EFFECT OF SPLIT ATTENTION MULTIMEDIA PRINCIPLE AND COGNITIVE LOAD ON SENIOR SECONDARY SCHOOL STUDENTS' RETENTION IN QUANTUM PHYSICS IN OGUN STATE NIGERIA

BY

JUDE BABTUNDE, KUTI

MATRICULATION NUMBER: 131423

B.A. (Benin), M.Ed (Ibadan)

A Thesis in the International Centre for Educational Evaluation (ICEE)
Submitted to the Institute of Education
In partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

of the

UNIVERSITY OF IBADAN

NOVEMBER 2012

ABSTRACT

The use of multimedia instructions during teaching and learning of quantum physics is becoming popular to overcome the abstract concepts within the subject as well as the resultant students' poor performance. It is also pertinent to consider the limitedness of the resources of working memory during multimedia instructions of abstract concepts in order to gauge irrelevant factors considered extraneous to learning which create unwanted cognitive load and hinder retention. However, the determination of the appropriate use of multimedia instruction is undergoing evolution and there is need for further study of the principles of the instructions. Split Attention, one of the theorised principles during multimedia instructions is investigated in this study in three design conditions (DCs) which are use of text with graphics delivered by a speaking agent or an instructor (DC-A), use of text with graphics and a digitised human voice (DC-B) and use of text with graphics only (DC-C). Abstract and spatial reasoning abilities were considered as moderating variables.

The study adopted a 3×3×2×2 non-randomised control group factorial design in a quasi-experimental setting. Using multistage sampling technique, 247 participants from six secondary schools comprising 115 and 132 participants in Ijebu and Remo educational zones of Ogun state respectively were selected. Five data collection instruments were used, namely; Quantum Physics Pre Test (r=0.78); Cognitive Load Test (r=0.89); Abstract Reasoning Test (r=0.62); Spatial Reasoning Test (r=0.74) and Retention test in Quantum Physics (r= 0.78). Fifteen hypotheses were tested. Data were analysed using Analysis of Covariance.

The main effect of treatment was significant on students' retention in quantum physics ($F_{2, 212} = 45.154; p<0.05$), revealing that students exposed to multimedia instructions delivered by an instructor (DC-A) performed significantly better than students exposed to other design conditions; ($\bar{x}$ DC-A = 40.344, $\bar{x}$ DC-B= 35.798, $\bar{x}$ DC-C=31.067). The main effect of cognitive load was significant on students' retention in physics ($F_{2, 212} = 3.526; p<0.05$), confirming that high cognitive load during instructions minimise retention. The two way interaction effect of treatment and abstract reasoning ability was significant on students' retention in quantum physics ($F_{2,212} =3.342$, $p<0.05$), thereby endorsing the abstract and intangible nature of quantum physics. The two way interaction effect of cognitive load and spatial reasoning ability was significant on students' retention in physics ($F_{2,212} =3.111$, $p<0.05$), which explained the impact of cognitive load on spatial processing. The three way interaction effect of cognitive load, abstract reasoning ability and spatial reasoning ability was significant on students' retention in physics ($F_{2,212} =4.630$, $p<0.05$).

Multimedia instructions delivered by a speaking agent (DC-A) offer utmost benefit for retention. Teachers should seek ways to train students to reason abstractly in order to overcome the abstract nature of quantum physics. In the use of multimedia instruction the arrangement of graphics, animations and text must align with appropriate spatial orientation in order to minimise cognitive load during instructions. There is a need to build into the physics curriculum for teacher education and other related disciplines the appropriate use of multimedia instructions in education.

Key words: Split attention multimedia principle, Quantum physics, Cognitive load, Senior secondary school students

Word count: 499

DEDICATION

This work is dedicated to

Our Lady

Seat of Wisdom

ACKNOWLEDGEMENTS

At the time of onset, it was difficult to know exactly how many people would be instrumental in helping me to complete this work. However, hindsight often serves as a reminder of the support and understanding of others that I did not fully recognize at the time. I hope those mentioned here understand how greatly I appreciate their support and encouragement even though I might not have let them know at the time.

I am completely indebted to my Creator, the righteous Father who remains faithful and whose grace has been sufficient to accomplish this work. To you be glory and praise forever. Amen

I am grateful to my Local Ordinary, Most Rev. Dr. Albert Ayinde Fasina, a father and guide, "*thank you for this opportunity*". I am equally indebted to all the priests of the Catholic Diocese of Ijebu-Ode.

I appreciate the efforts of Professor Adenike Emeke, for being more than a supervisor. Thank you for teaching me about life, academics and faith. I must mention that her patience and love for learning made this experience a positive one from which I have gleaned important information that will shape my academic and pastoral mission. I also remain sincerely grateful to Dr. Benson Adegoke, my co-supervisor for carefully reading through this work and giving helpful suggestions for excellence.

I owe a special thanks to all the faculty members of the Institute of Education, University of Ibadan for the research ability ignited within me, especially Drs. Adams Onuka, Joshua Adeleke, Modupe Oshokoya, Veronica Falaye, Monica Odinko, Eugenia Okwilagwe, among others. I also extend this appreciation to my fellow research students of the Institute of Education, in whose company I have garnered critical thinking. I greatly appreciate the principals and physics teachers of the various schools used in this study. A work like this depended greatly on the students used as experimental participants and I am particularly grateful to all of them. I also thank all the students of Sacred Heart Catholic College and Our Lady of Apostles Secondary School, Ijebu-Ode for being the inspiration for my academic pursuits. My special thanks are extended to the solid members of staff of both schools namely, Mercy, Rose, Phil, Edward Bankole, Mr. Okoroji, Mrs. Fakorede, Mr Rojaiye, Rev. Sr. Juliana, Mr Adesanya, Mrs Ajayi among others whose camaraderie and work manner have improved my personality. Special thanks must be given to the Education Department of the Catholic Diocese of Ijebu-Ode, directed by Rev. Fr. Patrick Balogun and the support staff in Mr Ajewole, Mrs Hassan among for keeping my progress on schedule.

I reserve this space for Rev. Fr. Ethelbert Ukpabi whose timely sense of humor, kind words and funds support helped me to continue trudging on when the way seemed rather bleak. I am deeply indebted to Rev. Fr. Francis Akinpelu who gave me his bed and desk to work, study and rest on every occasion I visited. You are indeed a brother.

I also thank my sisters, Mrs. Bukunola Adebanjo and Mrs. Omosalewa Fasanya for their loving presence. Very special thanks to Professor ‘Fola Adebanjo, of the Faculty of Science, National Open University of Nigeria. I vividly recognise my second family in Mr Folusho Adedigba, Mr and Mrs Odeleye, Kayode, Ope, Woyin, Temitayo, Bimbo and Bisola. Thank you all for the support that you have given me to help me reach this point in my life.

Finally, I am grateful to the loving memory Mrs Omishade Adedigba who saw the commencement of this study but never saw the end. I pray you find rest with my parents in the company of Mary, Our Lady Seat of Wisdom.

CERTIFICATION

I certify that this work was carried out by Jude Babatunde KUTI in the Institute of Education, International Centre for Educational Evaluation (ICEE), University of Ibadan, Ibadan, Nigeria

……………………………..…..   …....……………………..

Professor E. Adenike Emeke
(Supervisor)   **Date**
B.Ed.; M.Ed.; Ph.D. (Ibadan)
Institute of Education
University of Ibadan, Ibadan

………………………………...   ……………………….
Dr. Benson Adegoke
(Co-Supervisor)   **Date**
B.Ed Physics; M.Ed
Ph.D (Ibadan)
Research Fellow I
Institute of Education,
University of Ibadan, Ibadan

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.1 Background to the Problem

Verbal mode of presentation has been the primary means of explaining ideas to learners for many years. Consequently, classroom instructions have been delivered using verbal communications, such as lectures and printed texts. Mayer (2005) corroborates this premise in his assertion that verbal modes of presentations have often dominated the way ideas are conveyed in education. Verbal mode of presentation therefore has been a major focus in educational research. Although verbal communication offers a powerful tool for teaching and learning, there are, with the recent advent of powerful computer graphics and visualisation technology, enhancements that explore alternatives that go beyond the purely verbal approach since people learn better from words and pictures than from spoken or written words alone, (Mayer, 2009). An alternative therefore to purely verbal presentations is to use multimedia presentations in which people learn from words and pictures, a situation Mayer (2001) describes as multimedia learning. This genre of computer technology in education usually described as multimedia learning is when computer is used to control the presentation of graphics, video, animation, and sound to offer new possibilities for teaching and learning. With the facility of multimedia learning, instructors have the ability to supplement verbal modes of instructions with pictorial modes which are often enabled with compelling dynamic images in animations and videos.

Technology has transformed all aspects of life, from agriculture and transportation to modern culture. Science and technology have achieved great successes, increasing productivity, lowering costs and improving the quality of life for many people (Jonassen, 1988). Computers, for example are constantly redefining the way people in the world today live and work such as in music, sports, entertainment, education, medicine, engineering, agriculture, religion, politics, among others. The prevalence of computers in the home and workplace has increased exponentially (Schaller, 1997). The development of the internet has revolutionized how people communicate and introduced a new genre of entertainment and information. In fact, computer technology development is fast undergoing an expansive overhaul in memory capacities and processor speeds for example which are short-lived with rapid modifications (Schaller, 1997; Heyneman, 2001). Educators recognize the significance of this global trend and are eager to keep education abreast of this trend (Fluck, 2001). Along with this trend in education come the growing repositories of learning objects, educational resources that range in complexity from text or graphics to dynamic simulations (Conole, 2002; Friesen, Roberts and Fisher, 2002).

The Federal Government of Nigeria in its effort to associate with the technologically advancing world introduced computer education into the Nigerian Secondary School system, which came with the inauguration of the National Committee on Computer Education in December 1987. However, this enthusiastic attempt of the Federal Government of Nigeria to revolutionize education significantly in secondary schools with computer technology appears to have been subdued with unresponsive outlook. Odogwu(2000) corroborates this in his position that the enthusiasm with which the minister's address was received did not produce the necessary actions. Maduekwe (2003) decries that it seems as if the policy has disappeared with its formulators.

Though technology and education have long been intertwined, the movement to merge the two has lacked vigor (Cuban, 1986). A famous example is Thomas Edison’s prophesy for the motion picture: “I believe that the motion picture is destined to revolutionize our educational system and that in a few years it will supplant largely, if not entirely, the use of textbooks,” (Josephson, 1992). Similar statements were made about the role of radio, television, video, interactive video, the computer, and the Internet in education. Cuban (1986) argued that the romance of education with technology has clearly not lived up to expectations in developing nations. Although this may be due in part to practical constraints, researchers however, have had difficulty establishing the learning advantages of computer technology in theory (Clark, 1994; Kozma, 1994). In a series of papers, Clark and Estes (1998, 1999) assert that the “gradual eroding and splintering of technology in education,” is a crisis created by a lack of substantial research, aggravated by a reliance on intuition and enthusiasm for new technology. Other researchers in educational technology acknowledge that the rapid advancements in technology have developed ahead of the research required to support them (Mayer, 1997; Rieber, 1990). Muller, Eklund and Sharma (2006) observed three main obstacles which have hindered the progress of educational technology research. Firstly, proponents of technology have used the enthusiasm, assumptions, and excitement surrounding technology as substitutes and sometimes rebuttals for empirical evidence. Secondly, until recently, studies sought to uncover the advantage of one medium over another without considering how learning occurs and how the media concerned differ in this respect. Finally, although technological interventions are frequently developed and used, they are rarely based on or employ well-structured research. The combination of these factors has created a crisis whose only resolution lies in authentic, theoretically based research.

Research into teaching and learning with new technologies is currently a very dynamic, high-profile and relevant area of educational enquiry. Educational institutions are increasingly engaged with integrating technology into the delivery of course materials and in the provision of alternate methods for learning. Although the extent to which these efforts are based on sound principles established through research and experience is a matter for debate. Many studies in educational technology show a lack of an appropriate theoretical grounding and regard for scientific empirical testing (Muller, Eklund and Sharma, 2006). Though some advances have been made in developing new instructional technologies and in understanding how learners interact with media; however, a holistic view of educational technology research and its future remains elusive (Muller, et al). Despite some promising current research programs, the overwhelming consensus is that “with few exceptions there is not a body of research on the design, use, and value of multimedia systems” in education (Moore, Burton, and Myers, 2004).

One important benefit of multimedia instruction is the ability to simulate real world phenomena that may otherwise be unattainable due to cost, feasibility or safety through computer-based multimedia elements, that may be equally as effective as a real-life, hands-on laboratory experience in teaching students scientific concepts (Choi and Gennaro, 1987). Multimedia instruction actually refers to presentations involving words and pictures that are intended to foster learning (Mayer, 2009). In using multimedia to facilitate the teaching and learning of physics it must be noted that multimedia does not make teaching and learning of physics superficially easy, but it reveals its appropriate level of complexity by presenting only the germane load and explaining only the appropriate conception. In the early 1980s, Viennot(1979), McDermott (1981), and other physics education researchers like Clement(1982), and Halloun and Hestenes(1985), found that each student comes into a physics class with a system of commonsense beliefs and intuitions about how the world works. These commonsense beliefs, derived mostly from students’ previous personal experiences, are often referred to as misconceptions, preconceptions, or alternative conceptions. Researchers have shown that these commonsense beliefs are very persistent, and traditional (conventional) instruction does little to change them.

Physics education research has changed the view of students learning in the traditional instruction. Regardless of the emphasis on the importance of conceptual understanding of physics, researchers have found that students leave physics classes with less understanding of concepts than instructors expect (McDermott, 1990). Researchers have studied student difficulties in understanding physics and have focused on developing research-based instructional material to overcome these difficulties. McDermott and Redish (1999) reported a distribution of published studies in physics education in their resource letter containing annotated references to empirical studies about students’ understanding of physics concepts. As shown in Figure 1.1, McDermott and Redish resource letter showed that about 49% of research on students understanding of scientific concepts in physics has focused on simple mechanics, followed by studies on electricity and magnetism at 17%. Research on student understanding of light and optics and properties of matter, fluid physics, and thermal physics received almost the same proportion of attention, 13% and 12% respectively. Only about 4% of the research was devoted to waves and sound, and concepts in quantum physics, at 1% received the most limited attention in the literature.

