# THE EFFECTS OF CONSTRUCTIVIST-STRATEGIES AND DIRECT INSTRUCTION USING MULTIMEDIA ON ACHIEVEMENT AMONG LEARNERS WITH DIFFERENT PSYCHOLOGICAL PROFILES

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**by**

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### ABBREVIATIONS

| | |
|---|---|
| CSI | Constructivist-Strategies Instruction |
| DI | Direct Instruction |
| CI | Constructivist Instruction |
| CLE | Constructivist Learning Environment |
| LOC | Locus of Control |
| IAR | Intellectual Achievement Responsibility Questionnaire |
| PMR | *Penilaian Menengah Rendah* (Lower Secondary Assessment) |
| PMR_Science | Science Achievement in Lower Secondary Assessment |
| SPM | *Sijil Pelajaran Malaysia* |
| Sig. | Significant |
| n.s. | Not Significant |

**KESAN PENGAJARAN BERSTRATEGI KONSTRUKTIVIS DAN PENGAJARAN LANGSUNG DENGAN MENGGUNAKAN MULTIMEDIA TERHADAP PENCAPAIAN PELAJAR PELBAGAI PROFIL PSIKOLOGI**

## ABSTRAK

Soalan penyelidikan utama kajian adalah “Adakah dua strategi pengajaran yang berbeza menyumbang kepada perbezaan pembelajaran pada tugas ilmu berbeza paras untuk pelajar yang berbeza dalam ukuran psikologi bagi topik Kimia Jadual Berkala Unsur ?” Dua mod pengajaran, pengajaran berstrategi konstruktivis (CSI) dan pengajaran langsung (DI) yang menggunakan bahan multimedia yang disahkan dan serupa, telah diajar mengikut protokol oleh guru pembantu serta diselia oleh dua penilai untuk tempoh selama 5 minggu. Enam soalan penyelidikan yang berkait dengan enam hipotesis (bersama dengan sub-hipotesis) telah dibentuk dan diuji menggunakan statistik inferential (*Ujian-t*). Semua hipotesis terbentuk adalah hipotesis berarah *a priori* dan diuji pada paras signifikan $p < 0.05$. Pemboleh ubah lain dianalisiskan menggunakan korelasi, ANCOVA, dan regresi linear berperingkat bagi menentukan sumbangan kepada pemboleh ubah bersandar.

Kajian ini menggunakan rekabentuk kuasi-eksperimen 2X2 faktorial berulang untuk pemboleh ubah moderator dalam rekabentuk praujian-posujian dengan kumpulan kawalan tak saksama, dan melibatkan sejumlah 156 pelajar tingkatan empat dalam lingkungan umur antara 16 hingga 17 tahun dari empat sekolah menengah luar bandar. Kelas-kelas secara sepenuhnya telah diagih secara rawak dalam dua mod pengajaran, CSI atau DI, pemboleh ubah bebas kajian ini. Pemboleh ubah bersandar adalah min skor peningkatan untuk tugas ilmu berparas rendah dan tinggi serta skor penyelesaian masalah. Pemboleh ubah moderator merupakan ukuran Cattell untuk kecerdasan / kebolehan dan lokus kawalan dalaman (LOC) pelajar.

Kedua-dua kumpulan rawatan, CSI dan DI, telah menghasilkan pencapaian berbeza untuk pemboleh ubah bersandar, min skor peningkatan untuk tugas ilmu

berparas tinggi dan skor penyelesaian masalah. Tidak terdapat perbezaan yang signifikan dalam pencapaian tugas ilmu berparas rendah untuk kedua-dua kumpulan rawatan.

Kajian ini menyimpul bahawa CSI adalah lebih berkesan berbanding dengan DI untuk tugas ilmu berparas tinggi, dan kesan CSI adalah lebih kuat untuk pelajar berkebolehan tinggi dan berlokus kawalan dalaman tinggi. Kajian ini mendapati bahawa DI dan CSI adalah sama-sama berkesan untuk tugas ilmu berparas rendah. Dengan mengintegrasikan bahan multimedia ke dalam rancangan protocol yang ditetapkan dalam kajian ini, kedua-dua mod pengajaran mempunyai potensi dalam mempromosikan pembelajaran, bergantung kepada sifat topik yang wujud dalam Kimia.

Kajian ini mensyorkan bahawa para guru patut memilih strategi pengajaran yang terbaik untuk memenuhi keperluan pelajar untuk setiap jenis tugas pembelajaran. Memandangkan DI adalah berkesan dan menjimatkan masa, instructor boleh menguruskan pengajaran menggunakan DI untuk tugas ilmu berparas rendah, dan bertukar ke CSI untuk tugas ilmu berparas tinggi. Walau bagaimanapun, dalam mod CSI, pelajar diarahkan untuk membina pengalaman sendiri dan terlibat secara aktif dalam “pembinaan pengetahuan”, ini akan menuju ke pembinaan skemata yang berkesan berdasarkan model kajian ini. Maka cadangan adalah menggunakan pendekatan eklektik (CSI) dalam bilik darjah kerana pendekatan konstruktivis adalah berpusatkan pelajar dan mempunyai lebih potensi untuk menjana pembelajaran bermakna.

