by 56% of a sample of Grade-12 students (16-17 year old students).

Thus it could be seen that if students fail to understand these basic pre-requisite concepts, and teachers failed to recognize the importance of these pre-requisite concepts then Electrochemistry could be difficult to understand and to teach respectively. Table 1 indicated the topics taught to students in their first year (Form Four) and second year (Form Five) of chemistry. The fourth topic Electrochemistry has been made bold while concepts and topics that were inter-related to Electrochemistry have been underlined.

Table 1:
Topics covered in chemistry in Form 4

Form 4	Chapter	Topic	
	1	Matter	Concept of matter, Particulate theory of matter, states of matter, chemical symbol, mole concept relative atomic mass, chemical formula, empirical formula & chemical equations
	2	Periodic Table	History & development of the Periodic Table classification of elements, Characteristics of Elements in the Groups and Periods, transition elements
		Structure of atom	Structure of atoms, isotopes, electronic configuration, electron valency
	3	Chemical bonds	Formation of compounds, stability of the inert gases, formation of chemical bonds ie, the ionic and the covalent bonds. Differences between ionic compounds and covalent compounds
	4	**Electro-chemistry**	**Electrolytes and non-electrolytes , Process of electrolusis, Atoms and ions, Ionic theory Electrolysis of molten and aqueous solutions, electrolysis in the industry Electric energy from chemical compounds, types of chemical cells, Electrochemical series**
	5	Acids & Alkalis	Concept of acids & bases, Role of water in acids and alkalis, Strength of acids and alkalis, Measurement of acidity and alkalinity, indicators and concentration of acids and alkalis, Molarity, Neutralization and Titration.
	6	Petroleum	Carbon compounds, Petroleum, Fractional distillation & Hydrocarbon of Petroleum,Hydrocarbons, Homologous Series, Alkanes and alkenes, Structural and Molecular formula, Isomerism
	7	Chemical compounds in the industry	Alloy, Natural and synthetic polymers, pollution from from polymers, Glass, ceramics, sulphuric acid & its uses. Pollution of the environment
	8	Chemical	Production of food, the nitrogen cycle, Haber production compounds ammonia. Pesticides & its related issues, Synthetic hormones in agriculture

Table 2:
Topics covered in Chemistry in Form 5

Form 5	Chapter	Topic	
	9	Salts	Introduction of salts, Preparation of soluble and insoluble salts, preparation of crystals. Qualitative analysis of ions. Chemical stoichiometry
	10	Redox	Concept of oxidation, reduction & redox, Oxidising and reducing agents, Oxidation Number, Redox & the Electrochemical Series. Applications of redox in electrolysis, chemical cells, in displacement reactions, dispalcement of halogens from the halides, in corrosion, extraction of metals, and the Reactivity Series.
	11	Rate of reaction	Concept and calculations in the rate reaction Factors affecting rate of reaction, Collision theory, Applications of the factors which affect the rate of reaction.
	12	Thermo-chemistry	Change in energy in a reaction, Energy-level diagrams. Calculations of the enthalpies of precipitation, displacement, combustion & neutralization. Uses of chemical energy
	13	Alcohol, Organic Acids Fats and Oils	Alcohol, its homologous series, properties & preparationof ethanol. Organic acids & its homologous series, the naming, properties and preparation of ethanoic acid. Esthers in plants. Fats and oils, Saturated and unsaturated fats, Hydrogenation of unsaturated fats, Natural Polymers, Latex, starch and protein.
	14	Chemical compounds for consumers	Soaps, Saponification, Action of soap. Detergents Preparation of detergents. Food additives, Drugs

From tables 1 and 2, it can be seen that Electrochemistry is taught in Form Four and is repeated in Form Five in the topic Redox. The concepts of atoms and ions can be incorporated into the program as a prerequisite concept to Electrochemistry. Furthermore, if students can understand that ions or atoms either lose or accept electrons at the electrodes of the electrochemical during discharge, then it is hoped that they will be able to understand better the concepts of oxidation and reduction in the topic Redox.

Some of the observations made by the researcher about students' problems in Electrochemistry were confirmed by studies done by Hong (1997) who submitted that there appears to be confusion in the students' mind about concepts related to particles and their interactions (such as atoms, ions, molecules, bonds and others). Hong claimed that almost everything within chemistry is based on an understanding of particles and their interaction. According to Hong, if the conceptual and conjectural nature of many of the ideas of atoms, molecules and ions is not understood by students, then many alternative concepts may arise such as those related to the attribution of macroscopic properties to microscopic particles.

Other studies have also been done on misconceptions about molecular structure and bonding (Birk, Kurtz & Martha, 1999), the current flow in electrolyte solutions and the salt bridge (Sanger and Greenbowe, 1997), covalent bonding and structure (Peterson and Treagust, 1989) and other common misconceptions in chemistry (Bradley and Brand, 1985).

Through the years, the researcher observed that teachers tend to teach Electrochemistry straight from the third topic of chemical bond. In most cases, teachers probably assumed that students have understood all the concepts that have been taught in the first three topics. It is likely that few teachers would try to ensure that students have thoroughly understood all the pre-requisite concepts mentioned above before teaching Electrochemistry.

Multimedia in Teaching and Learning

Traditionally, learning has usually been 'controlled' by the teacher. Students have no power on their own learning. In many cases, from the researcher's observation, classroom teaching involves teachers trying to explain the concepts of a particular topic to the students while they in turn, are expected to listen and pay attention to the teachers. This one-way process in the transfer of knowledge from teachers to students totally ignored the individual needs and abilities of students. Teachers generally teach assuming that the whole class is made up of pupils with equal aptitude and capabilities.

Assessment of students' understanding of the concepts that were taught are usually in the form of a summative test or examinations. During these tests, students were usually required to regurgitate what has been taught in the classrooms. The whole process appeared to be the instructionist method of teaching as observed by Jonassen (1996).

Instructionism, Papert (1990) claimed, is the dominant method of teaching in schools. Instructionism is based on the idea that students are passive receptacles for the information and knowledge that the teacher or the instructional media impart to them. This method relies on the *sponge* method of teaching (Schank and Jona, 1991) where the goals of learners is to absorb what were given until the examination at which time the information is wrung out of them (Jonassen, 1996).

As an alternative to instructivism, Papert (1996) has proposed constructivism, where he believed that the learners should be constructors and producers of personal knowledge rather than receivers and repeaters of inert knowledge. This is because, knowledge which is actively constructed by learners will become more meaningful, applicable and memorable.

Multimedia presentations on the other hand, can provide a suitable alternative to the teaching and learning environment. They are more attention getting and attention-holding because they are usually multi-modal; they stimulate more than one senses at a time (Pek-Tan, 1996). Multimedia has also been used to make learning more exciting and entertaining (Liew, 1995). Schools have used multimedia to stimulate students' interest in the subject and to supplement classroom teaching.

An IMM courseware can be considered as a Computer-Assisted Instructions (CAI) or a Computer-Assisted Learning (CAL). Some of the advantages of CAL, according to Bell, Gladwin and Drury (1998) are points made during a lecture or a lesson can be stressed using visual cues. Attention can also be drawn to important concepts through the use of animations in a multimedia programme. The use of CAL in a directed tutorial environment can be used to reinforce concepts presented in lectures or classrooms. Bell et. al (1998) have also found that by using a variety of informative and interactive presentation styles, materials taught in the lesson can be reinforced. Thus an IMM courseware would fit the role that has been described, it has multimedia elements, it is interactive and there is a variety of presentation styles.

Another advantage with using CAL is that a lesson can be repeated as many times as required by the students. In their study, Bell et. al (1998) concluded that CAL can among other things highlight areas of a course that students find difficult, can enhance understanding and make learning an active process. The use of computers as an instructional delivery medium can facilitate learning by presenting instructional learning in an interactive mode in order to provide and control the individualized learning environment for each individual student (Burke, 1982; Reisdel and Clements, 1985). When learning becomes individualized and students become engaged in thinking about the content that they are studying in an IMM courseware, knowledge construction might be facilitated.