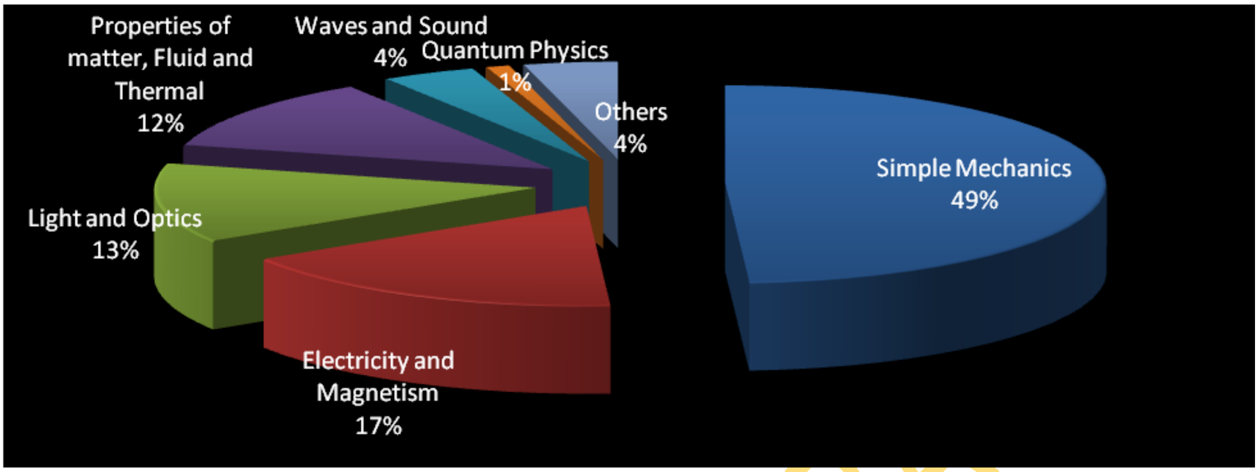


Figure 1.1 McDermott and Redish distribution of students' understanding physics content

There is a need therefore to study students' scientific understanding in quantum physics which is the basic index for understanding the complexities of modern technology (Egbugara, 1989; Ogundipe, 2004). The branch of Physics which receives ample attention of all the branches of physics is basically classical (Newtonian) physics. However classical physics has lots of limitations therefore quantum physics a branch of modern physics extends and corrects classical Newtonian physics, especially at the atomic and subatomic levels. Quantum physics describes with great accuracy and precision many phenomena where classical physics drastically fails. It is in fact the underlying framework of many fields of physics and chemistry (Mackey, 2004). Recent developments in nanotechnology, photonics, and superconductivity bring to our everyday life advanced engineering and business devices that can be appreciated and explained only through principles of quantum physics. In particular, the entire semiconductor electronics field uses quantum mechanical principles and without semiconductor electronics, the now-ubiquitous miniaturized and cheaply mass-produced electronic devices of today (such as computers, cell-phones and cameras) would be utterly impossible.

Quantum physics actually describes the behavior of intangible objects roughly ten billion times smaller than a typical human being (De Raedt, 2008), which cannot be observed with the senses. Students therefore apply conjectural and speculative approaches to its understanding which leads to ambiguity of the content of quantum physics. In fact studies on students' conceptual understandings of electricity and magnetism showed that a significant number of students viewed electricity as a fluid, an obsolete idea similar to that held by scientists in the late eighteenth century while many students explained motion in ways similar to the antique Aristotelian explanations that heavier objects would fall faster than lighter ones (Sequeira and Leite, 1991). For example, the chief examiner's report of the West Africa Senior School Certificate Examination observed in 2008 that candidates had poor sight of the required components of the definition of Heisenberg's Uncertainty Principle. Also in wave-particle duality, candidates' performance was very low as they speculated around concepts of reflection and refraction instead of diffraction or interference (WASSCE, Chief Examiner's Report, 2008).

Consequently, the abstract nature of quantum physics concepts requires different approaches in teaching the topic at the secondary school level. This must also take cognizance of the ability of different students to reason abstractly. Abstract reasoning assesses the ability to understand complex concepts and assimilate new information beyond previous experience and enhances the faculty to perceive relationships and then to work out any co-relationships. This is fundamental to the learning of quantum physics because of the level of abstraction required to its understanding since its phenomena are not visible.

Assessing spatial reasoning abilities is also relevant to this research since multimedia using pictures and animations requires the ability to visualise objects especially in three dimensions without physically examining them (as multimedia only simulates reality which cannot be physically examined). Appreciating space orientation and orienting oneself to a new or strange (learning) environment also are fundamental to spatial reasoning as well as the use of multimedia in learning concepts formerly learnt using conventional methods.

In the study of multimedia learning there are three concepts which necessarily must be defined viz, media, mode and modality. Media refers to the system used to present instruction, such as a book-based medium or a computer with the projector. Mode refers to the format used to represent the lesson, viz, verbal and nonverbal, such as words (verbal) versus pictures (nonverbal). Modality refers to the information processing channel used by the learner to process the information, viz auditory and visual (Mayer, 1997). This study focused on how specific combinations of modes and modalities affected students' learning of scientific explanations, such as when visual-verbal material (i.e., text) were combined or when auditory-verbal material (i.e., narration) were combined with visual-non-verbal materials (i.e., graphics, video or animations). Mayer (2009) observed that there are a few general design principles for instructions in which verbal, audio and visual information are combined and therefore argues that multimedia instruction should be based on research and grounded in theory. This is because multimedia instructions however popular they may be emerging can pose complexities in the mental capacity of the learner if not effectively applied. Sweller, Van Merriënboer and Paas (1998) investigated the effectiveness of multimedia instructions and observed that the form of instructions should depend on the learner's mastery of content. Kalyuga(2000) in his study discovered a conflicting finding that multimedia instructions may improve learning for learners who have poor mastery of content but may be ineffective or even harmful for learners who have high mastery of content. Also Mayer (2001) observed in the spatial contiguity principle effect that multimedia instructions may serve as positive instructional strategy for learners with low retention and not for learners with high retention.

These principles evidently derive from the premise that multimedia learning cannot be detached from the functioning of cognition (the working of the mental faculty). This means that multimedia instructions as used by the teacher must consider how the human mind works and its cognitive limitations. Mayer and Moreno (2002), emphasize that the cognitive architecture of the learner with the nature of memory must be respected by instructors. Cooper (1998) distinguishes between three memory types in his construction of cognitive architecture. These are the sensory memory, the (short-term) working memory and the long-term memory. These memory modes define an information-processing model of human cognitive architecture in an integrated way. The following figure illustrates this:

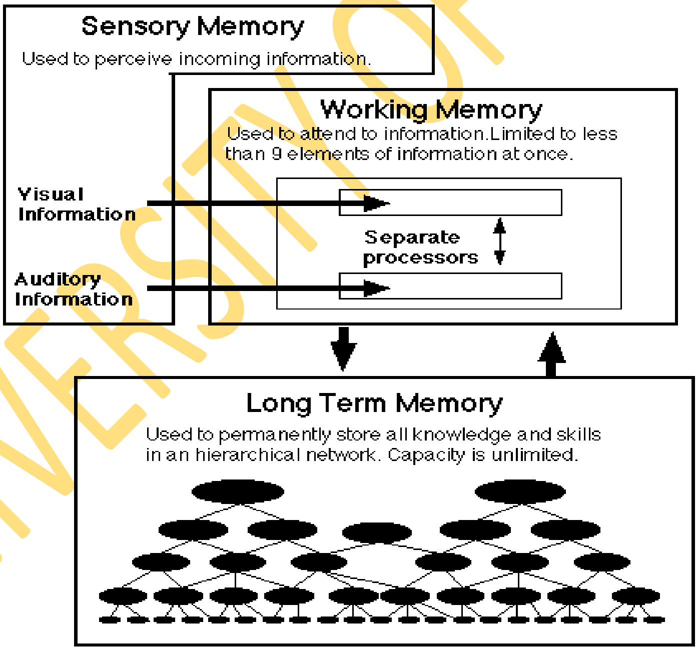


Fig 1.2 Model of human (learner's) cognitive architecture (Cooper, 1998**)**

Learning is the process by which information (in terms of knowledge and skills) is encoded into long term memory where they are retained, so they can be retrieved and applied at a later date (Cooper, 1998). Encoding takes place in working memory where relationships are created and content rehearsed. Information is processed in working memory and organised into a relevant schema which is stored (retained) in long term memory. Schemas can be understood as models or hypothetical structures that organise our knowledge of the world. Experts in fields such as biochemistry or mathematics have more extensive schemas for their area of interest, and can therefore better organise task-relevant information than novices. For example, the digit span 3.14285714 would be extremely difficult for an artist to remember if shown to him for 5 seconds. A mathematics expert, however, would access his 'maths schema' and immediately recognise the span as the first 9 digits of *pi*, increasing the likelihood that he would remember the sequence.

Form the foregoing there is a need to study the cognitive characteristics of the learner when using multimedia instructions. There are basically three cognitive theories of multimedia learning namely;

1. Dual coding theory- which states that working memory can process visual and auditory information simultaneously with no adverse effect on learning (Baddeley, 1986; Paivio, 1986).
2. Cognitive load theory- which suggests that effective instructional material promotes learning by directing cognitive resources towards activities that are relevant to learning rather than to processes that are an adjunct to learning (Chandler and Sweller, 1992)
3. Constructivist learning theory- which implies that students should be guided to an awareness of being responsible for their own knowledge formation (Mayer, 1997)

Actually, according to cognitive load theory, many instructional materials and techniques may be ineffective because they ignore the limitations of human working memory and therefore impose a heavy cognitive load. Cognitive load is fundamentally defined as the level of 'mental energy' required to process a given amount of information. As the amount of information to be processed increases, so too does the associated cognitive load. Cognitive load therefore bothers on the total amount of mental activity on working memory at an instance in time (Cooper, 2004).

Research in multimedia learning is not so much about identifying and measuring cognitive load but minimizing it. Faraday (2000) argues that multimedia can help direct the learner's attention to the most relevant information during instructions since irrelevant media may distract learners and actually decrease learning. Faraday considers attention as the cognitive process of selectively concentrating on one aspect of the environment while ignoring other things. Attention has also been referred to as the allocation of processing resources, that is, the sustained focus of cognitive resources on information while filtering or ignoring extraneous information (Anderson, 2004). Attention is a very basic function that often is a precursor to all other cognitive functions. James (1890) describes attention as focalization and concentration which implies withdrawal from some things in order to deal effectively with others.

Instructional split-attention refers to the learning effect inherent within some poorly designed instructional materials. Instructional split-attention occurs when learners are required to split their attention between multiple integrated sources of physically or temporally disparate information, where each source of information is for understanding the learning content (Ayres & Sweller, 2005). Split attention effect is apparent during instructions when the same modality such as *visual and visual* is used for various types of information within the same display. Figure 1.3 depicts the visual and visual modality in the use of text without audio narration while also showing the visual and audio modality in the use of text with audio narration.

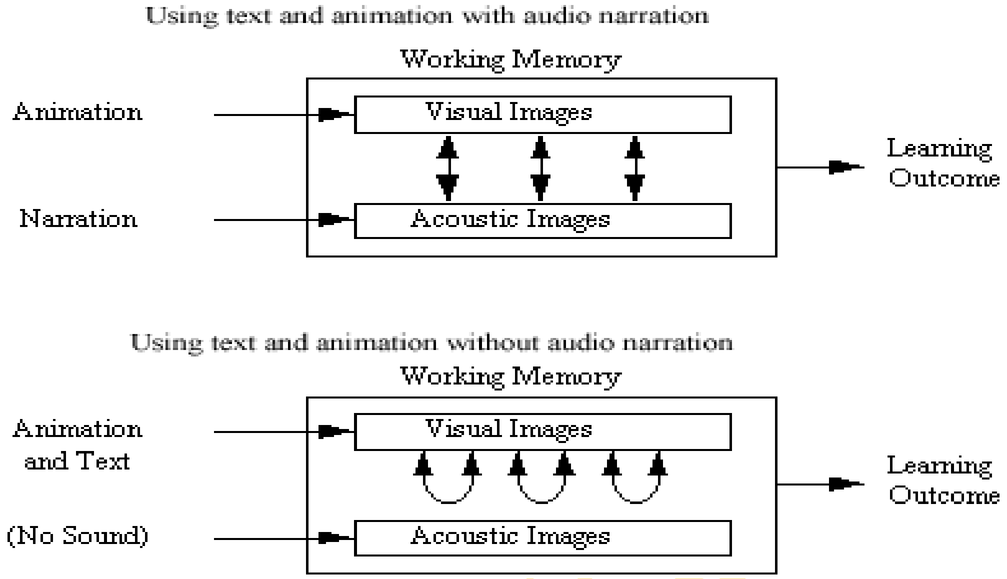


Fig 1.3 Cognitive structure of using text and animation with and without audio narration

The basic thrust of this study can be summarized in the following question; How should verbal information be presented to students to enhance learning from pictures and animations (Multimedia): auditorily as speech or visually as on-screen text? Is there any significant difference between using a visual and visual or visual and audio modality? Will instructor presence create split attention effect or not? Therefore, this study relied on contemporary theoretical reviews on the knowledge of human cognitive architecture and multimedia designs towards investigating alternatives that may be viable supplement to the text and black or whiteboard presentation of instructions.

1.2 Statement of the Problem

Modern science is increasingly relying on the principles of quantum physics, a branch of physics which describes the behavior of intangible phenomena which cannot be observed with the senses. The 2007 and 2008 Chief examiner's report of the West Africa Senior School Certificate Examination articulated the common challenges and consequences of studying quantum physics. The report outlined the abstract nature of quantum physics which made the students resign to applying conjectural and speculative approaches thereby leading to low mastery of the content and eventual poor performance.