# THE EFFECTS OF CONSTRUCTIVIST-STRATEGIES AND DIRECT INSTRUCTION USING MULTIMEDIA ON ACHIEVEMENT AMONG LEARNERS WITH DIFFERENT PSYCHOLOGICAL PROFILES

## ABSTRACT

The main research question of the study was "Do two different instructional strategies contribute to differences in learning at different levels of knowledge tasks for learners with different psychological profiles on the Chemistry topic of the Periodic Table ?" Two modes of instruction, Constructivist-Strategies Instruction (CSI) and Direct Instruction (DI), using similar validated multimedia materials were taught by teacher assistants following protocols and supervised by two assessors, for a period of 5 weeks. Six research questions associated with six hypotheses (together with the sub-hypotheses) were formulated and tested using inferential statistics *(t-tests*). All hypotheses formulated were *a priori* directional hypotheses and tested at the level of significance of $p< 0.05$. Other existing variables were analysed using Correlation, ANCOVA, and Stepwise Linear Regression to determine the contributions towards the dependent variables.

The study used a 2X2 quasi-experimental factorial design with repeated measures for the moderator variables in a non-equivalent Control Group Pretest-Posttest Design, involving a total of 156 Form Four students aged between 16 to 17 years old from four rural secondary schools. Intact classes were randomly assigned the CSI or DI mode of instruction, the independent variable of this study. The dependent variables were the mean gain score for lower and higher order knowledge tasks and the problem solving score. Moderator variables were the Cattell measure for intelligence/ability and the internal locus of control (LOC) of students.

The two treatments, CSI and DI, had led to differential attainments for the dependent variables of mean gain scores for higher order knowledge tasks and problem solving scores. There were no significant differences in attainments with regards to lower order knowledge tasks for the two treatment groups.

The study concluded that CSI was more effective than DI for higher order knowledge tasks, and the effects of CSI were stronger for high ability and high internal LOC learners. This study found that DI and CSI were equally effective for lower order knowledge tasks. By integrating multimedia resources into the lessons protocol prescribed for the study, both modes of instruction have potentials in promoting learning, depending upon the inherent nature of the topic in Chemistry.

This study suggested that the practicing teacher should select the best instructional strategies to meet the needs for students for each type of learning tasks. As DI is effective time-wise, the instructor can “manage instruction” using DI for lower order knowledge tasks, and revert to CSI for higher order knowledge tasks. However in the CSI mode, since learners are directed to draw upon their own experience and be actively involved in “knowledge construction”, this would lead to efficient schema construction based on the study’s model. Thus the recommendation is to employ this eclectic approach (CSI) in the classroom as constructivist approach is student-centred and has more potentials in creating meaningful learning.

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background to the Problem

Multimedia has become an important component of the delivery structure in schools. The advent of the Multimedia Super Corridor [MSC] (Ministry of Education, 1997a, 1997b), and specifically the Smart Schools flagship application, has brought multimedia into the main stream of educational pursuit. The often cited Smart Schools systems and its digital embellishments attempt to highlight the importance of technology-based instruction and that together with due encouragement, amongst others, postulates a philosophy that states that *all students can study and be taught* (i.e., accommodating different learning styles as spelt out in the Smart School executive summary) and that students possess high expectations and subscribes to an evaluation system that supports good instruction (Ministry of Education, 1997b). In addition to the use of technology, Smart Schools provide facilities to access multiple information resources, as well as approaches to instruction and learning that take into considerations the psychological profiles of students. As only 89 Smart Schools were established by 2000, a parallel effort was also implemented to provide a functional computer laboratory with sufficient computers. This involves most schools, at both the primary and secondary levels and in all localities including rural areas. This is also seen as an attempt to reduce the digital divide that exists in the different parts of the country by providing computer laboratories to more schools or as Ng (2002) says these schools would eventually be "smart" too. For a start 10,000 schools will be connected to SchoolNet, a nationwide broadband infrastructure to provide a high-speed always-on networking facility to enable students and teachers to conduct collaboration, prepare teaching materials and document sharing (Computimes, New Strait Times, 4 March 2004).

Neo (2003) commented that the infusion of multimedia into teaching and learning has altered considerably the instructional strategy in our educational institutions and changed the way teachers teach and students learn in the Malaysian classroom. Currently, modern educational theory is moving from the traditional recall of facts, principles, or correct procedures into the areas of creative thinking, problem solving, analysis and evaluation which is very much needed in today's knowledge based economy.

As there are many definitions for multimedia, an all-inclusive one would most likely be that multimedia comprises of a computer program that includes "text along with at least one of the following: audio or sophisticated sound, music, video, photographs, 3-D graphics, animation, or high-resolution graphics" (Maddux, Johnson, & Willis, 2001). The key difference between multimedia and so-called traditional presentation "not mediated" through computers is that of the concurrent modalities of presentation that appears to be seamless and "arresting" with multimedia. This may be compared to a narrator on the television screen and the paraphernalia like the chalk board and other audio visuals in a traditional situation.

How should we use multimedia presentations of information to effectively learn in the current context of brain-based learning theory? Contemporary learning theories as posited by cognitivists and constructivists and to some extent multiple intelligence theories (Gardner, 1993) all subscribe to brain functions for any learned behavior. The main idea of these theories presents that learning is the process by which humans receive and process sensory data, encode such data as memories within the neural structures of the brain, and retrieve those memories for subsequent use. These theories usually apply an information-processing paradigm as well as prescribing a systematic design of instruction to effectuate learning. The information-processing model as proposed by Gagné and Driscoll (1988) subsequently became the basis for

interpreting learning. The emphasis in this study is focused on the cognitivist information processing implications. Key areas of concern here are schemas or internal knowledge structures (with reference to existing cognitive structures), working memory (within the information processing model), cognitive load reduction, and cognitive theory of multimedia learning.