It must be noted that not all students learn the same way as there is plurality of intelligence (Gardner,1993). A multimedia courseware can be utilized to help supplement teacher's teaching to address the diverse learning styles of students. A study by Montgomerry (Montgomerry, October Communications, 1998) has been conducted to discern ways in which multimedia can be used to address the needs of a variety of student learners. The preliminary results of this study have shown that multimedia can be effectively used to fill in the gap caused by a dichotomy of learning and teaching styles of students and teachers respectively.

The use of an IMM can empower students to own and control their own learning where the user can control what and when these elements are delivered. This element of interactivity allows a user to navigate the contents of the multimedia product in a free-form manner and not restricted to a particular direction or series of events. Multimedia courseware in the market has included capabilities like text, images, graphics, sound, animation and full-motion videos. Some of the claims of multimedia according to Tan and Tan (1997) are that they can;

1. stimulate student's interest in a subject
2. be used as a supplement to classroom teaching
3. make a subject come alive with the help of graphics and animations
4. make learning easier
5. implement various teaching strategies like tutorials, activities and
6. games.
7. establish motivation
8. build confidence.

Pek-Tan (1997) in his study claimed that multimedia involves students in active learning. This is done through the physical interaction and cognitive engagement when the students are using the programme. Active learning can help to maintain attention, create new knowledge and improve achievement. Research in learning styles indicate that some students learn better through specific modalities like visual, audio or kinesthetic. Multimedia can provide information through multiple sensory channels, allowing students to use the sensory modes they prefer. The rationale for multimedia is based on studies which indicate that people retain only 20% of what they see, 30% of what they hear but 50% of what they see and hear. However as much as 80% of what they see, hear and can simultaneously be retained.

Another advantage of multimedia is that it allows students to explore the content from multiple perspective by using hypertext. The multiple promises of multimedia in education has provided a motivation to develop this particular programme. Another interesting feature of an IMM programme is hypertext which according to Jonassen (1989) is beyond normal text. Hypertext and refers to a non-sequential, non-linear method for organizing and displaying text. It is designed to enable readers to access information from a text in ways that are more meaningful to them (Nelson,1981). Hypertext information systems afford interactivity by permitting the dynamic user control of the information in the knowledge base than do most other systems.

Interactivity in multimedia is when the user can control the programme, where he or she wants to be, what and when to see, what to do first and how to experience the programme. In short, interactivity allows the user have control in the learning process to navigate the contents of the programme and can go to any part of the programme at will. End-users can control the links, determine the paths of navigation, set their own speed of information handling and construct the content in accordance with their needs' (Latchem *et al,*1993).

Exercising control over one's learning can be a valuable educational experience for the learner. The provision of control over instructions allows a student to tailor their own needs and interests (instructional relevance) and to effect their own learning outcomes. They make instructional decisions, experience the results of their own decisions, discover the best tactics for different situations, and learn how to effectively adapt to the different learning situations that make up the real world (Kinzie, Sullivan and Berdel, 1988; Kinzie, 1990). Students are believed to learn better in such learning environment because they become more competent, self-determining, and feel intrinsically motivated as the instructions are now thought to be more meaningful (deCharms, 1968; Lepper,1985; cited in Kinzie And Sullivan, 1989).

Students who exercise learning control also develop better self-regulation of learning and perception of self-control which further strengthens continuing motivation (Kinzie, 1990). According to Kinzie, "Self-regulation of learning implies a high level of cognitive engagement, including actively receiving and selecting information, making connections with existing knowledge, organize the approach to learning tasks, and continuously monitoring learning rehearsal and self-checking" (p.6).

A well-designed IMM programme can accommodate the needs of various learners within a single treatment through the use of remedial segments, flexible ordering of presentation, options for bypassing unnecessary instructions and variable feedback (Shcwier & Misanchuck, 1995). IMM claimed to benefit human learning in many ways because it is self-paced learning, it contains mastery of content, learning can be done in a shorter period of time, there is immediate assessment and feedback and there is individual monitoring (Abtar Kaur, 1996). In addition, advocates have claimed that students, who can be considered as contemporary youth are comfortable and proficient at processing information visually and multi-modally (Saye, 1997).

In the United States, multimedia CD-ROMs have been developed to help eachers prepare many laboratory activities in order to create appropriate opportunities or macroscopic observations. CD-ROMs have also been developed to provide a medium for delivering pictures of abstract ideas regarding the molecular level. In short, CD-ROMS can be used to provide a large rich database of visuals, as well as computer tools for illustrating microscopic, macroscopic and symbolic levels to students.

Some of the IMM CDs on Chemistry available in the Malaysian market includeThe Home Teacher Series CHEMISTRY LESSONS by Future Graph, Corel CD Home CHEMLAB by Corel Corporation, the SUPER TUTOR CHEMISTRY by Stanford, EXPLORING CHEMISTRY by Finson and MULTIMEDIA CHEMISTRY I and II by Pro One. An adaptive multimedia courseware in Chemistry, CHEMMAT, has also been developed in Singapore (Pek-Tan, 1996).

The use of an IMM programme has been found to help students achieve a better conceptual understanding of the processes occurring in electrochemical cells. It would appear from studies done by Lynch and Greenbowe (1992) and Parker and Greenbowe (1994) that an IMM programme has actually become a problem-solving tool, a conceptualizer and a tutorial for the students. Students' learning styles play a role in whether students benefit from viewing and working with animations, simulations and instructional modules.

It has been found that the use of multimedia provides students with an environment where active learning can take place whereby students are freed from being passive recipients of information. Intuitors prefer theories and interpretation whilst sensors prefer to deal with actual data and facts. Multimedia software favours visual learners where images, animations, movies and other visual objects greatly enhance the presentation of material.

There have been studies which support the positive effect of computers and multimedia presentation on student's achievement. Lectures reinforced with multimedia were presented to twenty-four students and their achievement measured by pre-test and post-test was found to be close. Class average for traditional lecture group was 71% while those exposed to multimedia was 78%(Kris,1996).

Other studies revealed that the use of audiographics or instructional images significantly improves motivational and attitudinal levels (Adel & Marshall, 1995). A meta-analysis by Kulik, Bangert and Williams (1983) have shown that computer-aided learning raised final examination scores by approximately 0.32 standard deviation (from the 50th to the 63rd percentile). Students also developed very positive attitudes towards the computer and gave favorable ratings to the computer-aided courses. Kulik and his colleagues concluded that the computer substantially reduce the amount of time that students needed for learning (Kulik, 1994).

IMM Courseware in Electrochemistry

A discussed earlier, students found Electrochemistry difficult to understand while teachers felt Electrochemistry difficult to teach. Thus, an IMM programme may be able to make the concepts within the topic easier to understand which in turn might help students achieve a higher score in their examinations. Findings of studies by Garnett &

Treagust (1992) on conceptual difficulties experienced by some students on electrochemical and electrolytic cells include;

- identifying the anode and cathode of electrochemical cells
- understanding the need for a standard half-cells
- understanding the current flow in electrochemical cells
- understanding the charge on anode and cathode
- identifying the anode and cathode in electrolytic cells
- predicting the products of electrolysis and the magnitude of the applied electromotive force (e.m.f.)

Experience gleaned from the researcher's teaching experience in Chemistry would agree with some of the above findings. In addition, the researcher found that many students do not know how to write balanced half equations to represent reactions taking place at the two electrodes in both the electrochemical and electrolytic cells.

The above study has recommended that teaching approaches need to be produced to minimize the formation of students' misconceptions in Electrochemistry. This is because alternative conceptions research has established that students develop different conceptions from those that they are expected to learn and that these conceptions can influence subsequent learning (Garnett, Garnett & Hackling, 1995). These alternative conceptions formed may also be highly resistant to change since once a misconception has set in it would be difficult to undo the damage (Novick & Nussbaum,1981).