The use of multimedia instructions during teaching and learning of quantum physics is becoming popular to overcome the abstract concepts within the subject as well as the resultant students' poor performance. It is also pertinent to consider the limitedness of the resources of working memory during multimedia instructions of abstract concepts in order to gauge irrelevant factors considered extraneous to learning which create unwanted cognitive load and hinder retention.

However, the determination of the appropriate use of multimedia instruction is undergoing evolution and there is need for further study of the principles of the instructions. It is to this end that Split Attention, one of the theorised principles during multimedia instructions is investigated in this study in three design conditions (DCs) which are use of text with graphics delivered by a speaking agent or an instructor (DC-A), use of text with graphics and a digitised human voice (DC-B) and use of text with graphics only (DC-C). Abstract and spatial reasoning abilities were considered as moderating variables.

1.2 Research Hypotheses

Based on the stated problem, the researcher tested the following hypotheses:

Ho_1: There is no significant main effect of treatment on students' retention in Quantum Physics

Ho_2: There is no significant main effect of cognitive load on students' retention in Quantum Physics

Ho_3: There is no significant main effect of spatial reasoning ability on students' retention in Quantum Physics

Ho_4: There is no significant main effect of abstract reasoning ability on students' retention in Quantum Physics

Ho_5: There is no significant interaction effect of treatment and cognitive load on students' retention in Quantum Physics

Ho_6: There is no significant interaction effect of treatment and spatial reasoning ability on students' retention in Quantum Physics

Ho_7: There is no significant interaction effect of treatment and abstract reasoning ability on students' retention in Quantum Physics

Ho_8: There is no significant interaction effect of cognitive load and abstract reasoning ability on students' retention in Quantum Physics

Ho_9: There is no significant interaction effect of cognitive load and spatial reasoning ability on students' retention in Quantum Physics

Ho$_{10}$: There is no significant interaction effect of abstract reasoning ability and spatial reasoning ability on students' retention in Quantum Physics

Ho$_{11}$: There is no significant interaction effect of cognitive load, abstract reasoning ability and spatial reasoning on students' retention in Quantum Physics

Ho$_{12}$: There is no significant interaction effect of treatment, abstract reasoning ability and spatial reasoning on students' retention in Quantum Physics

Ho$_{13}$: There is no significant interaction effect of treatment, cognitive load and abstract reasoning ability on students' retention in Quantum Physics

Ho$_{14}$: There is no significant interaction effect of treatment, cognitive load and spatial reasoning ability on students' retention in Quantum Physics

Ho$_{15}$: There is no significant interaction effect of treatment, cognitive load, spatial reasoning ability, and abstract reasoning ability on students' retention in Quantum Physics

1.3 Scope of the Study

This study was carried out among senior secondary school two physics students in Ijebu and Remo educational zones in Ogun state, Nigeria. Topics in quantum physics were taught as the subject matter. It is to be noted that quantum physics had not been taught to the students at this stage.

1.4 Significance of the Study

This study exposed the merits of learning through multimedia elements which are of increasing importance to teaching physics and thereby using multimedia specifically to support, relate to, or extend learning, not just as embellishment.

This study also is relevant for institutions that operate online studies such that where multimedia instructions are to be employed, appropriate use will be installed.

The study also may encourage learners to actively process and integrate information rather than receive them passively.

1.5 Conceptual Definitions

i. Learning: This is the process by which information (in terms of knowledge and skills) is encoded into long term memory, so they can be retrieved and applied at a later date

ii. Instructional Design: It is the entire process of analysis of learning needs and goals and the development of a delivery system to meet those needs which includes development of instructional materials and activities

iii. Multimedia instruction: This refers to presentations involving words and pictures that are intended to foster learning.

iv. Multimedia learning: This is an alternative to purely verbal presentations in which students learn from both words and pictures by a process of selecting, organizing and integrating information to form connections

v. Split attention effect: This is a learning effect inherent within some poorly designed instructional materials apparent when the same modality is used for various types of information within the same display thereby requiring learners to split their attention between multiple sources of mutually referring information.

vi. Sensory memory: This is the human faculty (also called sensory information storage)that deals with stimuli that are processed through our senses such as sights, sounds, smells, touches, and tastes.

vii. Working memory: This is human mental unit (also called short term memory) where information is organised and processed into relevant schema when learning.

viii. Long-term memory (LTM): This refers to the immense amount of knowledge and skills that we hold in a more or less permanently accessible form such that retrieval of facts from the LTM can be remarkably fast, especially for frequently used items.

ix. Quantum physics: Quantum physics is a fundamental physical theory which extends and corrects classical Newtonian physics, especially at the atomic and subatomic levels and it basically describes the smallest discrete increments into which elements are subdivided.

x. Abstract reasoning ability: This is the innate ability to perceive relationships and educe co-relationships which reveals the ability to understand complex concepts and assimilate new information beyond previous experience.

xii. Spatial reasoning ability: This is the ability to apprehend, encode, and mentally manipulate spatial forms which technically includes spatial orientation, spatial visualisation and spatial relations.

xiii. Cognitive Schema: This refers to hypothetical information structures in long-term memory that organise knowledge and facilitates transfer of information thereby increasing retention ability based on the ability to categorize problems using schemas stored in long-term memory.

xiv. Intrinsic load: It is a load in learning that occurs because of the complexity or difficulty level of the information or the to-be-learned content which cannot be modified by instructional design because regardless of how it is presented it retains its inherent level of element interactivity.

xv. Germane load: This is the load that helps learners build new complex schema in a successive manner by building connections and establishing learning which is based on a self effort to learn, and memorize information learned.

xvi. Extraneous load: This is the load that results from the techniques and instructional materials used in the presentation of the to-be-learned information that do not contribute to learning and which can be modified by instructional design.

xvii. Cognitive load: Cognitive load refers to the total amount of mental activity that the working memory has to attend to at an instance in time when non-related distracters create loads.

xviii. Media: This refers to the delivery system used to present instruction that is a book-based medium or a computer with the projector.

xix. Mode: This refers to the format used to represent the lesson, namely, verbal and nonverbal, where verbal refers to words and nonverbal refers to pictures and animation (graphics).

xx. Modality: This refers to the information processing channel used by the learner to process the information, namely, auditory and visual channels.

xxi. Verbal language: This refers to the means of communication involving spoken words or written text, which could be auditory or visual respectively

xxii. Non-verbal language: This refers to the means of communication using visual contents involving signs, graphics, pictures and animations.

1.6 Operational Definition

i. Retention: This refers to the mental custody of quantum physics instructions streamed through the sensory memory with the aid of multimedia elements, processed in the working memory and stored in the long term memory as schema such that retrieval of content learned and measured through paper and pencil tests can be remarkably fast, after two days and beyond.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

A number of researches have been conducted in relation to the variables used in this study. Literature was therefore reviewed theoretically and empirically under the following topics:

i. Theoretical Framework for Principles in Multimedia Instructions
ii. Education and Technology
iii. Motivation and Educational technology
iv. Cognitive theory of multimedia learning
v. Cognitive Architecture of Learners
vi. Cognitive load theory and retention
vii. Multimedia learning in physics education
viii. The Physics of Quantum
ix. Abstract reasoning in Quantum Physics
x. The role of spatial reasoning in multimedia learning
xi. Multimedia Instructions in Quantum physics
xii. Contrasting Attention and Split Attention
xiii. Retention in learning as schema construction
xiv. Split attention multimedia principle and retention
xv. Spatial reasoning and retention in science
xvi. Appraisal of Literature Review

2.2.1 Theoretical Framework for Principles in Multimedia Instructions

The question of whether one medium should be more effective than another for teaching has a long history in the literature on educational technology. Mayer (1997) calls it "a persistent, if somewhat unproductive question," since the effectiveness of an instructional message depends not on the medium but the methods employed within it. "It is possible to produce effective and ineffective instruction in both computer-based and book-based media. Researchers such as Kozma (1991, 1994) have furthered the notion that the attributes of a medium make possible different instructional methods (Kirschner, 2005), like multiple dynamic representations, for example (Ainsworth, 1999; Ainsworth and VanLabeke 2004; Kozma and Russell, 1997). A medium, then, is intrinsically neither better nor worse than any other but it possesses a potential set of attributes that can be exploited to greater or lesser degrees by an instructional designer. Clark (1994) argues that methods employed in any one medium, could be employed by another; whereas Kozma (1994) believes certain media have unique attributes that cater to particular methods better than any other. Kirschner (2005) also recognizes these two common standpoints on this issue and views the media effectiveness question as open-ended.

Mayer (1997, 2001) has shown that using multi-modal instruction is more effective than using any single mode. In a way, this finding supports Kozma's position and demonstrates that media do impact learning, by the instructional possibilities they enable. For example, based on Mayer's research, one could state that when used appropriately, the video medium should be more effective than radio since the latter cannot provide visual information. Another principle of Mayer's is the modality principle: verbal information is better presented as narration than as onscreen text when accompanying a visual presentation. This is because text causes the learner to split his attention between the animation and the verbal information, thus increasing extraneous cognitive load. For book-based media, Mayer's contiguity principle states that words must be placed around the visual representations to which they refer to minimize a similar split attention effect. It should stand to reason then that providing the verbal information orally could eliminate this split attention effect altogether. Mayer stops short of this recommendation, however, presumably since this is beyond the capabilities of book-based media.

Mayer's results show no evidence of this split attention effect, either. Learners often perform as well, if not better, when learning from static text media than from animations and narrations. Mayer uses these results in conjunction with the stigma associated with media comparison research to argue that no media is capable of facilitating knowledge construction better than any other. This ignores the fact that the cognitive theory of multimedia learning, as put forth by Mayer (1997, 2001) predicts such an effect. There are many reasons why this effect may not be visible in Mayer's studies. The pace of the animation may be too quick, increasing the extraneous cognitive load especially when learners have low prior knowledge. Since the verbal information does not cue the learners' attention to particular aspects of an animation, they may not know where to look at all times (i.e. what exactly the narration is talking about). If it is equally likely that learners cognitively engage or not with any media, the transient nature of the animation means they cannot look back and fill in gaps in their understanding. If the information were not intrinsically engaging, it would also be more likely for learners to "tune out" of the animation since reading requires a certain threshold level of cognitive engagement.

The above variables could be controlled in experiments to obtain a more complete picture of contextual factors influencing multimedia learning. One must approach the question of media effectiveness carefully since results can easily be misconstrued to support the causes of technology.

However, since theory exists that predicts lower extraneous cognitive load with elimination of the attention splitting effect, experiments should be performed to determine whether the theory is correct or if it requires alteration.

2.2.2 Education and Technology

Since the industrial revolution, technology has transformed nearly all aspects of life, from agriculture and transportation to modern culture. It seems only reasonable that one would expect technology to have an analogous impact on education. Science and technology have achieved great successes, increasing productivity, lowering costs and improving the quality of life for many. In doing so, they have become a goal in themselves, a hallmark of progress and advancement and a recipe for resolution to societies' ails (Jonassen, 1988). It is in this context that many educational technologists have directed their research, to expand the applications of technology to new realms.

Technology and education have long been intertwined (Cuban, 1986), but never has the movement to merge the two proceeded with more vigor. Since the late 1980's, the prevalence of computers in the home and workplace has increased exponentially matching the astronomical trends in technological manufacture (Schaller, 1997). The development of the Internet has revolutionized how people communicate and introduced a new genre of entertainment. Currently, technology development is undergoing an expansive overhaul; memory capacities and processor speeds are ballooning, instigating corresponding growth in the content and bandwidth of the Internet (Schaller, 1997; Heyneman, 2001). Educators recognize the significance of this global trend and are eager to bring education up to speed (Fluck, 2001). Authoring software is increasingly available and easy to use, enabling disciplinary experts to digitize their lessons. Along with this trend come the growing repositories of learning objects, educational resources that range in complexity from text or graphics to dynamic simulations (Conole, 2002; Friesen, Roberts and Fisher, 2002).

The novel capabilities of educational technology are incredibly exciting, fuelling an enthusiasm for their application to educational problems. Computer storage and processor speeds are growing exponentially, accompanied by similar growth in software development (Schaller, 1997). This enables 3-D systems (Dalgarno, 2004), microworlds, and other inspiring visual environments. It also enables a wider range of developers to create and tune multimedia presentations. The novel capabilities of technology have become its merits and excite growing interest in the field of educational technology.

It seems intuitively obvious that a dynamic presentation should be more effective for teaching than a static one. If one is trying to explain the workings of a dynamic system, a grandfather clock for example, it seems obvious that a dynamic representation can best describe the system (Lowe, 2004). Since means to display and even interact with such systems have never been available before, there is an underlying assumption that technology will facilitate learning better than traditional instruction. It can be easily demonstrated, however, that this oversimplifies the interactions between the learner and the medium. Contextual parameters must be specified scientifically to establish the best learning environment (Lowe, 2004). Intuition overlooks the important details of confounding factors, which technology promoters can gloss over.

Research into teaching and learning with new technologies is currently a very dynamic, high-profile and relevant area of educational enquiry. Educational institutions are increasingly engaged with integrating technology into the delivery of instructional materials and in the provision of alternate methods for learning. The extent to which these efforts are based on sound principles established through research and experience is a matter for debate. Research findings validating educational outcomes in the use of new technology are often contradictory, as research approaches tend to lag behind the capabilities of technology. Many studies in educational technology studies show a lack of an appropriate theoretical grounding and regard for scientific empirical testing.

The potential for improved learning does not easily translate into practice, however. Technology's record of failing to deliver on expectations has been well documented (Cuban, 1986; Clark, 1983), and has promoted a general skepticism among educational administrators and practitioners. On the whole, research in the field of educational technology when compared with other sciences is inconsistent, fragmented, and struggling to keep up with developments in technology itself. This is remarkable given the incredible amount of effort and money invested in this field. Some advances have been made in developing new instructional technologies and in understanding how learners interact with media; however, a holistic view of educational technology research and its future remains elusive. In a series of papers, Clark and Estes (Clark and Estes, 1998; Estes and Clark, 1999; Clark and Estes, 1999) assert that the "gradual eroding and splintering of [their] field," is a crisis created by a lack of substantial research, aggravated by a reliance on intuition and enthusiasm for new technology. Other researchers acknowledge that the rapid advancements in technology have developed ahead of the research required to support them (Mayer, 1997; Rieber, 1990). Despite some promising current research programs, the overwhelming consensus is that "with few exceptions there is NOT a body of research on the design, use, and value of multimedia systems," (Moore, Burton, and Myers, 2004). There are two major issues here: the problem of technology development and the problem of implementation. Although these issues are related, they are not inseparable.