In many ways also the present proposed study also attempts to involve issues of constructivist learning so clearly enunciated by the official document entitled "*Pembelajaran secara konstruktivisme*" (*Pusat Perkembangan Kurikulum, Kementerian Pendidikan Malaysia,* 2001) which, *inter alia*, encourages "exploration" (*penerokaan*), "questions from students" (*soalan daripada murid*), "investigation and specific studies" (*penyiasiatan dan kajian spesifik*), and "reflection" (*refleksi*).

It must be noted that while cognitive psychology has its roots in behaviorist principles, the acknowledgement of the mind as in the information processing paradigm has moved cognitive theory forward by the 1970's, and in fact by the late 1980's there is a further shift towards knowledge construction and social mediation as described by Wilson & Cole (1996). Constructivist learning involves the active participation of the learner in the learning process where, for example, the learner may be required to utilize cues or suggestions from the instructor to construct concepts beyond what is presented through peer interactions, referencing, questioning or any other independent self-directed modes. Clearly the difference between constructivist learning and the traditional direct instruction is one of involving learners helping themselves. However what is glaring in this instance is that "does using constructivist strategies in instruction cater for all students?" The researcher here surmises that it may not necessary be so as this depends on the characteristics of each student. Knowing very well the culture of silence (Jassem & Jassem, 1997), or "non-involvement" of Malaysian students

(Halimah & Ng, 2002) some of them may not want to participate actively in the constructivist activities during the teaching-learning procedures when required to do so.

In many ways multimedia as a technological intervention attempts to “present” information more effectively and structurally, as opposed to “teach”, while the learners will gain from such a presentation and consequently learn. The information and communications technology (ICT) that is so well represented by multimedia platforms is said thus to have significant advantages in creating a learning environment through multiple modalities which theoretically should help to build connections within the learner’s brain by engaging different areas within the brain (Moreno & Mayer, 1999b).

In this context the present study attempts to look at the comparison between direct instruction and instruction with constructivist strategies using multimedia on school students. The terms used for the two are “direct instruction (DI)” and “constructivist instruction (CI)”. CI is used as a term to describe instruction using constructivist strategies by Windschitl and Andre (1996), Clements and Battista (1990) and Becker & Maunsaiyat (2004). However as there are some constructivists (e.g., Jonassen, 1999) who are uncomfortable with the term constructivist instruction (CI) as it may imply a contradiction in that constructivism usually refers to student’s construction of their knowledge (von Glasersfeld, 1987;1989a) and hence does not go along with strategies like “instruction” or “teaching”.

This study uses a direct instruction approach mode and an instruction that uses constructivist strategies, thus there are actually two modes of *instruction*. Hence for lack of a better terminology in this study where the treatment is an *instruction* using constructivist strategies the term “constructivist-strategies instruction (CSI)” is used. CSI is the approach or strategies associated with the instructional treatment, and this CSI is compared to the direct instruction (DI) treatment. The lesson activities planned in

CSI actually use a matrix of strategies or some of the strategies that are suggested for constructivist learning environments. DI is often referred to as traditional instruction but for this study it is implemented more systematically and follows strategies adapted from Rosenshine (1985) and take into account the use of multimedia. DI requires a highly structured learning environment and careful orchestration by the instructor (Arends, 1994). Also while DI may not be in favour currently, it still has its potentials (Ng & Fong, 2000).

DI should not be confused with objectivist approach to instruction. The goal of learning from the objectivist perspective is to communicate or transfer complete and correct understanding to the learner in the most efficient and effective way possible (Bednar, Cunningham, Duffy, & Perry, 1991). It must be noted that the strategy in objectivist approach to instruction need not be direct instruction; it could even be performing a specific task with a well-written handbook as long as the learning outcomes are predetermined. Here the learner need not even know why it should be done in that specific way as long as the results are attained.

Objectivists believe learning involves gaining the answer, learners are not encouraged to develop their own understandings or interpretations of what they perceive (Jones, Li, & Merrill, 1990; Merrill 1992). It is the role of the instruction (teacher and instructional designer) to interpret it for them. In simple terms, objectivism holds that learners are the passive receivers of knowledge. Constructivists believe that because there are many perspectives, a correct answer is a limiting factor in learning. Constructivists say learning should focus on understanding and it may involve seeing multiple perspectives, and anchored in some real-world, meaningful context. More discussions on constructivism and instruction appear in Chapter Two.

It must be emphasized that the Malaysian School system as presently conceptualized allows for the use of technology-based delivery system as well as the management of instruction through multimedia. Soon (2003) in his large scale study on Smart Schools illustrated that:

> "….the smart schools programme with its computer as an enabler in instruction and learning is more effective when compared to the traditional approach. However the computer is only a facilitator of teaching and learning processes and cannot replace the curriculum or the teacher" (page 183).
>
> (…*program sekolah bestari dengan komputer sebagai enabler pengajaran dan pembelajaran adalah lebih berkesan berbanding dengan pendekatan tradisional. Walau bagaimanapun komputer merupakan satu-satunya pemudah proses pengajaran dan pembelajaran dan komputer tidak boleh menggantikan kurikulum atau guru*) (page 183).