Other research studies have also been done on alternate concepts or misconception in Electrochemistry (Garnet and Treagust, 1992; Ogude & Bradley, 1996; Garnett, Garnett & Hackling, 1995, Sanger and Greenbowe, 1997). The results obtained from the studies were quite similar where students had difficulty understanding the nature of electric currents in electrolytes. Students also had difficulty understanding the charge on both the electrodes and the subsequent movement of ions to the respective electrodes. For many, the research found that students were unclear about the function of the salt bridge. Another important finding from the research was that most students did not appear to appreciate the fundamental differences between the operation of electrochemical and electrolytic cells (Garnett, Garnett & Hackling, 1995).

Yet another research by Sanger and Greenbowe (1997) has also confirmed that students find this topic to be difficult. As a consequence, students' beliefs about problem complexity can affect their performance and learning. However, it would appear that the use of computer simulations and animations have helped students to visualize chemical reactions at the molecular level which in turn have helped decrease the proportion of students who have consistently demonstrated misconceptions in Electrochemistry (Sanger and Greenbowe, 1997).

Most of the difficulties students experienced were mainly the result of deficiencies in abstract thinking and formal reasoning abilities. Attributes of a computer courseware, especially in an interactive environment, can be utilized by a comprehensive computer-aided research. Grandey (1971) submitted that students may lack what Piaget refers to formal operational skills and thus were unable to relate the subject matter to various everyday application. The present mode of teaching does not seem to encourage students to attain formal-operation skill. Herron (1975) best describe,

> "…….there are a substantial number of students who do not function at the formal level perhaps as high as 50%, but the content of Chemistry and the approach that we normally take in teaching Chemistry require that the students operate at the formal level if he is to comprehend the concepts that is presented. What we're doing is to make Chemistry more difficult for weaker students who cannot understand abstraction. Even though Chemistry is abstraction, blind memorization of theories is repugnant. We should recognize that a large portion of students operate below the formal level." (p.149).

Thus, in order to help concrete operational learners begin to understand conceptual knowledge, concrete exemplars need to be provided. This is because as suggested by Griffith and Preston (1992), many chemical concepts require formal operational thinking or are taught by methods that require formal operational thinking.

In Malaysia, teachers should recognize that a large proportion of Malaysian students were found to be in Piaget's formal operation level. In his study, Chan (1990) has found that 26.7% of the Form Four students were found to be in the late formal operation level while 31.4% were in the early formal operation level. Meanwhile, only 15.0% of the students were found to be in the concrete level while 26.8% in the intermediate level of late concrete and early formal operation level. Thus, based on this mismatch between the requirement of the subject Chemistry in general, specifically in Electrochemistry, with the requirement of students' thinking abilities is concerned, an IMM programme could provide an answer to make abstract concepts concrete. Chan (1990), in his study has suggested that teachers use concrete models like audio-visual aids to help students in the understanding of chemical concepts.

Considerations of an IMM programme

IMM prgrammes can be considered as technology-enhanced, student-centered learning environments. These programmes are thought to be capable of organizing inter-related learning themes into meaningful contexts. They can provide interactive, complimentary activities that enable individuals to address unique learning interests and needs, study multiple complexities and deepen understanding. They also establish conditions that enrich thinking and learning (Hannafin and Land, 1997).

There are basically five considerations found rooted in technology-enhanced student-centered learning environments: Psychological, pedagogical, technological, cultural and pragmatic. The first of these considerations will be that all learning environments reflect underlying beliefs about how knowledge is acquired and used. Psychological foundations reflect views about how individuals acquire, organize and deploy knowledge and skill. Beginning with Skinner's behaviorism with stimulus-response-reinforcement associationism, relevant information was presented, practice elicited and specific, contiguous feedback is then provided. Directed drill and practice programmes as well as convergent tutorial programmes are consistent with behavioral foundations (Hannafin and Rieber, 1989) .

Secondly, the learning environment would move towards cognitive psychology. Cognitive researches including Gagne's, has focused on the processes associated with learning, such as selecting and processing limitations and capacities, organizing stimuli into meaningful units, integrating new with existing knowledge, and retrieving and using knowledge and skills(Hooper & Hannafin,1991). Information-processing theories on the other hand, would shift the theories of learning from the external behavioral conditions of learning to the underlying processes involved in selecting, encoding and retrieving. Next, constructivism as advocated by Piaget (1970), and Vygotsky (1978), among others believed that knowledge is not fixed or external; it is individually constructed. Thus understanding is derived through experiences that serve as a catalyst for constructing individual meaning.

The third consideration would be the pedagogical influences which focus on the activities, methods and structures of the learning environments. They provide the basis for the methods and strategies employed and the ways in which-to-be-learned content is organized. Direct instruction approaches frequently emphasize instructional strategies such as hierarchical structure of the to-be-learned content, objective-relevant questioning, feedback and assessment of progress toward mastery (Dick & Carrey,1990). Various psychology and pedagogical theories need to be used during the planning and development stage of the text.

The technological capabilities would form the fourth consideration where what is possible through advances in technology and not necessarily what is required or desired will dictate the outcome of the final programme. Technological capabilities can either constrain or enhance the types of learner-system transactions that are possible. Thus the type of authoring tools chosen to develop this program can influence the entire production (Hannafin and Land, 1997).

Cultural considerationson the other hand, would influence the design of the learning systems by reflecting social norms and values concerning the nature and role of education. In many Asian countries, the educational system appears to place a high degree of emphasis on competition and acquisition of rote knowledge. There is intensive classroom instruction followed by highly competitive national tests to determine eligibility into institutions of higher learning. This would imply that an IMM programme must be shown to be effective in improving the performance of students in the public examinations.

The design of the learning system was also affected by pragmatic issues like run-time requirements, hardware software availability and compatibility as well as financial constraints. Pragmatic concerns establish the gap between theory and reality. Pragmatic concerns emphasize practical reasons a particular approach is used in the learning environment. The production budget and technological expertise often have an impact on the final product to a greater extent than the content itself (Hannafin and Land, 1997).

Instructional design

Gagne and Wager (1992) have claimed that learning may happen without any instructions but the effects of instructions on learning are often beneficial and usually easy to observe. Instructions then is a set of events that affect learners in such a way that learning is facilitated. The purpose of a designed instructions is to activate and to ensue no one is educationally disadvantaged. Thus the concept of instructional design can be defined as follows: "Instructional design is a systematic process for designing, developing, implementing and evaluating instruction" (Dick & Reiser, 1989,p.3).

Some of the basic assumptions behind instructional design include:

- it is aimed at individual learning
- it is both immediate and long-range
- it can greatly affect individual human development
- it should be conducted systematically
- it is based on knowledge of human learning
- it takes into account the learning conditions that need to be established for the desired effects to occur

(October Communications 3, 1998).

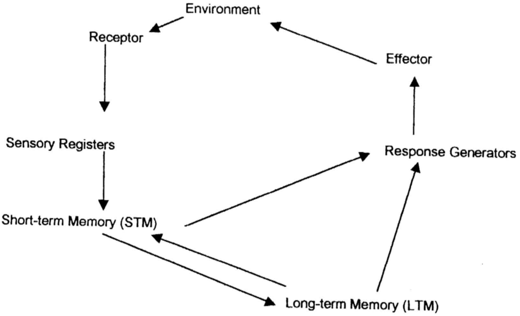
Other definitions of instructional design are as follows:

1. Establishing and maintaining efficient and effective human performance (Rothwell and Kazanas, October Communications).
2. Systematic process of translating principles of learning and instruction into plans for instructional materials and activities (Smith and Ragan,1993).
3. Include three phases; instructional analysis, instructional strategy and evaluation (Mager,1994).

There are basically two parts to the learning situation, one external to the learner and the other internal to the learner. The internal part of the learning situation derives from the stored memories of the learner while external learning are concerned with the process of learning or how learning takes place. If learning is to take place, then arrangements have to be deliberated on both the external and internal conditions of learning (Gagne, 1985).