In the research literature on learning with technology, history has certainly repeated itself. After the introduction of each new commercial media technology, inventors and marketers have made outlandish forecasts about the technology's impact on education. A famous example is

Edison's prophesy for the motion picture: "I believe that the motion picture is destined to revolutionize our educational system and that in a few years it will supplant largely, if not entirely, the use of textbooks," (Josephson, 1992). Similar statements were made about radio, television, video, interactive video, the computer, and the Internet. These technologies have clearly not lived up to expectations (Cuban, 1986). Although this is due in part to practical constraints, researchers have had difficulty establishing the learning advantages of technology in theory (Clark, 1994; Kozma, 1994).

Three main obstacles have hindered the progress of educational technology research. First of all, proponents of technology have used the enthusiasm, assumptions, and excitement surrounding technology as substitutes and sometimes rebuttals for empirical evidence. Secondly, until recently studies sought to uncover the advantage of one medium over another without considering how learning occurs and how the media concerned differ in this respect. Finally, although technological interventions are frequently developed and used, they are rarely based on or employ well-structured research. The combination of these factors has created a crisis whose only resolution lies in authentic, theoretically based research.

Developers and marketers have used the interest and enthusiasm surrounding technology and the assumptions that increased functionality leads to increased learning to promote educational products. For Edison, the emphasis was on efficiency; thus he asserted that on the average schoolbooks as they were written in his days accounted for only two percent efficiency. He concluded therefore that "the education of the future, will be conducted through the medium of the motion picture … where it should be possible to obtain one hundred percent efficiency". (Edison, 1922). Similar claims like Edison's are not restricted to a bygone era. Even after widespread publicity of the patterned failings of technological interventions (Clark, 1983; Cuban, 1986), promoters continued to predict incredible futures for new innovations (Semrau, 1994). This cycle continues even today, with technophiles often emphasizing the unique attributes of a new medium to explain how it will succeed where so many others have failed. These claims perpetuate the myth that functionality is equivalent to learning and foster enthusiasm for applying new technology. Educational technology is constantly being created, tested and implemented throughout the world at an amazing rate with incredible cost. This production is spurred by the rhetoric of technologists and the enthusiasm of interested individuals who believe that technology will revolutionize the practice of education. The fact that educational technology is produced everyday gives the field the appearance of maturity in terms of its research.

It would be a frustrating paradox, for a new researcher, to be confronted with established practices of instructional design on the one hand and little concrete research evidence validating these approaches on the other. Basically, the research to support these activities of technology's romance with education is distinctly incomplete. This does not completely debase the relationship of education with technology. For example, Blinn (1989) outlined a number of design criteria for educational animation, based on his work as an animator for a physics education video series. Although such works as Blinn's are very useful, these guidelines are a starting point for investigation rather than established principles of best practice. Clark and Estes (Clark and Estes, 1998; Estes and Clark, 1999; Clark and Estes, 1999) have classified educational technology uninformed by scientific research as "craft" solutions. They claim that it is this lack of concrete foundation that has led to the unreliability of technological solutions. These craft solutions are the most common type of educational technology, and, since they are not developed scientifically, they are unable to directly inform the body of research on learning with technology. This perpetuates the cycle of craft educational technology, further inhibiting progress in the field.

The common factor among the weaknesses of many previous educational technology studies is a lack of appropriate theoretical grounding and regard for scientific empirical testing. The perception of learners as passive absorbers of information and the practice of "craft" educational technology has led to unproductive research and ultimately to the separation of intervention development and supporting research.

2.2.3 Motivation and Educational technology

No one denies the importance of motivation for learning, but exactly how to quantify such a concept in relation to the use of multimedia is a complex challenge. Motivation can range from intrinsic to extrinsic to amotivation. Intrinsically motivated learners tend to behaviorally and cognitively engage with learning tasks and their contexts whereas amotivated learners do not (Ryan and Deci, 2000). Extrinsically motivated students, on the other hand, engage if the learning task or context appeals to them or has some perceived value, leading to situated motivation (Paris and Turner, 1994).

Ryan and Deci (2000) focus on the nature of the three motivational types and try to determine whether it is possible to shift learners towards intrinsic motivation. Their model associates increased and more sophisticated regulation and reflection with increased levels of intrinsic motivation. Multimedia and computers have the capacity to allow for external regulation and autonomy support (Stefanou, Perencevich, DiCintio, and Turner, 2004). Technology also provides for context and variety in learning tasks that theoretically could be exploited to situate motivation.

The difficulty in measuring motivation due to its multiple facets (Weiner, 1990) has led researchers to depend upon self reports, assumptions or eschew the idea altogether when evaluating an intervention. Lowe (2004) divorces the motivational aspects of animation from its instructive power, reproaching technology enthusiasts whose “conviction is based upon the naïve view of the power of animation’s affective characteristics,” Clark and Estes (1999), too, criticize motivation studies for impeding the progress of educational technology research. Mayer’s coherence principle (1997, 2001) states that instructional interventions must be stripped of all extraneous information that does not directly contribute to the learning task. This includes information that promotes interest in the instructional material. Mayer (2003) has however begun to investigate motivation effects as suggested by Reimann (2003), but this pertains only to phrasing of verbal material within an intervention rather than additional content.

Since motivation is difficult to define, measure, and control, research on the topic carries the stigma of being unproductive or highly subjective. It is vital, though, that this aspect of learning be considered in the design of educational technology or the range of potential instructional possibilities is artificially and likely critically impaired. Future studies must not search for a motivational effect for the use of technology in education, as has been proven futile in the past (Clark, 1994; Clark and Estes, 1999). Rather, studies must seek to identify the methods employed in various media that can demonstrably and repeatedly enhance motivation.

2.2.4 Cognitive Theory of Multimedia Learning

Cognitive theory of multimedia learning draws on dual coding theory, cognitive load theory, and constructivist learning theory. Figure 2.1 depicts a cognitive theory of multimedia learning with these assumptions.

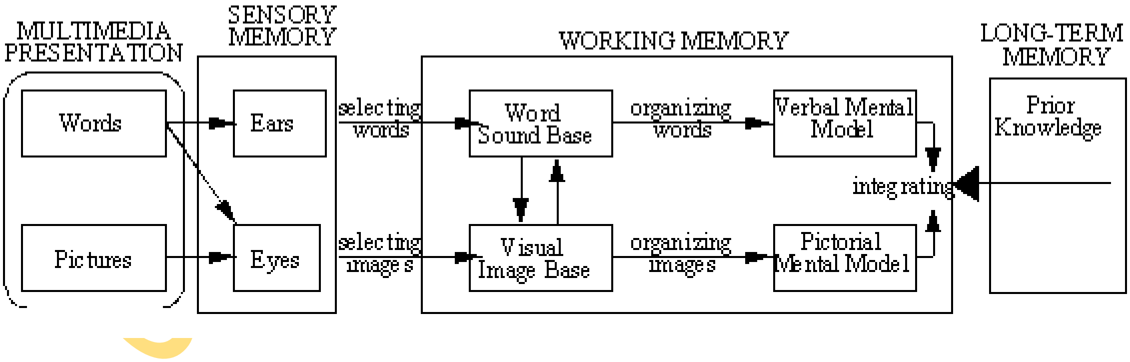


Figure 2.1 cognitive theory of multimedia learning

It is based on the following assumptions that working memory includes independent auditory and visual working memories (Baddeley, 1986) and also that each working memory store has a limited capacity, consistent with Sweller's (1988, 1994; Chandler and Sweller, 1992) cognitive load theory. It also relies on the submission that humans have separate systems for representing verbal and non-verbal information, consistent with Paivio's (1986) dual-code theory and that meaningful learning occurs when a learner selects relevant information in each store, organises the information in each store into a coherent representation, and makes connections between corresponding representations in each store (Mayer, 1997). Cognitive Load Theory (CLT) is an instructional theory that starts from the idea that our working memory is limited with respect to the amount of information it can hold, and the number of operations it can perform on that information (Van Gerven and Paschal, 2003). That means a learner should be encouraged to use his or her limited working memory efficiently, especially when learning a difficult task (Van Gerven and Paschal, 2003). We need to recognize the role and the limitation of working memory to help develop quality instruction (Cooper, 1998). Instructional designers need to find ways to help optimize the working memory, hence, the key aspect of the theory is the relation between long-term memory and working memory, and how instructional materials interact with this cognitive system (Ayres, 2006).

2.2.5 The Cognitive Architecture Of Learners

How do we remember what we have learnt? What are the components of the memory system? What is commonly called memory is not a single, simple function. It is an extraordinarily complex system of diverse components and processes. There are at least three, and very likely more, distinct memory processes. The most important from the standpoint of this research and best documented by scientific research are sensory information storage (SIS), short-term memory (STM), and long-term memory (LTM) (Lindsay and Norman 1977) which is consistent with Cooper's (1998) distinction between three memory types, viz, the sensory memory, the (short-term) working memory and the long-term memory. Each differs with respect to function, the form of information held, the length of time information is retained, and the amount of information-handling capacity. Memory researchers also posit the existence of an interpretive mechanism and an overall memory monitor or control mechanism that guides interaction among various elements of the memory system. These memory modes define an information-processing model of human cognitive architecture in an integrated way.

a) Sensory Information Storage (SIS)

Sensory information storage also called the sensory memory deals with stimuli that are processed through our senses. These can be sights, sounds, smells, touches, and tastes. These memories extinguish quickly, about half a second for visual information and 3 seconds for auditory information. Unless the sensory information is attended to, that is, identified, classified and assigned meaning to, it will be forgotten. The content of the sensory memory is constantly overwritten by new input while an afterimage is the visual short-term memory just as a visual trace. This overwriting mechanism is necessary because of the vast quantity of data in an image and the continuous changes in images. This has implications for graphical user interfaces and multimedia:

if images are not held on the screen long enough, we will not be able to extract much information from them. The function of SIS is to make it possible for the brain to work on processing a sensory event for longer than the duration of the event itself. The content of the sensory memory is still abstract with no meaning attached to its input. Meaning is generated when the input reaches the central cognitive short-term memory for interpretation. The cognitive processor is responsible for object identification. The cognitive processor has an associated short-term memory used for storage of temporary working information. This information can be extracted from the sensory processors or the long-term memory. The cognitive processor performs most of the 'thinking' activity. The results of thinking can either be placed back in short-term memory, stored in long-term memory or be passed on to the motor processor to elicit behaviour.

b) Short-Term Memory (STM)

Information passes from SIS into short-term memory, where again it is held for only a short period of time--a few seconds or minutes. Whereas SIS holds the complete image, STM stores only the interpretation of the image. If a sentence is spoken, SIS retains the sounds, while STM holds the words formed by these sounds. Like SIS, short-term memory holds information temporarily, pending further processing. This processing includes judgments concerning meaning, relevance, and significance, as well as the mental actions necessary to integrate selected portions of the information into long-term memory. When a person forgets immediately the name of someone to whom he or she has just been introduced, it is because the name was not transferred from short-term to long-term memory.

The short-term memory is also referred to as working memory. The contents of working memory can be combined with stored knowledge from the long-term memory and manipulated, interpreted and recombined to develop new knowledge, form goals, and assist learning and interaction with the physical world (Logie, 1999). The working memory or the short-term working memory is equivalent to computer RAM, that is, the working memory of the central processor. In contrast to computers, the human working memory has a low capacity; it loses its content unless being refreshed every 200ms. The read/write access time is quite quick (about 70 ms) which means that information can be held in working memory by continual rewriting. The working memory can typically hold 7+/-2 items for rehearsal (Miller, 1956, in Sutcliffe, 1995). It will rapidly decay if nothing special is done to it to keep it active. Instead of storing information in 'bytes', as in computers, it is stored in chunks of information. For example, it is common practice to combine phone numbers into chunks rather than listing all digits in one sequence. Consider remembering the phone number 9237 9154 as opposed to 9 2 3 7 9 1 5 4. The former number may be easier to remember than the latter.

A central characteristic of STM is the severe limitation on its capacity. A person who is asked to listen to and repeat a series of 10 or 20 names or numbers normally retains only five or six items. Commonly it is the last five or six. If one focuses instead on the first items, STM becomes saturated by this effort, and the person cannot concentrate on and recall the last items. People make a choice where to focus their attention. They can concentrate on remembering or interpreting or taking notes on information received moments ago, or pay attention to information currently being received. Limitations on the capacity of short-term memory often preclude doing both. Retrieval of information from STM is direct and immediate because the information has never left the conscious mind. Information can be maintained in STM indefinitely by a process of "rehearsal"--repeating it over and over again. But while rehearsing some items to retain them in STM, people cannot simultaneously add new items. The severe limitation on the amount of information retainable in STM at any one time is physiological, and there is no way to overcome it.

a) Long-Term Memory (LTM)

Long-term memory (LTM) refers to the immense amount of knowledge and skills that we hold in a more or less permanently accessible form. Retrieval of facts from the LTM can be remarkably fast, especially for frequently used items. For example, it doesn't take long to recall our name, date of birth or letters in the alphabet. For less frequently used information, retrieval time can be longer (Cooper, 1998). Retrieval can be a quite complex process. Often, remembering occurs minutes after original effort to retrieve the information has been made. During this intervention, attention would have been devoted to other matters; hence it appears that a background memory processor is invoked to effect difficult memory searches. According to the information-processing model, the retrieval process is simply a function of the cognitive processor. Memory seems to be activated by use, so frequently or recently used items are easier to recall (Sutcliffe,1995). The huge capacity of LTM to store associations between complex configurations and consequent actions, and to store complex associative networks, such as categorisation skills and sequential procedures has implications for instructional design.