The process of "managing instruction" in either a direct instruction or constructivist-strategies instruction may or may not overcome the inherent attributes of modality in information presentation. In other words we need to be cognizant of these competing effects of multimedia while using the technology in any one of the instructional approaches. It is also very possible that the concept of working memory and implications on cognitive load may bring about some insights into multimedia effects apart from modality effects. Working memory and the associated cognitive load issues are going to play a role in elaborating on the instructional aspects of multimedia and so does the methodology of using the digital materials.

Chemistry as a subject plays a critical role in science attainment. The availability of digital materials on chemistry concepts may help to improve learning of a critical topic. The Periodic Table is seen to be rather static and is often not given very serious attention in its instruction because it seems to be so straightforward. But this simplicity do not transcend well even with the visual representation of the Periodic Table as Hoffman (1995) so elegantly entitled his book "The same and not the same"!

Most educators would attest to weaknesses of students in the Chemistry subject due to a weak foundation in the basics of chemistry. A poor basic understanding of the principles and theoretical aspects of chemistry would lead to problems at a later stage in the subject. SPM (*Sijil Pelajaran Malaysia*) is the public examination for Form Five school leavers. Chemistry is one of the subjects that the students in the science stream have to sit in the SPM. The recent report on Chemistry performance in the Performance Report of SPM 2003 ["*Laporan Prestasi SPM 2003"*] (*Lembaga Peperiksaan, Kementerian Pendidikan Malaysia*, 2004) of the Malaysian Examination Board, Ministry of Education clearly highlighted this:

> "Topics on Chemical Formulae and Equations, The Structure of Atom, Periodic Table of Elements, and Chemical Bonds are the foundation of Chemistry that need to be given emphasis" (page 26)
>
> (*Topik Formula dan Persamaan Kimia, Struktur Atom, Jadual Berkala dan Ikatan Kimia adalah asas kimia yang perlu diberi penekanan*) (page 26).

The above report clearly stated that the Periodic Table is a foundation of Chemistry Education. This comment was in reference to a number of sub-questions in Questions 1, 2 and 5 of the Paper 2 Chemistry examination specifically. For example, the concept of mole, chemical bonding, the atomic mass, electron transfer, and redox (oxidation and reduction) reactions are not well attained by SPM students. Then there were also weaknesses in stating the oxidation number, arrangement of electrons in the various shells and uses of inert gases with reference to the Periodic Table. The performance of Chemistry for SPM 2003 and reports previous to it contained actual comments of experienced Chemistry teachers who had evaluated and assessed the examination scripts of the students and their comments are accepted and officially endorsed by the Ministry of Education, Malaysia. The reports' comments thus are more reliable than "off-the-cuff" opinions of randomly selected pools of chemistry teachers.

According to Hoffman (1995), the difficulty in comprehending the Periodic Table is because elements in the same group may seemingly share the same chemical and

physical properties but details of finer aspects of the group of elements will illustrate a gradual change in attributes. This may escape the attention and comprehension of the learners except when specifically referred to either by the instructor or arrived at by the inquisitive students.

Now that there are digital approaches to the instruction of the Periodic Table, does a parallel instruction on the Periodic Table using visuals similar to that in the digital version but taught or led mostly by the instructor be just as effective? It may be surmised that CSI would be more effective when compared to a teacher-led direct instruction. The apparent advantage of utilizing a CSI may be derived with the contention that the methodology of instruction and/or learning may make a difference. Here it is contended by most practicing constructivists that having learners actively "construct" their learning experience will lead to more effective learning (Jonassen & Reeves, 1996).

Alessi & Trollip (1991) contended that apart from the novelty effects of new media, most instructional designers using the digital medium were supportive of the advantages of multimedia in providing a richer and more realistic if not more interesting medium for the learners. Even with the digital medium it is not always fully media-based as vouched by studies on uses of digital media in even the Smart Schools, a flagship application of the MSC. Here it is expected that much more instructional transactions would be through the digital medium but for the most part the scenario is otherwise (Soon, 2003). According to Soon (2003), Smart Schools instruction thus far have not revealed an inclination for the use of multimedia in teaching-learning situations and this may have been due more to teachers' readiness than to the physical constraints within the school environment. Thus this study attempts to use the two approaches of instruction with a measured amount of instructor-led events and only when the portions that are presented using constructivist strategies, will there be any

specific comparison with the direct instruction for the same contents covered. In this study a set of protocols for the two approaches of instructions was developed.

Studies on differential psychologies have also indicated that students learn differently with mediated instruction (Mayer, 2001). Apart from innate intelligence, there are also other psychological considerations that may well play a part in the learning of materials presented either through direct instruction or through constructivist-strategies instruction using multimedia materials. Many studies conducted locally have illustrated that students with different psychological profiles reported different achievements using digital media (Fong & Ng, 2000). For example, students described as “high internals” in Locus of Control measures showed higher attainments than students who are “low internals” with or without multimedia instruction. Similarly, students who are “high” in Cattell measures also perform better than students “low” in Cattell measures in both modes of instruction (Toh, 1998). The local and other studies however do not analyse the results of the studies based on higher and lower order knowledge tasks which this study attempts to perform.

## 1.2 Problem Statement

Constructivism is highly encouraged as a methodology in schools even by the Ministry of Education Malaysia (*Pusat Perkembangan Kurikulum*, 2001), but despite workshops and encouragement, many teachers are still not sure of how to implement the constructivist approach. The challenge faced by the teachers is in adapting ICT / multimedia resources with methodologies (pedagogy) and curriculum requirements (UNESCO, 2005). To date there are no concrete representations of the success or otherwise of a constructivist instruction on all Malaysian students.