One model where both external and internal conditions of learning have been taken into account is one of information processing theory (IPT). This model has taken into consideration the relationships between the environmental factors, the receptors and the effectors of the human body as well as the short-term and the long-term memories of the brain. Figure 2 represents the IPT model.

Figure 2:
Information-Processing Theory model
(adapted from Gagne, 1985, p.71)



Stimulation from the students' environment activates the receptors and then transmitted as information to the Central Nervous System. This information is then transformed through sensory registers and then entered into the Short-term Memory

(STM). The transformation that occurs at this point is called selective or feature perception. Information stored in the STM is less than twenty seconds unless it is rehearsed.

Information to be remembered is, however, transformed again by semantic encoding before being entered into the Long-term Memory (LTM). Information from the LTM can be returned to the STM by a process called retrieval. When the STM is functioning in this manner, it is often referred to the working or conscious memory.

Information retrieved either from the STM or the LTM is transformed into action after passing through a response generator. When information has been "processed" as described, learning or performance is said to have taken place (Gagne, Briggs and Wager, 1992). At this point, control processes can occur. A control process is an internal cognitive strategy by which the learner selects and modifies their ways of attending, learning, remembering and thinking (Gagne,1985). Some of the cognitive strategies used can be classified as follows:

- rehearsal strategy
- elaboration strategy
- organization strategy
- affective strategy

  (Weinstein and Mayer, 1986).
- comprehension, monitoring strategy / metacognitive strategy

  (Brown, 1978)

Other cognitive strategies are:

- chunking strategies
- spatial learning strategies
- bridging strategies
- general rehearsal strategies

(Bonwell and Eison, 1991)

In summary, the internal processes are of the information-processing theory are as follow:

1. Reception of stimulus by receptors.
2. Registration of information by sensory registers.
3. Selective perception for storage in STM.
4. Rehearsal to maintain information in STM.
5. Semantic encoding for storage in LTM.
6. Retrieval from LTM to STM (Working memory).
7. Response generation to effectors.
8. Performance in the learner's environment.
9. Control of processes through executive strategies.

(Gagne, Briggs and Wager, 1992).

If instruction is to bring about effective learning, it must be made to influence the internal processes of learning. Instructions may be conceived as a deliberately arranged set of external events designed to support internal learning processes (Gagne, Briggs and Wager, 1992). The following set of external events is hoped to bring about the kinds of internal processing that will lead to learning:

1. Stimulation to gain attention to ensure the reception of stimuli
2. Informing learners of the learning objective- to establish appropriate expectancies.
3. Reminding learners of previously learned content for retrieval from LTM.
4. Clear and distinctive presentation of material to ensure selective perception.
5. Guidance of learning by suitable semantic encoding.
6. Eliciting performance, involving response generation.
7. Providing feedback about performance.
8. Assessing the performance.
9. Arranging variety of practice to aid future retrieval and transfer.

Functions of Instructional Design

Instructional design can be used to solve problems for those who lack knowledge and skills to perform a certain task. The instructional solution might address:

- teaching facts or concepts
- teaching processes, rules and principles
- increasing motivation

- teaching problem solving
- audiences with varying needs

(October Communications 2, 1998).

Instructional design focuses on the learner as compared to traditional instruction which focuses on the content. Some of the advantages of an instructional design model are; delivery of the instruction is replicable and revisable as well as opportunities for formative and summative evaluation are made available (October Communications 3, 1998).

The essence of instructional design models are to:

- identify the outcomes of the instruction
- develop the instruction
- deliver the instruction
- evaluate the effectiveness of the instruction

(October Communications 3, 1998).

Phases of Instructional Design

Instructional design is made up of several phases that lead to the implementation of the solution to the instructional problem. They are; needs analysis, design, development, implementation and finally, evaluation and revision (October Communications 2, 1998).

Needs analysis require that the target audience be identified. Questions about why we want them to know the particular subject, what is it most important that they learn, what do they need to know before beginning and what they will need to know afterwards have to be answered (October Communications 2, 1998). For content analysis, subject matter experts should be able to identify the list of facts, definition of concepts, critical attributes, examples, description of principles, theories and procedures for presentation (October Communications 2, 1998).

The subject matter expert can again help in the design by defining the objectives, giving structure to the content, identify what students already know and the facts for the students to recall. The subject expert should be able to define new terms, describe processes, principles and procedures. The instructions can then be sequenced whereby the mastery items based on the objectives can then be written. Finally, the instructional strategies can then be decided. The design phase serves as a "sketch" for the instructional material where the component parts of the instruction is put into a form that can be reviewed and modified (October Communications 2,1998).

The actual development of the instructional material will include preparation and the actual development of the text (manuals, study guides), visual aids, video or motion picture film (scripts, storyboard) and computer programming. Here the subject matter experts, the computer programmers, the graphic designers, the animators, the producers and directors need to come together to piece together the final product (October Communications 2, 1998).

Finally, the product is delivered, evaluated, revised and then maintained. Evaluation can be done by interviews, questionnaires, observation, results from practice exercises and from mastery tests or a combination of the above. Information and feedback of the product can be obtained from the target audience, other subject matter experts, expert performers or teachers of target audience. Data is gathered to see the effectiveness of the instruction, how it is received in the hands of the target audience and suggestions on how to better the instructional product. The data collected from this evaluation exercise can then be analyzed to effect changes and modifications to the product (October Communications 2, 1998).

Instructional Design Models

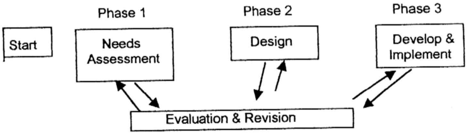
There are several instructional design (ID) models that can be adopted in the production of this programme. Some of these models include the Dick and Carey Design model (1989), the Seels and Glasgow model (1990), the Hannafin Peck Design model (November Communication 1, 1998), the Jerold Kemp Design model (November Communications 2, 1998), the Gerlach and Ely Design model (November Communications 3, 1998) and the Rapid Prototyping Design model (November Communications 4, 1998).

Most ID models are representations of the process one agrees to follow when doing ID. These models serve several purposes:

1. They visualize a systematic process, thus allowing those involved to reach a consensus on that process.
2. They provide a tool for managing the process and the project.
3. They allow the designer to test theories by integrating them within a practical model that can be applied.
4. They set tasks for the designer that can be used as criteria for a good design (Seels and Glasgow,1990).

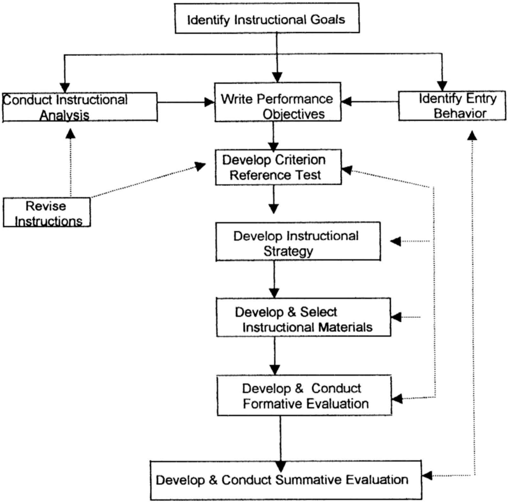
Some of these models follow a sequential pattern while others follow a holistic approach. The Hannafin Peck Design Model three phases. Figure 3 illustrates the model. This model is simpler but has still managed to retain the six phases of instructional design mentioned earlier.