Some information retained in STM is processed into long-term memory. This information on past experiences is filed away in the recesses of the mind and must be retrieved before it can be used. In contrast to the immediate recall of current experience from STM, retrieval of information from LTM is indirect and sometimes laborious. Loss of detail as sensory stimuli are interpreted and passed from SIS into STM and then into LTM and this is the basis for the phenomenon of selective perception. It imposes limits on subsequent stages of analysis, inasmuch as the lost data can never be retrieved. People can never take their mind back to what was actually there in sensory information storage or short-term memory. They can only retrieve their interpretation of what they thought was there as stored in LTM. There are no practical limits to the amount of information that may be stored in LTM. The limitations of LTM are the difficulty of processing information into it and retrieving information from it.

The three memory processes comprise the storehouse of information or database that we call memory, but the total memory system must include other features as well. Some mental process must determine what information is passed from SIS into STM and from STM into LTM; decide how to search the LTM data base and judge whether further memory search is likely to be productive; assess the relevance of retrieved information; and evaluate potentially contradictory data. To explain the operation of the total memory system, psychologists posit the existence of an interpretive mechanism that operates on the data base and a monitor or central control mechanism that guides and oversees the operation of the whole system. Little is known of these mechanisms and how they relate to other mental processes. Despite much research on the cognitive architecture of the learner, little agreement only exists on many critical points.

2.2.6 Cognitive Load And Retention

A well-known article written over 40 years ago by Miller (1956), titled "The Magic Number Seven--Plus or Minus Two," contends that seven--plus or minus two--is the number of things people can keep in their head all at once. That is, our memory capacity, usually tested by a series of digits is around 7 items. The principle does have relevance, however, with auditory interfaces (such as telephone IVR systems), where the caller must remember the spoken menu items and process them to determine their relevance to the task at hand. That limitation on working memory is the source of many problems particularly cognitive load. People have difficulty grasping a problem in all its complexity because of the load associated with learning. This is why we sometimes have trouble making up our minds. For example, we think first about the arguments in favor, and then about the arguments against, and we can not keep all those pros and cons in our head at the same time to get an overview of how they balance off against each other.

Cognitive load refers to the total amount of mental activity that the working memory has to attend to at an instance in time. The focus is on the role of working memory in the learning process. The number of elements that is imposed on working memory is the major contributor to cognitive load. For example:

the statement 9 2 has a cognitive load of 2

the statement 7 9 5 3 has a cognitive load of 4

the statement 3 9 2 4 6 7 1 5 has a cognitive load of 8

the statement 3 9 3 5 7 1 5 0 3 5 1 8 6 2 4 1 has a cognitive load of 16

Cognitive Load therefore simply refers to the load on working memory during instruction. This load may be brought into the instruction by the learner or created during the instruction. During instructions, cognitive load may vary due to intrinsic (I), germane (G), or extraneous (E) demands. Chipperfield (2006) states that during instructions, ‘I’ cannot be changed. But ‘G’ and ‘E’ can vary and are inversely proportional to each other. According to Chipperfield, the more extraneous load the less room for germane load. Thus, the duty of an instructor or instructional designer is to limit the amount of extraneous load and to build instructional presentations and activities that encourage germane load or schema formation to take place. We cannot change the intrinsic load, thus it leaves us only to work with germane and extraneous load. Germane load helps in new schema formation. Our ideal instructional design objective will be to increase the germane load and reduce the extraneous load. This means the more extraneous load the less room for germane load and vice versa.

Intrinsic load: Intrinsic (cognitive) load is determined by the intrinsic nature (difficulty) of the to-be-learned content. Regardless of how it is presented it retains its inherent level of element interactivity that is it cannot be modified by instructional design. It depends completely on the complexity or difficulty level of the information or of the to-be-learned content. It is the memory required by the thinking task at a given time (Chipperfield, 2006). It measures the amount of the working memory in use due to the interactivity of the amount of information being processed.

When the cognitive load is low (simple content) sufficient mental resource may remain to enable a learner to learn from “any” type of instructional material even that which imposes a high level of extraneous cognitive load.

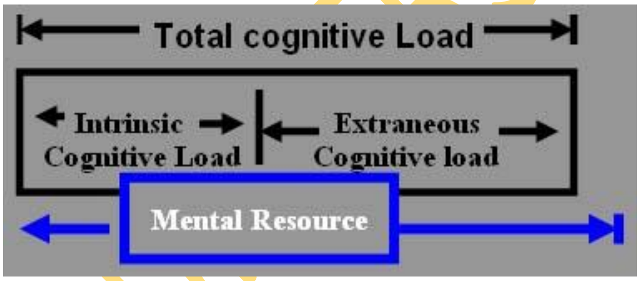


Fig. 2.3 When Intrinsic Cognitive load is low

If the intrinsic cognitive load is high (difficult content) and the extraneous cognitive load is also high, then total cognitive load will exceed mental resources and learning may fail to occur.

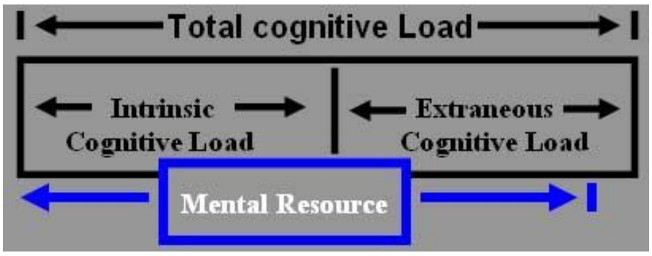


Fig 2.4 When Intrinsic Cognitive load is High

Modifying the instructional material to engineer a lower level of extraneous cognitive load will facilitate learning, if the resulting total cognitive load falls to a level that is within the bounds of mental resources.

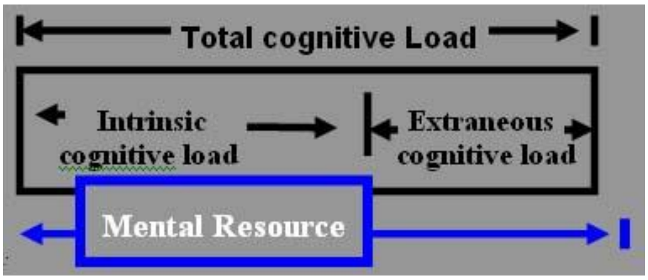


Fig 2.5 Modifying the instructional materials

Germane load: Germane load is the load that helps building new complex schema in a successive manner helping the learner to move from novice to expert. It is a self effort to learn, and memorize information learned.

Extraneous load: Extraneous cognitive load is due to the instructional materials used in the presentation of the information. As opposed to intrinsic load, this can be modified and manipulated by the instructional design to facilitate learning. Extraneous cognitive load does not contribute to learning (Chipperfield, 2006). This can be modified by instructional design. It can be changed in a variety of ways, by enhancing the organization, chunking, and presentation techniques of to-be-learned information. Other ways are by using adjunct aids, and providing specific learning instructions.

When the intrinsic load is low the mental resources are less “burdened” and more working memory should be available to learn from nearly any type of instructional material, even if the extraneous load is high. For example, if the to-be-learned material has simple content (i.e. low intrinsic load), it is likely to be learned and understood even if the way it is presented is difficult (i.e. high extraneous load). However, if both intrinsic and extraneous cognitive loads are high, the total cognitive load will exceed the mental resources, which may result in failure to learn and impossible retention. Conversely, if the extraneous load is low the chances of learning difficult material (which has high intrinsic load) will increase.

According to Kearsley (2006), cognitive load theory can be best applied in the areas of instructional design of cognitively difficult and technically challenging material. He states that to maintain effective learning environment and assure retention we need to keep the cognitive load of the learners at a minimum during the learning process.

2.2.7 Multimedia Learning in Physics Education

Physics education refers both to the methods currently used to teach physics and to an area of pedagogical research that seeks to improve those methods. Historically, physics has been taught at the senior secondary level primarily by the lecture method together with laboratory exercises aimed at verifying concepts taught in the lectures. These concepts are better understood when lectures are accompanied with demonstration, hand-on experiments, and questions that require students to ponder what will happen in an experiment and why.

Unfortunately, owing to the abstract and counter-intuitive nature of many of the elementary concepts in physics, together with the fact that teaching through analogies can lead to confusions, the lecture method often fails to help students overcome the many misconceptions about the physical world that they have developed before undertaking formal instruction in the subject. In most introductory physics courses physics usually is the first area of physics that is discussed. Newton's laws of motion, which describe how massive objects respond to forces, are central to the study of physics. Newton arrived at his three laws of motion from an extensive study of empirical data including many astronomical observations. However, students frequently have preconceptions about the world around them that makes it difficult for them to accept Newton's Laws of Motion. As an example Newton's First Law, also known as the law of inertia, states that, in an inertial frame, a body at rest will remain at rest and that a body moving at constant velocity will continue to move with the same velocity unless a net force acts on the body. Many students hold the misconception that a net force is required to keep a body moving at constant velocity. They know that to slide a book across a table a "push" has to be exerted on the book. However, they fail to take into account that there is more than one force acting on the book when it is being pushed across the table at constant velocity. In addition to the "push" being exerted, there also is a frictional force in the opposite direction acting on the book from the tabletop. When the book moves at constant velocity those two forces balance out (add vectorially) to produce a net force of zero.

In an active learning environment students might experiment with objects in an environment that has almost no friction, for example a block moving on an almost frictionless air table. There they would find that if they start the block moving at constant speed, it continues to move at constant speed without the need for a constant "push". Such active learning environment can be simulated using multimedia instructions. The impact of multimedia learning modules on an introductory course on electricity and magnetism was investigated by Stelzer, Brookes, Gladding, and Mestre (2006) where web-based multimedia learning modules were added as pre-lectures to reformed introductory electricity and magnetism course. They observed that in addition to a modest increase in exam performance, the changes dramatically improved student attitudes toward the course in general and lectures in particular. Harms, Krahn and Kurz (2010) used Slice (self-directed learning in an interactive computer environment) which is a multimedia learning environment to integrate textual material, animation, simulation, video to teach 'Oscillatory Motion' and they observed that The Slice Units developed and fostered self-learning abilities which they considered an essential prerequisite for lifelong learning and continuing education.

2.2.8 Multimedia Instructions In Quantum Physics

Quantum physics is a mathematical theory that can describe the behavior of objects that are roughly ten billion times smaller than a typical human being (Smith, 2000). Quantum particles move from one point to another as if they are waves. However, at a detector they always appear as discrete lumps of matter. Quantum physics studies the microscopic particles of the movement of the branches of physics, it is the main research of atoms, molecules, condensed matter, and the structure of nuclei and elementary particles the nature of the basic theory, it is with the theory of relativity together form the theoretical basis of modern physics. Quantum physics is often considered difficult to learn and difficult to teach because it involves the concept on one end and the apparent reality (or knowledge) on the other end far apart.

The approach adopted in many textbooks on quantum physics is that the mathematical solution of model problems brings insight in the physics of quantum phenomena. The mathematical prerequisites to work through these model problems are considerable. Moreover, only a few of them can actually be solved analytically. Furthermore, the mathematical structure of the solution is often complicated and presents an additional obstacle for building intuition. The basic concepts and fundamental phenomena of quantum physics may be introduced through a combination of computer simulation and animation. The primary tool for presenting the simulation results is computer animation. Watching a quantum system evolve in time is a very effective method to get acquainted with the basic features and peculiarities of quantum physics. The images used to produce the computer animated movies are obtained by visualisation of the simulation data.

In traditional classroom teaching, teachers work with limited capacity of the blackboard; teaching time is limited, teaching is often dull, rigid, lack vigor and vitality, and efficiency is not high. With the use of multimedia teaching, a lot of teaching Information can be preset in the computer, ready to call at arbitrary switching of buttons, projecting visually the related graphics, images, vivid, onto the screen (Han Fang 2004). Lijun (2005) reveals the demerit in the use of traditional hand-drawn electron cloud writing on the blackboard, as slow hand-drawing, and not very accurate, and this he connects with the direct impact on teaching effectiveness. He opines further that some courseware flash format, can allow the student to enter and adjust the principal quantum number, azimuthal quantum number, magnetic quantum number, among others which usually gives a deep impression on the student.

Multimedia instructions can expand teaching space, such that students can also read copies of electronic lesson plans and online review of electronic lesson plans after school, and gradually change the student over-reliance on classroom teachers who over-rely on the traditional teaching mode, enhancing the ability of students to acquire knowledge, thereby help creative talents and personality development of students. Jinyan (1998) had earlier analyzed the role of multimedia teaching, particularly in quantum physics and observed the following problems which he believes is worth the attention of researchers. That firstly it ignores the two-way communication and that it lacks the possibility of enhancing mathematical deductions. He observed that in the face of the media in large formula, students are very quick to feel tired, or even lose interest, which eventually greatly reduced the effect of teaching. Thus he concludes that traditional teaching should be integrated with multimedia teaching and when teaching mathematical derivation teachers should use the traditional blackboard more, and use less or even no use of multimedia.

Bennett, S. J. and Brennan, M. J. (1996) attempted to improve the general understanding of quantum physics while providing some context for the students in an environment that could increase the opportunities for student engagement and independence. They opined that Multimedia does not help students develop the practical laboratory skills that are the basis of scientific research since there is no substitute for hands-on experience. In their investigation, the inclusion of multimedia instructions was observed to have an impact on traditional teaching methods. The support of the notes and tutorial material would leave students free to concentrate on the main concepts, rather than being concerned with taking verbatim notes, or getting their experiment to work. It would also allow the lecturer to act as a facilitator for learning and would give more opportunity to promote discussion.