This is more so when digital materials (many in CD-ROMs) are used as stand-alone software and in most instances “taught” using what is in the program, i.e., as a

presentation device (Soon, 2003). So despite all the theory building and exhortations by constructivist experts in the field like Duffy, Lowyck & Jonassen (1993), Jonassen (1999), and Wilson (1995, 1996), there are not many studies implementing constructivist strategies and confirming their effectiveness. In the area of the Periodic Table, the commercially available courseware are mostly in English and they tend to be mostly drill-and-practice. It is important to re-vamp such materials together with any similar materials in the National Language and modifying the instructional approaches to include activities using these multimedia materials.

While constructivism is well discussed in the 1990's, Airasian & Walsh (1997) commented that there was no "instruction of constructivism" that can be readily applied in classrooms, only suggestions of strategies (e.g. cooperative learning, problem solving) that are likely to foster student construction of knowledge. In Malaysia, there were relatively few studies on the methodology of constructivist instruction despite the effects of Ministry of Education to promote constructivist learning through the "5E approach" – Engage, Explore, Explain, Elaborate, and Evaluate (*Pusat Perkembangan Kurikulum*, 2001) . Thus far there is one study by Lim (2002) who has ventured into the effectiveness of constructivist approaches to web-based learning in Biology for secondary school students. Another study by Neo (2003) was on the use of multimedia mediated constructivist learning environment on project work by students at the university level.

Science teaching in Malaysia is very typically teacher-centred as reported in the TIMSS 2003 (IAE, 2005) the Third International Mathematics and Science Study and also known as the Trends in International Mathematics and Science Study in the U.S.A. Throughout the world (including Malaysia), Direct instruction is still a dominant mode of instructional strategies since 57% of the class time were on the three most

predominant activities: “teacher lecture”, “teacher-guided student practice”, and “students working on problems on their own”.

This study contends that in Malaysia, there was little evidence of the teacher practicing constructivist approach in the classroom. This is mostly due to a lack of understanding of the way or prescription to using constructivist approach. The instruction should shift away from teacher-centred towards teacher-led as well as more student participatory learning so as to provide a framework for instructional practices and strategies. This mode would have to take into account the present introduction of multimedia materials to enhance instruction and how this can be leveraged towards a constructivist mode of instruction.

Most Malaysian schools are provided with a computer laboratory, notebooks and LCD projectors, multimedia resources/courseware, and access to Internet. As such teachers are expected to use these digital materials effectively. Despite workshops and encouragement, many teachers are still not too sure of how to use these multimedia resources effectively (UNESCO, 2005). The mode of use is going to impact on the effectiveness of the media (Clark, 1994).

Discounting Smart Schools, there are also many schools in Malaysia with well-endowed computer equipment and supporting courseware that can be used by the school teachers. The challenge faced by the teachers are in adapting these resources to existing pedagogy and strategies. There are some useful digital materials in the National Language (*Bahasa Melayu*) available commercially whose contents do fit the school curriculum. However their “teaching methodology” are still very behaviorist or cognitivist, that is very direct in information presentation and engaging the learner in a mostly “drill and practice” manner (Ng, 2001).

Alessi & Trollip (2001b) suggested that despite the low credence given to behaviorist and cognitivist learning theories which propose that learning is no more than the transmission of a body of knowledge from teacher to student as in the instructional approaches, there are no interactive multimedia that can lay claim to being constructivist in nature. Jonassen (1991) rightly proclaimed that most interactive multimedia programs are frequently found with behaviorist traditions: “The roots of behaviorism extend deeply into IST [instructional systems technology] practice”. Thus a review of existing CD-ROM programs or any other digital modes on the Periodic Table have to be conducted to identify one that is least behaviorist and then to “emulate” it into a format that can be used in the study to accommodate direct instruction and constructivist strategies instruction. It must be emphasized that these courseware are proprietary and as the source codes are not available, the researcher is obliged to develop a new set of protocols that is suitable for the research and that is also reflective of the chemistry curriculum. Clearly, as stated by Herrington & Standen (2000), the solution to attain constructivist instruction is much more than the software itself. It is the methodology of using the software and the accompanying interactions with the software that is going to decide on the methodology identified. What is a constructivist teaching tool and what is one that is cognitivist direct instruction will be explained in the development of protocols of multimedia instruction using the two approaches in this study.

The study takes note that a new technology may not by itself lead towards changes in practices or even improvements after discounting novelty effects. Heinich, Molenda, Russell, & Smaldino (1999) warned that older teaching-learning technologies such as television, audio tape, film and overhead projector still are used as they do have their own advantages. In fact some newer technologies such as the *Internet* and digital software may be able to present contents in a newer mode but their impact on educational transformation have not yet been seen (Educational Technology, 1993).

Abdul Kalim (1995) emphasized the need for computer-based instructional materials to encourage higher order thinking. In fact he contended that there are limits to what can be learnt or taught but if the students acquired higher order thinking, this would inevitably lead to better science learning.

Thus if the instructional materials can be used to encourage students to “think” using constructivist principles (Duffy & Cunningham, 1996), it may help overcome the reported lack of higher order thinking skills in students. This is supported by an observation by Kozma (1991) that the presentation medium and the presentation method are interrelated; both being a part of the instructional design and that they may either assist or reduce the effects of the instruction. Similarly Ismail M. Zain (1994) reported that suitable instructional design can enhance instruction and this is dependent on the matching of the instructional approach with the type of learner. Ismail M. Zain (2002) further stated that the process of applying multimedia in the instruction whether it be computer or non-computer based depends on both the infrastructure and its suitability to the student.