Figure 3 :
The Hannafin Peck Design model (November Communications 1, 1998)



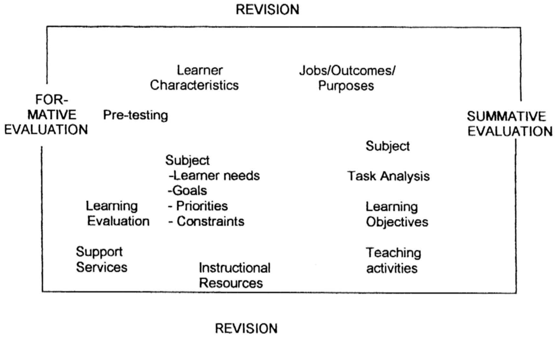
The Dick and Carey Design model follows a sequential pattern and can be illustrated in the following flowchart in Figure 4. This model has included many of the considerations mentioned earlier, namely needs analysis, design, development, implementation, evaluation and revision.

Figure 4:
The Dick and Carey Design Model (from Wedman,1989, p.42)



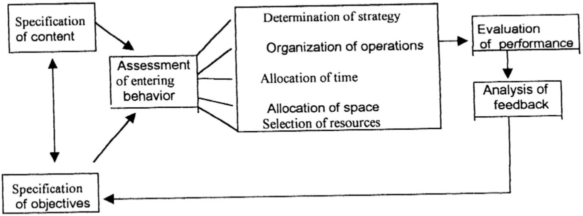
The Jerold Kemp Design Model used a more holistic approach to ID which include considerations of the learning environment like subject analysis, learner characteristics, learning environment, instructional activities, teaching activities, jobs, outcomes and purposes and their relationship with one another. In addition, both formative and summative evaluation have been clearly positioned in the model. The process is iterative and the design subject to constant revision. Figure 5 illustrates this model.

Figure 5:
The Jerold Kemp Design model
(November Communications 2, 1998).



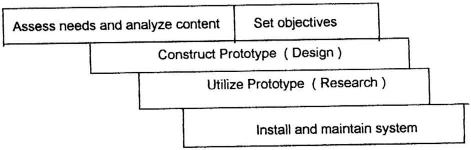
The Gerlach and Ely Design model is meant more for novice instructional designers who have knowledge and expertise in specific content. This model is illustrated in Figure 6.

Figure 6:
The Gerlach and Ely Design model
(November Communications 3,1998)



The Rapid Prototyping Design model is another sequential model which is illustrated in Figure 7. This model has not included the phases evaluation and revision in it sequence.

Figure 7:
The Rapid Prototyping Design model
(November Communications 4,1998).



Emphasis of an ID model is effected whether it is supporting procedural or declarative instruction. A procedural instruction which focuses on examples and practices would favor the Dick and Carey or the Gerlach and Ely ID Design models. Meanwhile, a declarative instruction which emphasizes on analogies and discovery-type of instruction would favor the Rapid Prototyping Design model. A unit or module or even a lesson done on a small scale would favour either the Dick and Carey model, the Gerlach and Ely model or the Rapid Prototyping model.

There are more similar traits than differences among these ID design models. It would appear that basically, the systematic processes commonly described in all of these models involve the following phases. They are:

1. analysis – inquiry of what the problem is, the conditions and characteristics of the learners and the teachers
2. objectives – identifying the performance objectives after identifying entry behaviour and learner characteristics
3. instructional strategies – determining and developing the strategies of instructions
4. instructional materials – selection of resource materials
5. design - creation of a blueprint for the instructional methods and materials
6. production – constructing the prototype
7. evaluation – utilizing the prototype in research and improvement of the programme by trying it out
8. revision – fine-tuning the product based on feedback

Therefore, the phases described above would be adopted for the development of the IMM courseware programme in this study. This particular sequence was found to be the easiest and most logical sequence to follow for the development of the programme.

Theories of Learning and Instructional Strategies Applied to Computer Courseware.

Most learning theories agree that certain conditions are necessary for learning to take place. Some of these conditions include continuity, reinforcement and also repetition. Skinner (1968), for example, believe that students are active learners who control the learning situation to a large extent. He emphasized the importance of the immediacy of reinforcement following the elicited response from a certain stimulus. In other words, Skinner (1968) advocates the stimulus-response and reinforcement as the learning model. Skinner's illustration of how to develop a programmed learning sequence is directly applicable to the design of a computer-aided learning courseware modules. The sequence as described by Chambers and Sprecher (1983) and Smith (1989) is as follows:

1. obtain a clear and detailed objective specification of what it means to know the given subject matter
2. write a series of instructions. Questions and answers frames that expose students to the material in graded steps of increasing

difficulty and that frequently retest the same facts from many different angles

3. require the learner to be active (provide a high level of interactivity)
4. provide immediate feedback for each response
5. try to arrange the material and questions in such a manner that the correct response is likely to occur and be reinforced
6. permit students to proceed at their pace
7. provide ample back-up reinforcement for diligent and effective work.

The cognitive learning theories of Gagne on the other hand are primarily based on information- processing models which are concerned with how individuals gain knowledge and how they use it to guide decisions and perform effective actions. The main concerns of the cognitive learning theories are;

1. the effect of stimuli on the organizing receptors
2. the storage of instruction in the short-term or working memory
3. the storage of instruction in the long-term memory
4. the processes involved in encoding and decoding information
5. the retrieval of the stored information

The importance of identifying the goals of learning tasks followed by the development of specific instructional objectives to meet these goals have been emphasized by Gagne(1981). He also emphasized that such objectives be stipulated in concrete behavioral terms. Gagne identified five categories of learning outcomes which he believes represents all types of learning. They are;

1. intellectual skills – enable students to interact with their environment in terms of symbols or conceptualizations
2. cognitive strategies – capabilities that govern the individual's own learning, remembering and thinking behaviour
3. verbal information -- declarative knowledge
4. motor skills – when students can perform the act in a variety of contents
5. attitudes – affective domains, to amplify an individual's positive or negative reaction towards something.

Based on Gagne's learning outcomes, the following steps can be done to perform a task analysis;

1. write an instructional goal
2. determine types of learning
3. conduct information –processing analysis
4. conduct a pre-requisite analysis
5. write specific performance objectives for the instructional goal.

Both Gagne and Skinner emphasized that learning must occur in small steps beginning with the lower level learning required for performance of higher learning order. Reinforcement in a repetitive manner is also emphasized. Reinforcement can be strengthened by a verbal praise, a good grade or a feeling of increased accomplishment or satisfaction.

Gagne, Wager and Briggs (1989) have recommended the nine events of instructions in courseware sequences that can be of significant help to most computer-aided learning designs. They are :

1. gaining attention
2. informing learner of the objective
3. stimulating recall of pre-requisite learnings
4. presenting the stimulus materials
5. providing learning guidance
6. eliciting the performance
7. providing feedback about performance correctness
8. assessing the performance
9. enhancing retention and transfer

The principles of the Dual Coding Theory (Paivio, 1986) can also be applied in the development of programmed instructions. The main principle in this theory which is recall or recognition is enhanced by presenting information in both visual and verbal form. Three types of processing has been identified:

1. representational, the direct activation of verbal or non-verbal representations
2. referential, the activation of the verbal system by the nonverbal system or vice-versa, and

3. associative processing, the activation of representations within the same verbal or non-verbal system.

An IMM programme actually involves active leraning where it is defined as "involving students in doing things and thinking about the things they are doing" (Bonwell and Eison,1991). Some of the active learning strategies include visual-based instructions, problem-solving, decision-making, computer-based instructions, simulations and games. On the other hand, Bruner (1966) defines learning as an active process in which learners construct new ideas or concepts based upon their current/past knowledge. The learner selects and transforms information, constructs hypotheses, and make decisions, relying on a cognitive structure to do so. The principles in Bruner's constructivist theory states that;

1. instruction must be concerned with the experiences and contexts that make the student willing and able to learn(readiness)
2. instruction must be structured so that it can be easily grasped by the student (spiral organization)
3. instruction should be designed to facilitate extrapolation and or fill in the gaps (going beyond the information).