Rebello et al (1997) used a combination of a simulation and an interactive program to present Light emitting diodes (LEDs) which many students had no knowledge of the name but may have seen them in their computers, remote controls, etc. They also used a variety of solid light sources such as infrared detector cards to improvise for television repairers. Television repairers need to know for example if a television remote control is emitting infrared. How can they do that? It is rather simple if they have a video camera. The camera responds to IR and shows a bright spot where the IR is emitted. So, every television repairers needs a video camera, to find out whether there is light coming out of the remote control. But that is rather expensive. Another way to detect IR is with rattlesnakes, which are sensitive to infrared. So, every television repairers could have a rattlesnake. But that is rather expensive in a different way. However, one can buy a little card that responds to IR by emitting visible light. Thus, it absorbs low energy light and emits higher energy light. When these and several other devices are introduced to students it becomes possible to show how the devices are related to quantum physics. Further, the students learn how the devices work at the atomic level.

Kirstein (1999) in teaching wave nature of matter to secondary school students used an experimental observation that shows how electrons can behave as waves. After the students have discussed how interference patterns indicate wave behavior and have observed the interference of light, their attention was turned to electrons. He used video simulations and pictures in books to elaborate this. To investigate the wave nature of electrons further, the students used a simulation program which enabled them to control variables in electron, two-slit experiments. They compared the changes in the pattern for changes in energy of electrons with similar changes when one observes the interference of light at different wavelength. They then concluded that the wavelength of electrons decreased as the energy increased. Kirstein reports that approximately 175 different teachers in 160 different schools have used the materials in classes and observed students' attitudes toward these materials were very positive. Which is summarized in their frequently comments like, "I really like this better than our regular physics. Can we keep doing it?"

2.2.9 The Physics Of Quantum

Quantum physics, also known as quantum mechanics or quantum theory, is a branch of physics providing a mathematical description of much of the dual particle-like and wave-like behavior and interactions of energy and matter (Mackey, 2004). It departs from classical physics primarily at the atomic and subatomic scales, the so-called quantum realm. In advanced topics of quantum physics, some of these behaviors are macroscopic and only emerge at very low or very high energies or temperatures (Davies and Brown, 1986). The name, coined by Max Planck, derives from the observation that some physical quantities can be changed only by discrete amounts, or quanta, as multiples of the Planck constant, rather than being capable of varying continuously or by any arbitrary amount. In the context of quantum physics, the wave–particle duality of energy and matter and the uncertainty principle provide a unified view of the behavior of photons, electrons and other atomic-scale objects.

Quantum physics is perhaps the most important building block in the revolution of physics (1900-1925 period) which erased the limitations of classical physics and created the physics of today. Quantum physics, and the understanding of quantum entities (i.e. things which operate under the laws of quantum physics) that it provides, has been an absolutely indispensable tool in the creation of much of today's modern technology (Hake, 1998). In particular, the entire semiconductor electronics field uses quantum physics principles. Without semiconductor electronics, the now-ubiquitous miniaturized and cheaply mass-produced electronic devices of today (such as computers, cell-phones and cameras) would be utterly impossible. Also, lasers and medical diagnostic tools such as MRI (magnetic resonance imaging) could not exist without knowledge of quantum physics. Modern chemistry (and through it, biochemistry) is increasingly relying on the principles of quantum physics to further its understanding of molecular interaction (Garcia and Aguilar, 2007).

Quantum physics is extremely important, and not only for the technology it offers but for the profound influence on our understanding of the very nature of reality.

2.2.10 Abstract Reasoning In Quantum Physics

Learning about quantum physics involves a fundamental reconceptualization or shift in intellectual activity in many different areas. In thinking about quantum physics students must move beyond models based on sensory experience towards models that encapsulate theoretical sets of abstract properties. It may be expected that if the context of learning does not promote the kinds of activity that foster conceptual development and personal involvement in meaning making and remaking, then students will fail to develop adequate mental models as a basis for reasoning, researching and problem solving in this field. Quantum physics was developed in the period (roughly) 1900-30. It grew out of a series of subtle experimental observations which are, even today, outside most people's normal experience. It was put together by a group of scientists of formidable mathematical expertise, and though several seemingly different 'representations' of the subject have appeared subsequently, this mathematical bias still persists. Historians of science judge that this development marked a radical change in scientific thought - from 'Newtonian' to 'modern' physics - and they often focus on two particular items as symbolic barriers that had to be surmounted: the wave-particle paradox and the Heisenberg uncertainty principle.

The teaching and learning of quantum physics is very frequently postponed until relatively late in a student’s academic career. In the U.S. for example, universities students typically do not study quantum physics in any depth until the fourth year. Thus, the major concepts which have driven much of the development of physics and of modern technology during the 20thcentury are delayed until the end of a physicist’s academic career (Zollman, 2010). In fact in the Nigerian syllabus, it is usually the last topic in physics taught as advanced physics shortly before the West Africa senior school certificate examination.

One reason for this delay is the rather abstract nature of quantum physics itself. We can easily argue that, for the way in which quantum physics is traditionally taught, students need to have generally developed their formal reasoning skills. Formal reasoning skills according to the Piagetian school of thought refers to formal operations which include hypothetical and deductive reasoning, abstract thought, use of symbolic representation, and the use of transformations (Piaget and Inhelder, 1973; Santrock, 2008).). Quantum physics is a hypothetical system for understanding very small objects. It relies heavily on the use of symbolic representations and deduction to apply quantum physics to a variety of situations. Symmetry arguments, and therefore transformations, are a significant part of many presentations of quantum physics. Therefore overall, we can assume that the traditional mode in which quantum physics is taught is very abstract and requires rather sophisticated formal operational procedures.

Significant research dating back to the 1970s has shown that many secondary school students have not yet developed formal operations (McKinnon and Renner 1971). In fact, the traditional way of teaching classical physics is a significant mismatch for many of these concrete operational students. Many people have concluded that learning quantum physics at a lower level is not possible and thus should not even be attempted (Arons 1990). They argue that the students will only be able to memorize isolated facts and repeat things without true understanding. Thus, the students are better served if more time is spent on classical physics where concrete learning experiences can more easily be constructed rather than attempting to teach them something that they could learn only with great difficulty, if at all.

The discussion about the abstract nature of the normal presentations of quantum physics seems rather valid. The simplest response to these conclusions is to avoid teaching this topic at any but the most advanced levels. However, some arguments favour attempting to find ways to teach the topic to students who have not yet reached full formal operations. For example, quantum physics was the most important development in 20thCentury physics, and it has dominated physics and technology for well over a half a century (Zollman, 2010). Thus, at the beginning of the 21stCentury it is time to allow all interested people access to these ideas. Further, many experts predict that within the next 10 years miniaturization of electronics will reach the quantum physics limit. It would be nice if people who are trying to take the next step in development or business understood what that meant.

Abstract reasoning studies date back to the research done by the psychologist Charles Spearman in the 1920’s. Spearman used a statistical technique called factor analysis to examine relationships between people's scores on different tests or sub-tests of intelligence. This led him to believe that there are one or more factors that are common to all intellectual tasks. As a result of this research Spearman developed a two-factor theory of intelligence.

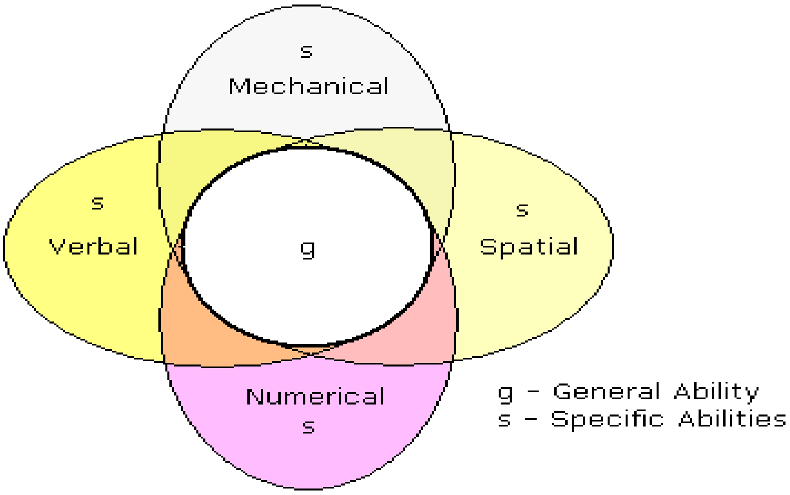


Fig. 2.2 Spearman's two-factor theory of intelligence.

Spearman differentiated between 'g' as the general ability also considered as ability to make formal deductions and the varying specific abilities, 's', such as one person better at mathematics, while another better verbally. Spearman defined 'g' as "the innate ability to perceive relationships and educe co-relationships". Even though Spearman's research was done many years ago, his theory of 'g' is still widely accepted by psychologists and a great deal of research has supported it.

2.2.11 The Role of Spatial Reasoning in Multimedia Learning

Spatial reasoning ability refers to the cognitive and perceptual abilities with space and shapes. Imagination, visualisation and critical reasoning play important role to determine spatial abilities. Spatial ability therefore is the skill to analyze, visualise, comprehend and express imaginative signs and shapes. Some researchers categorically submit that it is beyond dispute that spatial ability plays a crucial role in multimedia learning (Blake 1977; Hays 1996; Large et al. 1996; Yang et al. 2003). However, reviewing literatures on the role of spatial ability relating to learning with visualisations is a very inconclusive and heterogeneous discourse.

Mental animation takes place within a limited capacity store specialized for processing spatial information, similar to the spatial working memory system proposed by Shah and Miyake, (1996). Although similar to some accounts of the visual-spatial sketchpad proposed by Baddeley (1986), spatial working memory is conceptualized as including both specialized storage mechanisms for spatial information and specialized processes for transforming spatial information. Howard Gardner (2010) opined that spatial ability is one of the eight cognitive skills which may be collectively called intelligence. Although there is no definite consensus as to the number of distinct spatial abilities that may exist and how best to characterise them, recent reviews suggest that there is evidence for two or three correlated factors Caroll, (1993) and Lohman (1979) in consonance with Thurstone, characterised spatial ability as spatial relations, spatial visualisation and spatial orientation. Hegarty and Steinhoff (1997) allowed some people to make written notes on diagrams of mechanical systems in a mental animation experiment. Although only about half of those who were allowed to make notes actually did so, making notes improved performance as predicted. Low-spatial subjects who made notes had fewer errors than those who did not make notes. Hegarty (2005) offers the hypothesis that, in learning with dynamic visualisations (in contrast to non-dynamic visualisations), spatial ability might play the role of an enhancer. Learners with high spatial ability might profit from learning with animations, while learners with low spatial ability might not (ability-as-enhancer hypothesis; Huk 2006; Mayer and Sims 1994). Later, however, Hegarty and Kriz (2008) found no such interactions in eight studies examining a mechanical device. Isaak and Just (1995) solely found a main effect for spatial ability in that high-spatial-ability learners viewing an animation were less susceptible to an optical illusion, but no interactions. As another plausible hypothesis, some authors point out the possibility of a compensating effect for low spatial ability in that learners with low spatial ability might be supported by dynamic visualisations because the visualisation provides the learners with an external representation of a process or procedure that helps them to build an adequate mental model; it should be unequally more difficult to construct such a model by using static pictures (Hays 1996). Animations might therefore act as a "cognitive prosthetic" (Hegarty and Kriz 2008) for learners with low spatial ability. Höffler et al. (2006) found such an effect for animations versus static pictures. Hays (1996) could not find a significant ATI-effect (aptitude-treatment-interaction) supporting this hypothesis, but he showed that low-spatial-ability participants receiving animations plus text made significantly greater gains than those receiving either static pictures plus text or text alone. For two different simulations, one of them in line with the spatial contiguity principle (people learn more deeply when corresponding information is presented near rather than far from each other on the screen or page; Mayer 2001), Lee (2007) found significant support for the ability-as compensator hypothesis; that is, learners with low spatial ability performed better in the treatment group than in the control group, while for learners with high spatial ability, it made no difference.

Moreover, many questions concerning possible moderating effects of the role of spatial ability are still open. If learner's spatial ability is low, how should the format of instruction be designed to support the learning process? For example, Huk (2006) found the role of 3dversus 2d-visualisations important as to this question. Mayer and Sims (1994) found an enhancing effect of additional verbal input for high spatial learners. Garg et al. (2001) indicated a possible compensating effect of self-paced versus system-paced visualisations. Narayanan and Hegarty (2002) addressed the question of the role of different instructional domains as a possible moderating variable. On the whole, the role of spatial ability on learning with visualisations is still rather unclear and superficially defined.

2.2.12 Contrasting Attention and Split Attention

Attention according to Anderson, (2004) is the cognitive process of selectively concentrating on one aspect of the environment while ignoring other things. Attention has also been referred to as the allocation of processing resources (Strayer, Drews and Johnston, 2003). Examples include listening carefully to what someone is saying while ignoring other conversations in a room or listening to a cell phone conversation while driving a car. Attention is one of the most intensely studied topics within psychology and cognitive neuroscience. Attention can implicitly be described as the sustained focus of cognitive resources on information while filtering or ignoring extraneous information. Attention remains a major area of investigation within education, psychology and neuroscience. Areas of active investigation involve determining the source of the signals that generate attention, the effects of these signals on the tuning properties of sensory neurons, and the relationship between attention and other cognitive processes like working memory and vigilance. Attention is a very basic function that often is a precursor to all other neurological/cognitive functions. The clinical models of attention offer five different perceptions of attention, viz,

a) Focused attention: The ability to respond discretely to specific visual, auditory or tactile stimuli.

b) Sustained attention (vigilance): The ability to maintain a consistent behavioral response during continuous and repetitive activity.

c) Selective attention: The ability to maintain a behavioral or cognitive set in the face of distracting or competing stimuli. Therefore it incorporates the notion of "freedom from distractibility."

d) Alternating attention: The ability of mental flexibility that allows individuals to shift their focus of attention and move between tasks having different cognitive requirements.

e) Divided attention: This is the highest level of attention and it refers to the ability to respond simultaneously to multiple tasks or multiple task demands (Sohlberg and Mateer, 1989).

The concept of attention in neurological studies is concerned primarily with the ability of the learner to attend to tasks but instructional split-attention refers to the learning effect inherent within some poorly designed instructional materials. Instructional split-attention occurs when learners are required to split their attention between multiple integrated sources of physically or temporally disparate information, where each source of information is for understanding the learning content

(Ayres and Sweller, 2005). It is apparent when the same modality (e.g. visual and visual) is used for various types of information within the same display. To learn from these materials learners must split their attention between these materials to understand and use the materials provided.