When Lim (2002) compared the constructivist approach with the direct approach for a web-based learning on a science topic involving 168 Malaysian students, Lim found that the constructivist web-based learning is more superior than direct web-based learning. But it did not bring about differences in attainments based upon science epistemological knowledge and attitude towards science. However with regards to locus of control, Lim (2002) demonstrated that students categorized as high internal in locus of control measures attained significant better scores with constructivist approach compared to those with direct instruction. This finding is consistent with the Kalechstein & Nowicki (1997) explanation that learners with high internal locus of control get maximum benefits from an unstructured environment such

as constructivist learning situations which requires them to actively assimilate information during learning.

Lim's (2002) finding is parallel to the larger study of Soon (2003) that states that the digital instruction enhances learning more than the non-digital instruction. However both these studies are in contrast to Roziah (1998) that reported the advantages accrued to higher ability students with multimedia. Perhaps the methodology of use of the media is more important and this study attempts to investigate into it. A more recent study comparing two forms of instructional strategies by Becker & Maunsaiyat (2004) and a brief review of that study has been made so that better implementation of treatments can be utilize for this research. The study uses the "constructivist instruction (CI)" versus "direct instruction (DI)" modes. While no significant differences are noted in the immediate posttest, there was however a high delayed (retention) test score for students following the CI. And based on both groups of students' attitudes surveyed, items like "Teacher's use of examples", "Helpfulness of teacher's explanation" and "Teacher's enthusiasm for the lesson" scored 4 and above (on a 5-point Likert scale) when compared to more student-centred items. Becker & Maunsaiyat noted that "however, some students believed that mixing both approaches together would be beneficial." Hence they concluded that "an argument can be made that the constructivist approach is at least as effective as the traditional approach." So for the present study, the constructivist-strategies instruction (CSI) has been further ameliorated to include the pivotal role of the teacher in using appropriate constructivist strategies.

With regard to the nature of Chemistry, Johnstone (1991) believed that Chemistry exists in three forms which can be thought of as corners of a triangle (Chemistry Triangle). These forms of the subject are: the macro and tangible form, the sub-macro form, and the representational form. Johnstone has suggested that

Chemistry is customarily taught at three different levels, microscopic, macroscopic, and symbolic. Changing back and forth between these levels is part of what makes Chemistry difficult to understand. However the use of images or visuals can help to bridge the gap between the microscopic and macroscopic worlds of Chemistry. Thus both modes of instruction in this study utilized similar images or visuals and video clip from the multimedia materials to assist learning in Chemistry.

Another viewpoint on learning theories is elaborated by Ertmer & Newby (1993) and Ng (2002) that, *inter alia*, proposes that the three learning theories cater for three different strategies that affect learning tasks with the constructivist being “stronger” in promoting higher level learning tasks and commensurate with the level of cognitive processing.

This study will prescribe and report on the differences in attainments using constructivist-strategies instruction and whether or not this approach helps in both low and high level task knowledge acquisition. It is possible that the constructivist approach would be contributing towards higher order learning as suggested by Ertmer and Newby (1993) and Ng (2002). But will it contribute to varying degrees of attainment for students who are different in their psychological profiles? It can be noted that von Secker (2002) provided evidence that student-centred, inquiry-based approaches are not effective for all students of varying demographic profiles, and that learner-centred pedagogy may actually decrease achievement among less advantaged students.

The key to measuring differential effects is to base on higher-order learning as suggested by many practicing constructivists and focused on analysis, evaluation, generation (knowledge building) and problem solving (Scardamalia & Bereiter, 1991; Sanger & Greenbowe, 2000). This will in many ways fulfill the constructivist principles positing that learning is achieved by active construction of knowledge supported by

various perspectives within meaningful contexts (Dede, 1995; Duffy & Cunningham, 1996), and this can be further enhanced when social interactions are built into the learning process of learning and cognition (Vygotsky, 1978). These strategies (social interaction – collaboration and small group activities, multiple perspective, problem solving) have been incorporated into this study's definition of CSI.

In addition, the digital learning materials selected should organize information in conceptual clusters with the intent of accommodating relevant cognitive load as well as having questions and practices in order to engage a learner's interests for both approaches of instruction. In direct instruction where the instructor uses these digital materials to teach to a big class, interaction of learners with the digital materials are thus limited to teacher-led activities. Direct instruction is likely to have less impact on learning comparatively when students are not given opportunities to work interactively with the materials/courseware. In a constructivist classroom instruction, apart from teacher-led instruction, students are directed to draw upon their own experiences and ideas, preferably working in pairs or groups, to work on questions posed for further self-improvement (Brooks & Brooks, 1993). The main difference of this constructivist classroom instruction from that of direct instruction is how students are learning and not just what they are recalling (Brooks & Brooks, 1999). Thus will there be a difference in attainment using the two differing approaches? The study attempts to find out if these differences are significant statistically.

With the two versions of instruction employing selected appropriate multimedia materials, the study can thus focus on the differential attainments, if any, on psychological profiles of general ability or intelligence as measured by the Culture Fair Intelligence Test Instrument (Cattell & Cattell, 1973), and the internal locus of control using the Intellectual Achievement Responsibility Questionnaire (Crandall, Katkovsky &

Crandall, 1965). These moderator variables are suggested to influence learning due to effect of individual differences and are discussed in Chapter Two.