Mager (October Communications, 1998)) developed the Criterion Referenced Instructions (CRI) framework which include the following:

1. goal task analysis- to identify what needs to be learned
2. performance objectives-exact specification of the outcomes to be

accomplished and how they are to be evaluated

3. criterion-referenced testing-evaluation of learning in terms of the knowledge /skills specified in the objectives
4. development of learning modules tied to specific objectives.

Some of the principles in this theory can be used in the development of this IMM. Students are given opportunities to practice each objective and obtain feedback about the quality of their performance. Students should receive repeated practice in skills or concepts that are used often or are difficult to learn and students are free to sequence their own instruction.

Hull's Drive Reduction Theory states that reinforcement is the primary factor that determines learning. His principles states that the student must want to learn, the student must be attentive, the student must be active and the learning must satisfy the learner's want (Hull, October Communications, 1998). Although reinforcement is the primary force that determines learning, in addition, drive reduction or need satisfaction plays a much more important role in behavior compared to the other frameworks.

It was found in a survey by Montgomerry (Montgomerry, October Communications, 1998) that; 67% of students learn best actively; yet lectures are typically passive 57% of the students are sensors; yet teachers teach them intuitively 69% of the students are visual; yet lectures are primarily verbal, 28% of the students are global; yet teachers seldom focus on the "big picture".

The aim of instructional design theory proposed by Merril (1991) is to build a technology that enables the learners to construct appropriate mental models, not via an extreme constructivist approach, but through a combination of effective experimental learning environments enhanced by more directed instructional strategies and pre-specified interactions which are known to be necessary for the acquisition of knowledge, attitudes and skills. The sequencing of instructions is one of the most important issues in the application of learning theories where the order and organization of learning activities can affect the way information is processed and retained (Glynn & DiVesta, 1977; Lorch & Lorch, 1985; Van Patten, Chao, & Reigeluth, 1986).

Courseware design

To develop a good courseware, Gagne, Wager and Rojas (1981) have suggested five information-processing abilities to be included, which are:

1. memory and attention
2. language/text characteristics
3. graphics and visual processing
4. cognitive characteristics of the user
5. feedback to users.

For optimum use of computers in education, the courseware to be developed need to have a considerably high level of interactivity, contain individualized instruction, interesting and motivating, have an efficient feedback system on students' progress, user-friendly and can be self-controlled by the user.

There are several approaches to the development of a computer courseware in education. The courseware being developed can be 'drill and practice', tutorial, demonstration, simulation and educational games.Different educational coursewares can be utilized for different ability-group of students. For instance, drill and practice-type of coursewares are recommended for students who have not mastered the concepts being taught. Drill and practice only assist the learner in reviewing, reinforcing and over-learning previously learned skills. It is useful in sustaining, refining or perfecting some category of behaviour previously learned by another method (Geisert and Futrell, 1990). Tutorial-type of courseware are usually appropriate for presenting factual information and for learning problem-solving strategies (Gagne, Wager and Rojas, 1981). The main focus of tutorials is on knowledge acquisition and comprehension (Zoraini, 1993).

The first step in any courseware design project is to identify the particular needs to be met through the ultimate implementation of the materials. These needs form the basis for the development of overall goals and specific instructional objectives. The specific field topic and educational level of the target user must also be established.

A CAI tutorial lesson typically begins with an assessment of the students' knowledge, followed by a set of instructions or other essential information like purpose and nature of the lesson (Bullough and Beatty, 1991). This is then followed by the presentation of concepts or rules which are then further elaborated. An activity or a question is then presented to evaluate the students (Alessi and Trollip, 1985).

A developer of IMM courseware need to be highly skilled in applying ideas from behavioral psychology, cognitive psychology, adult learning, systems theory and media technology. There are three key issues in optimizing IMM design. They are linking, human interface and content (Latchem, Williamson and Henderson-Lancett, 1993).

Linking in IMM need to be both non-linear and non-hierarchical. The aim is to provide the end-user with optional and implicit navigation routes which facilitate freedom of movement within the environment for the purpose of research and cognitive processing. The user interface of a multimedia product is a blend of its graphic elements and its navigation system. If the content are disorganized and difficult to find, if users become disoriented or bored, then the multimedia project is considered a failure (Latchem, Williamson and Henderson-Lancett, 1993). It will be obvious that poor graphics can cause boredom whereas poor navigation aids can make users feel lost and unconnected to the content. A multimedia project designer need to be aware of these pitfalls and try to create a user interface that will satisfy both the users who are computer literate and those who are not.

Communications in an IMM programme can be executed through the use of buttons, icons or metaphors with a mouse or other pointing device. The interface design should be aesthetically pleasing, appropriate to the content and suited to the learner's prior knowledge. The content to be selected need to be stored in ways that promote understanding. Beattie and Preston (1990) have proposed some of the characteristics of a good courseware. They are:

1. content accurate
2. content has educational value
3. purpose of package well-defined
4. package achieves its defined purpose
5. presentation of content clear and logical
6. level of difficulty appropriate for target audience
7. graphics/ colour/ sound used for appropriate instructional reason
8. use of package motivational
9. feedback on students' response effectively employed
10. learner can control rate and sequence of presentation
11. students can easily and independently operate the pogramme
12. programme reliable in normal use.

A courseware using multimedia should help to convey and communicate a message that the user can attend to, comprehend and retain information about the message. The user's attention can be captured by effective use of colour, sound, music and animation. The media elements used in the presentation should complement rather than distract and divide their attention. The strength of a multimedia courseware lies in its ability to transform static information into dynamic data that can be processed at a faster rate by the learner than if one is to read about it. How the information is presented plays an important role in its retention. The learner need to be shown the different concepts that will be covered and then guided through each of the concepts. A summary of each concept at the end will help reinforcement as well as ensure learners do not get lost and help organize the information processed (Neo and Neo, 1997).

Interactivity during learning can help in the retention of information. Interactivity is when the student can actively selects instruction which have been arranged in such a way that when selected by the student will result in meaningful learning. This feature of interactivity which empowers the student will eventually result in increased motivation to learn (Abtar Kaur, 1996). It will also be a plus if the courseware design has an element of entertainment which will induce a relaxed environment for the learner and probably help in the retention of information (Neo & Neo, 1997).

Technical considerations in developing an IMM programme

Apart from considering the design guidelines, the technology needed to produce and develop an IMM programme has to be deliberated in great details. Since the programme will be using computers, it is important to consider these playback or delivery systems that the user will be using. Hence it is important to set a minimum standard for multimedia applications that can be used. The computer system must be powerful enough to provide interaction with any combination of video, photographs, animations, text, sound and music (Walsh, 1995).

Basically, the computer is made up of two elements: the hardware and the software, both of which will allow a user to perform a variety of tasks and applications. The hardware refers to the physical components of the computer itself while the software refers to the programmes that run the computer.

One of the most important considerations of a multimedia computers is the processor speed which is usually expressed in hertz (Hz). Since most multimedia files are huge, especially the video and sound files, there is a need for a multimedia application to be equipped with fast and powerful processors, at the very minimum, a 486 66MHz computer system. Multimedia programs and applications are also memory hungry, thus a minimum of 16MBs to 32MBs of Random Access Memory or RAM will be required (Walsh, 1995).

In addition, the multimedia system must also possess three distinct capabilities: video display, audio play-back and the computing power to deliver it all while providing interactivity. A high-quality video display will produce a high-resolution, high quality full color video display. This will depend largely on the video card whose main function is to process the image data quickly and then pass the information to the monitor without noticeable delay. Any delay will result in choppy and sluggish video playback.

The audio or sound card makes it possible for computerized sound to be displayed on speakers while enhancing the quality of the sound coming from the computers. Thus it is important that the sound card be capable of producing high quality audio. Next, the computer must also be equipped with a Compact Disc Read Only

Memory or CD-ROM Drive which gives the computer access to the information found in the CD-ROMs. A single CD-ROM holds the equivalent of nearly 600 low-capacity floppy discs and typically contains graphics, sound, and/or text (Walsh, 1995). The minimum CD-ROM drive needed will be the quadruple speed drives.