The phenomenon that the physical integration of verbal and pictorial information sources, compared to their physical separation, enhances learning is known as the split-attention effect. Gabriele Cierniak (2010) in an experimental study, where students learned about physiological processes with either an integrated or a split-source format observed that learners with split-source format achieved lower learning outcomes, but did not show worse secondary task performance than learners with integrated format. These results contradict the assumption that only an increase in extraneous load for learners with a split-source format mediates the split-attention effect. Mediation analyses of the subjective load ratings revealed that both, extraneous and germane load contributed to the split-attention effect. These results support the assumption that germane load also plays a crucial role in mediating the split-attention effect. This assumptions shall necessitate that split attention must be related to the theories of multimedia learning.

2.2.13 Retention in Learning as Schema Construction

Physically, the brain consists of roughly 10 billion neurons, each analogous to a computer chip capable of storing information. Each neuron has octopus-like arms called axons and dendrites. Electrical impulses flow through these arms and are ferried by neuro-transmitting chemicals across what is called the synaptic gap between neurons. Memories are stored as patterns of connections between neurons. When two neurons are activated, the connections or "synapses" between them are strengthened. Practically, as you read this chapter, the experience actually causes physical changes in your brain. In a matter of seconds, new circuits are formed that can change forever the way you think about the world (Johnson, 1992). Imagine memory as a massive, multidimensional spider web. The interconnectedness of information stored in memory is the most important property of memory. One thought leads to another. It is possible to start at any one point in memory and follow a perhaps labyrinthine path to reach any other point. Information is retrieved by tracing through the network of interconnections to the place where it is stored. Retrievability is influenced by the number of locations in which information is stored and the number and strength of pathways from this information to other concepts that might be activated by incoming information. The more frequently a path is followed, the stronger that path becomes and the more readily available the information located along that path. If one has not thought of a subject for some time, it may be difficult to recall details. After thinking our way back into the appropriate context and finding the general location in our memory, the interconnections become more readily available. We begin to remember names, places, and events that had seemed to be forgotten.

The information in our long term memory is stored in schemas which makes retention of facts and connections possible, although practice, experience and formal education contribute to the differences in people's schemas, especially about the same knowledge areas. People who specialise in an area have a deeper, richer and more complex schema than do people who are only aware of the basics. Learning is most successful when the new information is clearly related to existing schemas. If we already know something about a topic, then learning new information is easier. If the new information conflicts with what we know, then learning can be harder. If information is presented within structures than are unrelated to the domain, or even without structure, then learning is also harder. For example, telling someone to perform a sequence of actions in a certain way, without evidence of rhyme or reason, will be very difficult and we would have to rote learn the material.

Once people have started thinking about a problem one way, the same mental circuits or pathways get activated and strengthened each time they think about it. This facilitates the retrieval of information. These same pathways, however, also become the mental ruts that make it difficult to reorganise the information mentally so as to see it from a different perspective. One useful concept of memory organization is what some cognitive psychologists call a "schema." A schema is any pattern of relationships among data stored in memory. It is any set of nodes and links between them in the web of memory that hang together so strongly that they can be retrieved and used more or less as a single unit. Any given point in memory may be connected to many different overlapping schemata. This system is highly complex and not well understood. This conception of a schema is so general that it begs many important questions of interest to memory researchers, but it is the best that can be done given the current state of knowledge. It serves the purpose of emphasizing that memory does have structure. It also shows that how knowledge is connected in memory is critically important in determining what information is retrieved in response to any stimulus and how that information is used in reasoning. Concepts and schemata stored in memory exercise a powerful influence on the formation of perceptions from sensory data.

It used to be that how well a person learned something was thought to depend upon how long it was kept in short-term memory or the number of times they repeated it to themselves. Research evidence now suggests that neither of these factors plays the critical role. Continuous repetition does not necessarily guarantee that something will be remembered. The key factor in transferring information from short-term to long-term memory is the development of associations between the new information and schemata already available in memory. This, in turn, depends upon two variables: the extent to which the information to be learned relates to an already existing schema, and the level of processing given to the new information.

Depth of processing is the second important variable in determining how well information is retained. Depth of processing refers to the amount of effort and cognitive capacity employed to process information, and the number and strength of associations that are thereby forged between the data to be learned and knowledge already in memory. There are three ways in which information may be learned and retained in memory: by rote, use of a mnemonic device or assimilation. (Bellezza, 1980).

By Rote: Material to be learned is repeated verbally with sufficient frequency that it can later be repeated from memory without use of any memory aids. When information is learned by rote, it forms a separate schema not closely interwoven with previously held knowledge. That is, the mental processing adds little by way of elaboration to the new information, and the new information adds little to the elaboration of existing schemata. Learning by rote is a brute force technique. It seems to be the least efficient way of remembering or retention.

By Using A Mnemonic Device: A mnemonic device is any means of organizing or encoding information for the purpose of making it easier to remember. A biology student cramming for a test might use the acronym "MRNIGER" as a device for remembering the first letter of each of the characteristics of living things, viz, movement, respiration, nutrition, irritability, growth, excretion, reproduction, Mnemonic devices are useful for remembering information that does not fit any appropriate conceptual structure or schema already in memory. They work by providing a simple, artificial structure to which the information to be learned is then linked. The mnemonic device supplies the mental "file categories" that ensure retrievability of information. To remember, first recall the mnemonic device, then access the desired information.

By Assimilation: Information is learned by assimilation when the structure or substance of the information fits into some memory schema already possessed by the learner. The new information is assimilated to or linked to the existing schema and can be retrieved readily by first accessing the existing schema and then reconstructing the new information. Assimilation involves learning by comprehension and is, therefore, a desirable method, but it can only be used to learn information that is somehow related to our previous experience.

Schemas (or schemata for plural) actually are information structures in long-term memory that enable learners to solve certain category of problems and at the same time save working memory by chunking information elements and production rules into a whole. It facilitates transfer of performance of an acquired knowledge (Van Gerven, 2003). According to Chipperfield (2006), the difference between learners with high retention and learners with low retention is based on their ability to categorize problems using schemas stored in long-term memory. Memory processes tend to work with generalized categories. If people do not have an appropriate category for something, they are unlikely to perceive it, store it in memory, or be able to retrieve it from memory later. If categories are drawn incorrectly, people are likely to perceive and remember things inaccurately.

In conclusion, some factors influence how information is stored in memory which affects future retrievability. These factors include: being the first-stored information on a given topic, the amount of attention focused on the information, the credibility of the information, and the importance attributed to the information at the moment of storage.

2.2.14 Split attention multimedia principle and retention

Despite the huge production of all sorts of multimedia instructions, educational research has yielded surprisingly few general design principles for instructions in which verbal and visual information are combined. Instructional designers seem to base their design choices more on intuitive ideas than on sound research results. Multimedia instruction in its most elementary form consists of a picture with an explanatory text. Because picture and text cannot be perceived simultaneously, the learner is forced to switch back and forth between the two and integrate them mentally. According to Cognitive Load Theory (Sweller, 1988; Sweller, van Merriënboer and Paas, 1998) this integration process is cognitively demanding and at the expense of mental resources that could otherwise be allocated to the learning process. Sweller calls the unnecessary cognitive load caused by the presentation format of instructions extraneous load. A design guideline that follows from cognitive load theory is to keep the extraneous load of instructions as low as possible, so that the available mental resources can be used for the actual learning process. Multimedia can help direct the learner's attention to the most relevant information on a page. At the same time, and for the same reason, irrelevant media may distract learners and actually decrease learning thus Faraday (2000) advises that designers of multimedia instructions should not have unrelated pictures and meaningless motion (gratuitous animation). Najjar (1998) suggested that multimedia should be made interactive, and be used for supportive not decorative purposes in order to effectively focus the learner's attention.

Humans can integrate information from different sensory modalities into one meaningful experience--such as when they associate the sound of thunder with the visual image of lightning in the sky. They can also integrate information from verbal and non-verbal information into a mental model--such as when they watch lightning in the sky and listen to an explanation of the event. Therefore, the multimedia instructional designer is faced with the need to choose between several combinations of modes and modalities to promote meaningful learning (Moreno & Mayer, 2000). Should the explanation be given auditorily in the form of speech, visually in the form of text, or both? Would entertaining adjuncts in the form of words, environmental sounds, or music help students' learning? Should the visual and auditory materials be presented simultaneously or sequentially? How should verbal information be presented to students to enhance learning from animations: auditorily as speech or visually as on-screen text?' In order to answer these question, Mayer and Moreno (1998) asked students to view an animation depicting a complex system (the process of lightning formation, or how a car' braking system works), either along with concurrent narration or along with concurrent on-screen text. They observed that when pictures and words were both presented visually (i.e., a split -attention situation), learners were able to select fewer pieces of relevant information because visual working memory was overloaded. When words and pictures were presented in separate modalities, visual working memory can be used to hold representations of pictures and auditory working memory can be used to hold representations of words.

Although multimedia learning offers very high potential educational opportunities by the presentation of rich visual information such as graphics, animation, and movies, Mayer and Moreno (1998) observed that computer-based instructional materials are usually based on what current technology advances can do rather than on research-based principles of how students learn with technology. In their first study they showed that students learn better from designs that do not present simultaneous mutually-referring visual information. The split-attention principle emphasizes the need to present animation with auditory speech rather than on-screen text. Presenting an animation with simultaneous on-screen text forces students to hold one source of the visual materials in working memory while attending to the other source, creating a high cognitive load.

In their second study, they observed that students learn better if the verbal material is presented auditorily rather than visually even in sequential presentations. It showed that the advantage of narration presentations over on-screen text presentation does not disappear when both groups are forced to hold the information contained in one source of the materials before attending to the other. These results suggest not only that more information is likely to be held in both auditory and visual working memory rather than in just one but that the combination of auditory verbal materials with visual non-verbal materials may create deeper understanding than the combination of visual verbal and non-verbal materials. Faraday and Sutcliffe (1997) conducted a series of studies that tracked eye-movement patterns during multimedia presentations. The authors identified guidelines for improving the learning of information. Some of these include: Use speech to reinforce an image (including captions and labels); Reveal information systematically to control attention; Avoid animation or reveal motion during the moment of time when a label is being mentioned, and; Use animation to show more than just the initiation of an action; use it to show the result as well.

Najjar (1998) observed that certain characteristics of Web sites could significantly affect learning, and therefore submitted that when using multimedia, the information presented in one medium needs to support and extend the information presented in the other medium. For example, adding closely related, supportive graphics (illustrations or images) to textual or auditory verbal information improves learning. Lee and Bowers (1997) studied a group of university students to determine under which set of conditions people learned best. The participants were given a pre-test, they then learned the material, and then were given a post-test. Their learning was compared with the learning of a control group that took the same pre- and post-tests, but studied a different topic in-between. When compared with the learning performance of the control group, the people in the different groups always demonstrated more learning. The result of their research is presented as follows;

Hearing spoken text and looking at graphics – 91% more learning,
Looking at graphics alone – 63% more,
Reading printed text plus looking at graphics – 56% more,
Listening to spoken text, reading text, and looking at graphics – 46% more,
Hearing spoken text plus reading printed text – 32% more,
Reading printed text alone – 12% more,
Hearing spoken text alone – 7% more.

2.2.15 Spatial reasoning and retention in science

Spatial reasoning ability, sometimes referred to as spatial intelligence or spatial visualisation, can be described in multiple ways. Common definitions of spatial ability are: being able to view, conceive, and manipulate objects or ideas within the "mind's eye"; the capacity to perceive the visual world accurately, perform transformations and modifications upon one's initial perception; and being able to recreate aspects of one's visual experiences even in the absence of relevant stimuli. Additionally, spatial intelligence goes beyond simple "visual" intelligence as it is the ability to perceive a form or object—the most elementary form (with examples of blind humans having this ability)—to the manipulation of the object or form in the "spatial realm" of thought.

The ability to mentally model objects has long been recognized as a valuable skill in the fields of engineering, particularly when dealing with design and graphical representations. Recently, spatial ability has been acknowledged for its relevance in areas such as surgery, chemistry, physics, and even mathematics. As noted in a course on spatial intelligence at Purdue University (Benes, 2005), a variety of people use their spatial ability in everyday life, research, and leisure. For example, Albert Einstein often mentioned that he frequently used mental models rather than pure mathematical lines of reasoning and that verbal processes did not seem to play a part in his creativity. Nikola Tesla used his spatial ability to visualise the many machinery inventions he was responsible for as well as the important electrical discoveries he is credited with. Until the helical structure of DNA was spatially realized, it was not explainable. Friedrich Kekule explained how he visualised the Benzene ring in his sleep prior to developing the chemical model of its properties. Chess players, cartographers, artists, and even Gikwe bushmen in Africa have been tested for and exhibit high spatial intelligence. Indeed, even Piaget's early work was testing children to determine their spatial development (Piaget and Inhelder, 1948). The famous Water Level Task (WLT) used to test the concept that water will always seek a level horizon in respect to the Earth's surface, was developed by Piaget for testing the spatial ability in children. For example, their testing revealed that young students invariably drew the water level parallel to the base of the glass and were not able to discern the difference until they were older. During the late 1970s, it was discovered that there was a gender difference in accuracy in performing the WLT and it was adopted by cognitive psychologists for testing, and experiments in, the gender differences seen in spatial ability (Liben and Golbeck, 1980).

The importance of spatial ability has been linked to measures of practical and mechanical abilities that are quite useful in technical occupations (Smith, 1964), but what about a link to abstract reasoning abilities? Spatial imagery is tremendously important in art, creative thinking (Shepard, 1978), and may have an important role in abstract engineering disciplines such as electronics. Spatial abilities are frequently attributed to creative and higher order thinking skills in science and mathematics.