## 1.3 Objectives of the Study

This study attempts to design a better instructional approach to the teaching of the Periodic Table using two approaches of instruction and using almost similar digital materials. The study adapted and used specific parts of the validated courseware on the Periodic Table (Appendix L) in either a direct instruction or constructivist-strategies instruction approaches / treatment. The two groups of students were exposed to the same digital materials and the differences were in the way the digital materials are utilized as explained in the lesson protocols (Appendix O). This is different from most local studies that tend to focus on the attributes of the multimedia (e.g., animation, feedback, and different modalities) and not the methodology of using the courseware. In view of the potential of multimedia it is necessary to ascertain if learning from the media is effective, to take into considerations of the cognitive load on learners as well as to consider the influence of specific psychological profiles of students. Thus the study was multi-fold and is based on the following objectives:

a. To evaluate and incorporate suitable multimedia courseware on the topic of Periodic Table.
b. To determine if two approaches (direct instruction and constructivist-strategies instruction based on the protocols) of using multimedia instructions would lead to different overall attainments.
c. To determine if two approaches (direct instruction and constructivist strategies instruction) of using the courseware would lead to different attainments based on level of knowledge tasks and problem solving.

d. To determine if two approaches (direct instruction and constructivist strategies instruction) of using the courseware would lead to different attainments for students with different psychological profiles.

## 1.4 Research Questions and Hypotheses

Research questions (Q) and their accompanying hypotheses (H) are constructed based on the problems identified and their objectives for the study. Recent studies (Lim, 2002; Becker & Maunsaiyat, 2004) had demonstrated that constructivist instructional strategies had been more superior than a direct instruction mode. The theoretical postulates by Ertmer & Newby (1993) and Ng (2002) also support the use of constructivist mode of instruction especially when the contents of the instruction involved higher order learning efforts. Hence the hypotheses in this study are stated as Research Hypotheses (Gay, 1996) in that it is expected one treatment (here Constructivist-Strategies Instruction, CSI) is more superior to the other (the Direct Instruction, DI). Research Hypothesis is also known as “directional hypothesis” that can be tested as statistical hypothesis (Borg & Gall, 1989).

All hypotheses formulated were *a priori* directional hypotheses and tested at significant level of $p < 0.05$. Null hypotheses were not used in this study.

Q1. Are there differences in attainments by students using the two approaches of instruction on the periodic table?

H1: Students following constructivist-strategies instruction will attain significantly higher mean gain scores than students following direct instruction.

Q2. Are there differences in attainments by students using the two approaches of instruction on the periodic table for different levels of knowledge tasks?

H2.1: Students following constructivist-strategies instruction will attain significantly higher mean gain scores than students following direct instruction for lower order knowledge tasks.

H2.2: Students following constructivist-strategies instruction will attain significantly higher mean gain scores than students following direct instruction for higher order knowledge tasks.

Q3. Are there differences in attainments by students of high and low ability (Cattell & Cattell, 1973) using the two approaches of instruction on the periodic table?

H3.1: High ability students following constructivist-strategies instruction will attain significantly higher mean gain scores than high ability students following direct instruction.

H3.2: Low ability students following constructivist-strategies instruction will attain significantly higher mean gain scores than low ability students following direct instruction.

Q4. Are there differences in attainments by students of high and low ability (Cattell & Cattell, 1973) using the two approaches of instruction on the periodic table for different levels of knowledge tasks?

H4.1: High ability students following constructivist-strategies instruction will attain significantly higher mean gain scores than high ability students following direct instruction for lower order knowledge tasks.

H4.2: High ability students following constructivist-strategies instruction will attain significantly higher mean gain scores than high ability students following direct instruction for higher order knowledge tasks.

H4.3: Low ability students following constructivist-strategies instruction will attain significantly higher mean gain scores than low ability students following direct instruction for lower order knowledge tasks.

H4.4: Low ability students following constructivist-strategies instruction will attain significantly higher mean gain scores than low ability students following direct instruction for higher order knowledge tasks.

Q5. Are there differences in attainments by students of high and low internal locus of control using the two strategies of instruction on the periodic table?

H5.1: “High Internal Locus of Control” students will attain significantly higher mean gain scores than “Low Internal Locus of Control” students following either constructivist strategies or direct instruction.

H5.2: “High Internal Locus of Control” students following constructivist-strategies instruction will attain significantly higher mean gain scores than “High Internal Locus of Control” students following direct instruction.

H5.3: “Low Internal Locus of Control” students following constructivist-strategies instruction will attain significantly higher mean gain scores than “Low Internal Locus of Control” students following direct instruction.

Q6. Are there differences in attainments by students of high and low internal locus of control using the two approaches of instruction on the periodic table for different levels of knowledge tasks?

H6.1: “High Internal Locus of Control” students following constructivist-strategies instruction will attain significantly higher mean gain scores than “High Internal Locus of Control” students following direct instruction for lower order knowledge tasks.

H6.2: “High Internal Locus of Control” students following constructivist-strategies instruction will attain significantly higher mean gain scores than “High Internal Locus of Control” students following direct instruction for higher order knowledge tasks.

H6.3: “Low Internal Locus of Control” students following constructivist-strategies instruction will attain significantly higher mean gain scores than “Low Internal

Locus of Control" students following direct instruction for lower order knowledge tasks.

H6.4: "Low Internal Locus of Control" students following constructivist-strategies instruction will attain significantly higher mean gain scores than "Low Internal Locus of Control" students following direct instruction for higher order knowledge tasks.