The software programmes used to create multimedia products are called authoring software or tools. Multimedia authoring tools provide the important framework needed to organize and edit the various multimedia elements in the project. These tools are used for designing interactivity and user interface, for presenting the project on the screen as well as assembling multimedia elements into a single cohesive project. Multimedia authoring requires that the various multimedia elements be created and developed separately and then importing them into an authoring software. A single authoring system combines all the functions and interfaces required to join the various media elements from different sources. An authoring tool should include the ability to create, edit and import specific types of data, assemble raw data into a playback sequence or cue sheets and provide a structured method or language for responding to user input (Vaughan, 1993).

Some of the considerations in choosing an authoring tool include:

- the software should represent the best balance between power and ease of use
- the authoring software should be the best available in terms of speed and efficiency
- can be used for future projects

- the software should have a good fit in terms of design specification and lesson capacity (Pek-Tan, 1996)

Some of the authoring systems that can be used are; the slide metaphors, the icon-based flow-chart, the script-based or event-based, the card or page-based tool and the time-based system.

The slide metaphor follows a presentation sequence where slide-by-slide is sequentially displayed. In the time-based authoring tools, a visual time line for sequencing events of a multimedia presentation is displayed. The card and page-based authoring system presents the graphic images forming the backbone of the project, both as the navigational menu and as the content. The script-based tool create a multimedia programme that is executed line by line (Straits Times, 1995).

The icon-based event-driven tools, on the other hand, provide a visual programming approach to organizing and presenting multimedia. In this system, a structure or flowchart of events, tasks, and decisions is built by dragging appropriate icons from a library. These icons can include menu choices, graphic images, sounds, and computations. The flowchart graphically depicts the project's logic. When the structure is built, text, graphics, animations, sounds and video movies can be added to the content. Then in order to refine the project, the logical structure can be edited by rearranging and fine-tuning the icons and their properties.

One of the most powerful multimedia authoring tools in the market is the Macromedia's *Authorware*. *Authorware* was considered useful as a design tool for storyboarding because it allows changes to be made to the sequences by adding options and restructuring interactions by simply dragging and dropping icons. The navigation map or flowchart can even be printed out. *Authorware* offers more than 200 system variables and functions for capturing, manipulating, and displaying data, and for controlling the operation of the project. Variables include interaction, decision, time, video, graphics, general file, and user. The software *Authorware* has a complete set of tools for incorporating and editing multimedia elements (graphic, images, sounds, animations and movies) created with other software. The versatility of this authoring tool is higher compared to others in the market like Asymmetrix's *Multimedia Toolbook* or Aimtech's *Iconauthor* (Vaughan, 1993).

Another time-based authoring tool used was Macromedia's *Director* 6.0. This authoring tool is a powerful and complex multimedia tool with a broad set of features used to create multimedia presentations, animations and interactive multimedia applications. Both *Authorware* and *Director* used formed the basic tool set for building multimedia projects since both contained the various editing applications for text, image, sounds and motion video. Animations add visual impact to a multimedia project. The most widely used tool for creating multimedia animations is Macromedia's Director. The computer generated animations actually consisted of many bits and pieces carefully orchestrated to appear as one image, in one motion (Vaughan. 1993).

The use of video clips needed careful storyboarding which should fit properly into the design and programming of the project. Video, being the most engaging of multimedia venues, can effectively present the message and reinforce the story of the project. Users and viewers tend to retain more of what they see.

Furthermore, video clips let the user have the feeling that they were watching the demonstrator performing the experiments (Hartley, 1994).

To display video (television) images on a computer monitor, the video signal must first be converted from analog to digital form. To digitize and store a 10-second clip of full motion video in the computer requires transfer of an enormous amount of data in a very short amount of time. Reproducing *one frame* of digital component video at 24 bits requires almost 1 Mb of computer data; 10 seconds of video will fill a 300Mb hard disk. A full-size, full motion video requires that the computer deliver data at about 30Mb per second! Thus data compression techniques are critical to enabling motion video on small computers (Vaughan,1993). The compression methodology used to make digital video possible is the Moving Picture Experts Group or MPEG. The MPEG scheme allows compression of audio where the compression speeds are fast. Decompression also occurs in real time (Neo and Neo,1997).

An important consideration to be made when importing the video clip into the actual program was to decide on the size of the screen for the actual video clip. A smaller screen size (160 x 120 pixels) would enable the video clip to be viewed at the normal pace with zero drop in quality by the lower-end computers with a processing power of at least 100MHz. A bigger screen size screen (320 x 240) however would allow for better and detailed viewing of the experiments found in the video clip. This would favor those with higher-end computers with a speed of at least 166MHz. The bigger sized screen was favored to allow the user to have a better view of the video.

Images are the most commonly used media type to enhance the appearance of a multimedia presentation or to add important information. In general, multimedia applications work with bitmapped images as opposed to vector images (December Communications, 1998). One of the most important considerations is the resolution (size of the image in pixels) and color depth (number of colours) which will be used to create the production of the image. Images used in a production come from a raw format and often need to be edited or have special effects added to them. This requires the use of editors, or third-party image creation, effects, and conversion programs (December Communications, 1998).

Sounds can be combined in a multimedia presentation to provide information and enhance the other media being presented. Three file formats widely used are wave(.WAV), sound (.SND) and MIDI (.mid) files. The recording of voice and sound effects use the first two flies whilst the third audio type is used to create digital sound from midi-compatible instruments. It is often necessary to have a third-party software to edit audio and create effects (December Communications, 1998).

Sound from microphone, music from CDs, tape recordings can be digitized. In order to obtain an accurate reproduction of all sounds, a 16-bit sample size at 44.1 kHz sampling frequencies are recommended. However this require a lot of disk storage space. Thus considerations need to be made on managing digitized sound in a multimedia project. In Windows, digitized sounds are stored as wave files (WAV.), the default and most common format. A project which requires CD-quality digitized sound at 41.1 kHz and 16-bits, then recording of audio should be done in a recording studio using Digital Audio Tape (Vaughan, 1993).

The embedding of video in multimedia application is a powerful way to convey information. The pre-production, production and postproduction of the video itself can be a time consuming and expensive affair. Next, the necessary software are needed to digitize the video and make further editing. The common digital video formats are motion pictures expert group (.MPEG), Quicktime (.MOV) and Video for Windows (.AVI) (December Communications, 1998).

Preparation of the IMM Courseware Programme

To produce a multimedia project, several financial decisions need to be made concerning the authoring tool, the computer system, and the extra hardware and software needed. The high cost in developing a multimedia product is in the personnel resources and their time invested in producing and creating the multimedia application.

Producing a multimedia project requires not only creative skill and high technology, but also organizing and business talents as well. For some of these elements, there are issues of ownership and copyright that need to be considered. If text from books, scanned images from magazines, reference books, audio and video clips need to be used, then permission and often payment of a fee to the owner need to be made. Sound and audio to be used in a multimedia project can be obtained from some software vendors with unlimited-use and royalty-free license to prevent infringing copyrights problems (Vaughan, 1993).

Basically there are four phases of programme development; planning, design, production and finally implementation. The planning and design stages would be considered as the preparation stage. The issues that need to be considered in the planning phase are:

- the feasibility of the product
- the audience using this product
- an outline of the content of the product
- the goals and objectives of the product
- an identification of the media to be used in the product
- selecting authoring and delivery systems
- the usage (educational) context for the product
- planning evaluation strategies

(October Communications 6, 1998).

The design phase is where decisions regarding specific content, behavioral objectives and instructional strategies are considered. The instructional interactions need to be specified This stage usually results in the development of the project to storyboard level where flowcharting, writing scripts and formatting screens need to be designed.

Another important considerations to be made in the development of this IMM programme was the navigation and hyperlink. It was imperative that navigation of the program be user-friendly to ensure one do not get lost while navigating the programme. Buttons and directions had to be strategically placed on the screen for easy usage of the program. The text for the main concepts have to be different to differentiate from those in the hypertext.