The above research questions lead to the generation of *a priori* directional hypotheses and this thus allowed for the analyses of data of the quasi-experimental study to be conducted using *t-tests* (Borg & Gall, 1989) instead of beginning with Analyses of Variances (to determine if between group variances is significantly greater than within group variances) to look for differences amongst the specified variables. The results of the *t-tests* significant at $p<0.05$ are then used to support or reject the *a priori* directional or research hypotheses.

In this study, ability and internal locus of control are used as the moderator variables, there are also other existing variables that may have effects to the dependent variables. These existing factors are readily available in the forms of previous performance scores in the *Penilaian Menengah Renda*h (PMR) examination, or more specifically individual science subject's performance. PMR being a national examination has more robustness and is used as a predictor of subsequent academic success in later examination. Thus the study will consider the effects of existing science ability of students (Science performance in PMR, namely PMR_Science) in the subsequent analysis in conjunction with the moderator variables and the dependent variables.

Correlation can be conducted to check on the inter-relatedness of existing factors (the existing ability in science i.e. PMR_Science; and prior knowledge which is

based on the pretest scores) among the variables in the study (independent, dependent and moderator variables). Additionally an analysis of covariance (ANCOVA) is used to determine if any one of the intervening or moderator variables and independent variables are correlated significantly in the Pearson Correlations analyses. As a final analysis, regression equations are generated to determine the amount of contributions of these variables to the mean gain scores and problem solving scores.

## 1.5 Importance of the Study

There are already an extant number of studies in multimedia, mainly with regards to the manipulation of variables within the multimedia (e.g., text with graphics and with or without sound, types of feedback, and animation) and how these affect differences in learners. The meta-analyses of 22 research in these areas done at University of Science Malaysia illustrated that most of the independent variables are variations in the mode or modality of the media as reported in Ng & Fong (2001), and not the methodology or approach in the use of the media. Out of these 22 researches, there is only one study by Lim (2002) which has ventured into different approaches to web-based instruction. Hence while constructivism is well discussed in the 1990's there were relatively few studies on the methodology of constructivist instruction.

The study reported on the differences in attainments using constructivist-strategies instruction versus direct instruction and if these approaches helped in both low and high level task knowledge acquisition.

The study demonstrated ways of adapting ICT / multimedia resources with methodologies (pedagogy) and curriculum requirements on Science Education. Instruction can be designed to include different instructional strategies or activities using these modifying multimedia materials based on the targeted levels of knowledge tasks. The lessons protocol and student's worksheet were prepared ahead of the

lesson, and served as guides to implement different instructional strategies (e.g. providing guidance and scaffold, social interaction / collaboration among learners, creating group learning activities with multimedia / virtue experiment, selecting task for students to work in small groups as a goal,  worked example effect, completion effect in the problem solving as in CSI and DI lessons protocol).

This is an apt study to abide by Richard Clark's (1994) contention that media do not influence learning but other events such as instructional strategies and learner's psychology do. In fact Ruth Clark (2002) reiterated and reinforced Richard Clark's position in that "…we know from hundreds of studies that it is instructional methods, not the media, that determine learning effectiveness". Thus this study uses similar media and materials for both approaches of instruction and thus does not attempt to relate the attainment scores to the media but to the treatments.

The study has come up with a practical application of constructivist-strategies instruction using the teacher or instructor as a facilitator and guide to the student's learning and not to surrender the learning or construction solely to the students. This is especially so with regards to the parts of the topic under discourse that require higher order cognitive tasks. This CSI approach is thus more acceptable by Malaysian instructors/teachers as opposed to the more radical interpretation of constructivism.

The study had laid the foundations for managing instruction using protocols and observation schedules to ensure "what is planned is implemented" for subsequent studies that may want to replicate this study.

This study has prescribed to Constructivist-Strategies Instruction by employing the "best practices" of the constructivist teacher through the lessons protocol and student's worksheet. This will contribute towards research-tested instructional

strategies for practicing teachers in any subject area. It is up to the teachers to implement the protocol accordingly.

## 1.6 Theoretical Framework

The study is on the approach or strategies associated with the instructional treatments, namely, constructivist-strategies instruction (CSI) compared to the direct instruction (DI). Both approaches are implemented to bring about learning. Learning then comes about through acquisition and construction of “knowledge” from the environment (from a constructivist viewpoint) or learning is transmitting knowledge in direct instruction. Learning had been explained from the behaviorist to cognitivist and now constructivist perspectives. The research also noted the contention that the method of instruction is critical to learning from a given instruction (Clark, 1994; Ruth Clark, 2002). This research’s theoretical framework then is based on the following theories and models. They are the Information Processing Model by Gagné & Driscoll (1988), Cognitive Theory of Multimedia Learning by Mayer (2001) and Cognitive Load Theory (Sweller, 1999; Cooper, 1998). All these theories have influence on learning and carry with them implications on instructional strategies e.g., using a number of representations for the same concept by applying the constructivist strategy of orientation towards multiple perspectives. More of these constructivist strategies are discussed in Chapter Two. Brief explanations of the models and theories are presented in this Chapter and are elaborated further in the literature review sections.

The Information Processing Model (Gagné & Driscoll, 1988) in Figure 1.1 becomes the basis of learning as a product of transaction between the environmental inputs and the processing of these inputs with what is already available within the individual. Much of this Information-Processing Model has been used to explain the cognitive psychology of learning. This Information-Processing Model can also be used to represent constructivist learning as the learning is a measure of change in meaning.