According to Vaughan (1993) an interactive multimedia project would typically consists of a body of information through which a user navigates by pressing a key, clicking a mouse, or pressing a touch-screen. This body of information can be displayed in the form of text. Therefore, any text to be displayed should only consists of a few paragraphs per page. This is because experiments have shown that reading text on a computer screen is slower and more difficult than reading text in hardcopy or book form. The font used for the text should be compatible to most computers. The size of the font should one that the user is comfortable with.

The multimedia elements to be used in this programme need to be designed in such a strategic way to effectively bring out the message in the process of communication. These elements include the type of fonts used for the text, the choice of background color and textures, the music, the video clips and their placement on-screen which should balance and complement each other (Vaughan, 1993).

Development of an IMM Courseware Programme

Prior to discussing the processes involved in the development of an IMM courseware programme, the terms interactivity, multimedia and courseware need to be clearly defined. The term courseware is used in the context of computer-based software, that is using computers to deliver or present information. Next, the use of multimedia presentations in education settings derives from the belief that differences in students' learning modalities can be matched in some ways through the provision of audio, visual and textual versions of the presentation. On the other hand, the value and nature of interactivity in an instructional process is dependent on the depth of processing or the quality of thinking that is demanded of a student (Romiszowski, 1993).

Thus in developing a multimedia application in a learning environment, three important areas which require considerations are; content, presentation and programming. The content is the important information which is being conveyed through the multimedia application. It should be provided by an expert resource person in the particular subject matter.

The aesthetic appearance of the multimedia application and the composition of the variety of media are very important in conveying the content of an application. The color scheme used, the user interface designed, and the integration of various media are all elements of consideration in designing a professional-quality multimedia presentation (December Communications, 1998).

The production stage would also cover the development of the authoring interactions, creating graphics, preparing adjunct materials, conducting pre-production, production and post-production. The optical media as well as the authoring code need also be integrated. Prototypes that are used for testing and for evaluation with target groups are then developed. The main purpose of this form of evaluation is to provide timely and cost-effective feedback for revisions.

Formative Evaluation of an IMM Courseware Programme

Flagg (1990) has defined formative evaluation as the 'systematic collection information for the purpose of informing decisions to design and improve the products'. *Formative evaluation is a process used to determine the feasibility and effectiveness of* a particular product.

The purpose of formative evaluation is to validate the goals of instructions achieved and if necessary, to improve the instructions. This can be done by means of identification and subsequent remediation of problematic aspects. Weston, McAlpine and Bordonaro (1995) have suggested that formative evaluation can either be executed throughout the design of instruction or at the specific time later in the development of the instruction (draft stage) or it goes beyond the design and development of instruction. Another function of formative evaluation in instructional design is a means to improve instructional materials through tryouts with learners, and experts and revision based on this feedback (Hannafin and Land, 1997).

The changes that are considered at this stage usually revolve around the interface and presentation of the content, rather than major changes to instructional design and/or media. The areas which may be changed include;

- interface design
- user friendliness
- appeal
- comprehensibility
- persuasiveness

Other aspects of the software that can be evaluated is the user interface where the user can evaluate the ease of use, navigation, cognitive load, mapping, screen design, knowledge space compatibility, information presentation, media integration, aesthetics and overall functionality (Reeves & Harmon, 1993).

Strategies that can be used for formative evaluation include expert review, pilot studies, field testing and obsevatoin of individual learners (Reeves, 1992). Other approaches to qualitative evaluation methods include:

- introspection
- direct observation
- recording results
- query techniques: interviews and questionnaires
- continuous evaluation: user feedback and field studies

(October Communications 4, 1998).

The type of evaluation method to be used would actually depend on the evaluation questions asked (Savenye, 1992). This approach would be similar to the ROPES guidelines developed by Hannafin and his associates which blends the best of behaviorism and cognitivism (Hooper & Hannafin,1988, Hannafin & Rieber,1989).

Summary

An IMM programme has great potential as an instructional tool. With the mmencing of the Smart Schools and its emphasis on technologically-dependent and ıdent-centered teaching and learning materials, the development of multimedia ogramme like "ELEKTROKIMIA" is timely and relevant. One of the advantages of this ogramme over other available ones in the market is its rigorous research in structional design and relatively comprehensive evaluation done on the programme.

The review of literature revealed that computer-based instructions, pecially in the interactive mode, can offer many advantages to students as well as achers (Culp and Castleberry, 1981; O'Shea and Self, 1983; Savenye, 1990). An IMM ogramme can be used to address the different learning styles of students (Scwier and isanchuck, 1995). Other advantages of a multimedia programme such as this include aking learning more enjoyable, stimulate interest establish motivation in the subject ıd build confidence. The physical interaction and cognitive engagement when using e programme makes for active learning which can help improve achievement. fferent forms of representing information can markedly influence children's thinking lartley,1994).

The motivation to develop this programme was driven by studies done on isconceptions in Electrochemistry (Garnett, Garnett and Hackling,1995; Ogude and radley,1996; Sanger and Greenbowe, 1997). Many researches have also confirmed e suspicion that Electrochemistry is a difficult subject for students to understand Sarnett and Treagust, 1992; Saadah, M, 1992; Sanger and Greenbowe,1997).

Based on the researcher's experience, the topic of Electrochemistry is currently ught in schools largely through the chalk and talk method and experiments done by udents. Some of the difficulties that research has unveiled were probably similar to the problems of the local students. Electrochemistry was the topic selected to be developed in this IMM programme because it is related to four other topics in the *KBSM* syllabus. It is also related to other concepts that the students might meet in the higher institutions of learning like Faraday's Law and the calculations of potential difference. Lastly, a lot of multimedia elements like graphics, video clips and animations can be incorporated in the program which might help students visualize the movements and migration of ions and electrons in electrochemical cells. These considerations constituted the needs analysis of the Instructional Design theories.

IMM programmes in have been successfully developed in America where they have become a problem-solving tool, a conceptualizer and a tutorial for students (Lynch and Greenbowe, 1992; Parker and Greenbowe, 1994). These are in the English language and the content do not meet the requirements of the Malaysian syllabus. Thus a locally developed IMM programme in Electrochemistry can contribute to the lack of such programmes in the country.

The development of this IMM programme was also influenced mainly by the pedagogical, psychological, cultural, technological and pragmatic considerations. The main emphasis in this programme is to help students focus on the important concepts that they should know about electrochemistry at the Form Four level. Assessment questions provided were closely similar to those found in the national examinations.

The instructional design utilized was a combination of several models proposed by several authors (Dick and Carey, 1985; Kemp,1985; Gerlach and Ely, 1989; Hannafin and Peck, 1989; Seels and Glasgow, 1990). Basically, the major phases of the design involve needs analysis, specification of content and objectives, develop instructional strategy, the selection of instructional materials and resources, develop and conducting formative evaluation and finally revision. The theories of learning adopted were also a combined mix of reinforcement, behaviorism, cognitive learning, dual coding and constructivism (Smith, 1989;Chambers and Sprecher,1993;).

The courseware design of this programme can be considered as a tutorial-cum-drill and practice type of courseware. It is meant for students who have finished learning the concepts with their respective teachers but have not toatally mastered the concepts of Electrochemistry. The programme can also be used for those who need reinforcement in this particular lesson. The study of these literature provided the theoretical basis for this study.

Chapter 3

METHODOLOGY

In this chapter, the researcher shall describe the methodology used in this study. An overview of the methodology will be presented first followed by the description of each step of the procedures and instrument.

Overview of the Methodology

In this study, the researcher has utilized the major phases of instructional design described in the literature which has taken into consideration most of the practical aspects of all the instructional design models mentioned in the previous chapter. They are:

1. identifying instructional goals.
2. specification of content.
3. writing performance objectives.
4. develop instructional strategy
5. identifying resource materials - develop and select instructional material