Cognitive psychology has made important contributions to the understanding of how people encode, remember, and transform visual images. Shepard (1978) and his students conducted seminal research in the 1970s, which posed interesting questions for cognitive scientists regarding two basic findings that were found relevant. The first, that time played a factor in determining whether two figures could be rotated into congruence which suggests that mental rotation is an analog process that has a one-to-one correspondence to actual physical rotation, and second, that the rotation process is a mental representation that somehow preserves information about the objects' structure during the rotation transformation itself. However, most agree that spatial knowledge can be represented in more than one way. Though there is much research and theory in cognitive psychology and artificial intelligence regarding the nature of spatial knowledge and processing, it does not address the source of the individual differences seen in spatial processing. The most popular hypothesis is the notion that spatial abilities can be explained by individual differences in the speed that subjects exhibit when performing mental rotations correctly. The most common and reliable tests are designed to measure this context. However, this cannot explain the gender difference, which consistently has shown a statistically significant preference for the male subjects scoring above the female subjects, nor can it explain the high correlation between time and correct answers on the most difficult of rotations for those that score near the median on the overall test. Although the rate of processing time and accuracy on rotations is confounded, the differences on the accuracy scores are much higher than the differences on the time processing for those with high spatial ability versus those with low spatial ability. Perhaps it is a function of working memory space.

In other words, those with low levels of working memory take more time for the rotations simply because they need more time to process the information though they have an equal amount of spatial ability as those who can process the information more rapidly within their working memory. Given enough time, nearly everyone can determine the answer to the problem: "If the minute and hour hands on an analog clock indicate the time is a quarter past noon, what time will it be if we swap the minute and hour hands on the clock?" Perhaps timed mental rotation problems are good measures of spatial ability because they not only require mental manipulation, but good use of mental memory storage as well. A number of investigations have attempted to find a difference in the type of mental representations created by high and low spatial ability subjects (Cooper, 1982; Lohman, 1979). These studies show that the difference between high and low spatial ability is not so much the ability to remember stimuli as it is the ability to remember structured stimuli. Low spatial ability subjects find it difficult to construct structured images while those with high spatial ability appear to not have much difficulty. Furthermore, it has been shown that those subjects with high spatial ability remember complex polygons by breaking them into simpler geometric shapes. It may take a bit longer for memory processing, but the accuracy when asked to reassemble the complex polygon is much higher for the high spatial ability subjects. Contrarily, those subjects with lower spatial ability try to remember the complex polygons "as is" with a consequential lower accuracy when asked to reassemble the same polygons. Hence, subjects of different spatial ability tend to solve spatial tests in predictably different ways. Factorial studies of spatial ability routinely show that spatial ability tests are good measures of "*g*"—the highest-order common factor that can be extracted in a hierarchical factor analysis from a large battery of diverse tests of various cognitive abilities. One example, from research on reading comprehension conducted by Kintsch and Greeno (1985), showed why many children fail to solve word problems in mathematics. What they discovered is that a model based simply on the text was not enough. The children also needed to construct a visual mental model that could be coordinated with the text model. They found also that as the complexity of the problem increased, the importance of constructing a visual model became apparent. A good example would be trying to decipher the oftentimes confusing text that comes with a new toy that requires assembly. Though the words are in English, they can be very difficult to comprehend, “Put the hex nut R and lock washer P on tapered spindle Q-3 and tighten.” If one cannot visualise the assembly, then it may not be understood. Beginning books for children contain many pictures. As the books progress to only textual content, the child must now use language to construct visual models and images and hence coordinating the two. This is depicted in Baddeley’s (1996) central executive theory of working memory. He claims that working memory is comprised of two systems: a phonological loop and a spatial-visual scratch pad. We can replay the words over and over but need to create a mental image to tie the concept together. In other words, the ability to create and appreciate metaphors and analogies in language and to generate visual-spatial models that can then be coordinated with that textual input are cognitive traits of those individuals that succeed in occupations that require such spatial abilities.

2.2.16 Neuroscience and Education

Although an increasing number of researchers are seeking to establish educational neuroscience as a productive field of research, debate still continues with regards to the potential for practical collaboration between the fields of neuroscience and education, and whether neuroscientific research really has anything to offer educators.

Willingham (2009) argues that "whether neuroscience can be informative to educational theory and practice is not debatable" and states that “it has been informative to education”. He backs his argument up with his research on neuroimaging which was able to reveal reduced activation for children with dyslexia in brain regions known to support phonological processing, thus supporting behavioural evidence for the phonological theory of dyslexia. Bruer (1997) suggests that the link between neuroscience and education is essentially impossible without a third field of research to link the two a position which other researchers consider to be a very pessimistic view. While acknowledging that more bridges must be built between basic neuroscience and education, Thomson, Baldeweg, and Goswami (2005) claim that cognitive developmental neuroscience has already made several discoveries of use to education, and has also led to the discovery of ‘neural markers’ that can be used to assess development. In other words, milestones of neural activity or structure are being established, against which an individual can be compared in order to assess their development. Furthermore, the response of these neural markers to focused educational interventions may be used as a measure of the intervention’s effectiveness. Researchers such as Goswami assert that cognitive neuroscience has the potential to offer various exciting possibilities to education. For special education, these include the early diagnosis of special educational needs; the monitoring and comparison of the effects of different kinds of educational input on learning;

and an increased understanding of individual differences in learning and the best ways to suit input to learner.

There has been a significant increase in neuroscience research examining young children's processing of language at the phonetic, word, and sentence levels (Tomblin and Zhang 2006). There are clear indications that neural substrates for all levels of language can be identified at early points in development. At the same time, intervention studies have demonstrated the ways in which the brain retains its plasticity for language processing. Intense remediation with an auditory language processing program has been accompanied by functional changes in left temporo-parietal cortex and inferior frontal gyrus (Fonteneau, van der Lely, Pinker and Steven 2008). However, the extent to which these results generalize to spoken and written language is debated (Guttorm, Leppänen, Poikkeus, Eklund, Lyytinen and Lyytinen, 2005).

The application of neuroscience to understanding mathematical processing has already resulted in understanding beyond the early cognitive theories. Cognitive neuroscience research has revealed the existence of an innate 'number sense' system, present in animals and infants as well as adults, that is responsible for basic knowledge about numbers and their relations. This system is located in the parietal lobe of the brain in each hemisphere. (Landerl, Bevan, Butterworth, 2004). This parietal system is active in children and adults during basic numerical tasks, (Ansari, Garcia, Lucas, Hamon, Dhital, 2005) but over the course of development it appears to become more specialised. Furthermore, children with mathematical learning disabilities (dyscalculia) show weaker activation in this region than typically developing children during basic number tasks (Dehaene, Spelke, Pinel, Stanescu, Tsivkin,1999). These results show how neuroimaging can provide important information about the links between basic cognitive functions and higher level learning, such as those between comparing two numbers and learning arithmetic.

In addition to this basic number sense, numerical information can be stored verbally in the language system, a system that neuroscience research is beginning to reveal as qualitatively different at the brain level to the number sense system (Zago, Pesenti, Mellet, Crivello, Mazoyer, Tzourio-Mazoyer, 2001). This system also stores information about other well learned verbal sequences, such as days of the week, months of the year and even poetry, and for numerical processing it supports counting and the learning of multiplication tables. While many arithmetic problems are so over learned that they are stored as verbal facts, other more complex problems require some form of visuo-spatial mental imagery (Kucian, Loenneker, Dietrich, Dosch, Martin, von Aster, 2006). Showing that these subsets of arithmetic skills are supported by different brain mechanisms offers the opportunity for a deeper understanding of the learning processes required to acquire arithmetic proficiency.

Neuroimaging studies of mathematical learning disabilities are still rare but dyscalculia is an area of increasing interest for neuroscience researchers. Since different neural mechanisms contribute to different elements of mathematical performance, it may be that children with dyscalculia show variable patterns of abnormality at the brain level. For example, many children with dyscalculia also have dyslexia, and those that do may show different activation of the verbal networks that support mathematics, while those who have dyscalculia only, may show impairments of the parietal number sense system. Indeed, the few studies carried out on children with dyscalculia only point to a brain level impairment of the number sense system (Salovey and Sluyter, 1997; Goleman, 1995). Such evidence has contributed to a theoretical debate between researchers who believe that dyscalculia is caused by a brain level deficit of the number sense and those who believe that the disorder stems from a problem in using numerical symbols to access the number sense information. With the continued development of theoretical models of dyscalculia that generate explicit testable hypotheses, progress should be rapid in developing research which investigates the link between mathematical learning disorders and their neural correlates (Goswami, 2004).

Buer (1997) considers the link between neuroscience and education as a bridge too far. He believes that the two disciplines are simply too different to ever be directly linked in a practically meaningful way. Many researchers such as Pinker and Jackendoff (2005) advocate a cautious optimism with regards to the marriage between education and neuroscience, and believe that to bridge the gap between the two, the development of new experimental paradigms is necessary and that these new paradigms should be designed to capture the relationships between neuroscience and education across different levels of analysis such as neuronal, cognitive, behavioural.

2.2.17 Appraisal of Literature Review

In some ways, technology has seamlessly integrated itself with education. Electronic databases and search engines have replaced card catalogues and PowerPoint is commonly used in lectures. These innovations have eased the mechanical labour of traditional processes, digging through filing cards, and writing every lesson on the blackboard. Learning is not such a mechanical process however, and therefore more care must be taken in designing and implementing technological teaching tools. The dominant feature of the vast majority of educational technology research is a lack of appropriate theoretical foundations. Researchers believed that students were receptacles for knowledge rather than active learners. This led to studies that searched for a better vehicle for conveying knowledge, ignoring the cognitive processes of the learner and using enthusiasm and assumptions above or in place of empirical evidence.

Contemporary researchers are examining learning with technology from the ground up, seeking to understand the fundamental "active ingredients" to proceed scientifically to "authentic educational technologies," (Clark and Estes, 1999). What must not be overlooked is the information that can be gleaned from successful, already-implemented interventions. These can be used to generate hypotheses that can be tested in theoretically based experiments, taking into account the experience of the learner. Finally, given current theories of multimedia learning (Mayer, 2001), aspects of the media debate should be reconsidered. In physics for example, experiments have sometimes yielded apparent contradictory results. These occasions have resulted not in skepticism and dismissal of observations, but in unique clarity of new insight realized through careful experimentation and specification of parameters.

This review of literature expands the background to the problem thereby giving a robust comprehension to this study and emphasising the effect of building appropriate theoretical foundation for multimedia instructions. Fundamentally, all instructional interventions must be based on clearly defined theories to ensure research and development contributes to the overall body of knowledge rather than being independent of it.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter focuses on research methodology which includes research design, target population, sample and sampling techniques, instrumentation, data collection and data analysis.

3.2 Research Design

The study adopted a 3×3×2×2 non-randomized control group factorial design in a quasi-experimental setting. The layout of the research design is as follows

Experimental Group 1 - $\mathbf{O_1}$ $\mathbf{X_1}$ $\mathbf{O_2}$
Experimental Group 2 - $\mathbf{O_1}$ $\mathbf{X_2}$ $\mathbf{O_2}$
Experimental Group 3*(control group)* - $\mathbf{O_1}$ $\mathbf{X_3}$ $\mathbf{O_2}$

O_1 = represents quantum physics pre-test and O_2= represents retention post-test
X_1= represents Design Condition A (DCA)
X_2= represents Design Condition B (DCB)
X_3= represents Design Condition C (DCC) which shall also serve as control group

3.3 Factorial Design

The Factorial Matrix Design **(**3×3×2×2**)** used in this study is represented in Table 3.1

Table 3.1 Factorial Design showing 3 x 3 x 2 x 2

TREATMENT	COGNITIVE LOAD	ABSTRACT REASONING	SPATIAL REASONING
DCA DCB DCC	Over Load	Low	Little
			Considerable
		High	Little
			Considerable
	Partial Load	Low	Little
			Considerable
		High	Little
			Considerable
	No Load	Low	Little
			Considerable
		High	Little
			Considerable

3.3 Variables in This Study

The following variables were employed in the study;

3.3.1 (Independent Variable) Treatment

The treatment in this study occurred at three levels, viz,

i. Design Condition A (DCA)

ii. Design Condition B (DCB)
iii. Design Condition C (DCC)

3.3.2 Moderator Variables

The moderator variables built into the study are;

i. Cognitive load: This was measured at three levels, viz, no-load, partial load and overload.
ii. Abstract reasoning ability: This was measured at two levels, viz, high and low
iii. Spatial reasoning ability: This was measured at two levels, viz, considerable and little

3.3.3 Dependent Variable

i. Retention in Quantum Physics

3.4 Target Population

The target population of this study comprised all the senior secondary school (SSS) two students in all private and public boarding schools of the nine (9) local governments areas in Ijebu and Remo educational zones.

3.5 Sample and Sampling

The experimental nature of this study required the researcher to purposively select participants who were available for the research because of the time factor for retention investigation. Therefore schools with boarding facility were selected because of the forty-eight hours or two days tempo span after the treatment to ensure internal validity by avoiding attrition of participants.

Multi-stage sampling was used for the study. Six local government areas were randomly selected from the nine local governments in Ijebu and Remo educational zones of Ogun state. Six schools were randomly selected for the study from the selected six local government areas. Table 3.2 shows the distribution of students with treatment administered for the selected six local governments for the research. A total of 247 students were used for the study. Experimental treatments were however, assigned to the groups of students at random and intact classes were utilized.

Table 3.2 Sample Distribution Local Government/Treatment crosstabulation

		TREATMENT			Total
		DCA	DCB	DCC	
	Ijebu-Ode	43	-	-	43
	Ikenne	-	40	-	40
	Odogbolu	-	51	-	51

	Ijebu East	41	-	-	41
	Sagamu	-	-	41	41
	Ijebu North East	-	-	31	31
Total		**84**	**91**	**72**	**247**

Reasons for the sampling procedure

1) Random sampling is effective in order to control for extraneous variables.
2) Boarding schools are selected to avoid attrition of participants.
3) SS 2 students were selected as sample option for this study because they are not preparing for external examination like the SS 3 students which can invariably affect the study negatively.

3.6 Instrumentation

Instruments

Six instruments were used in this study. They are:

1) Quantum Physics Pre Test (QPPT)
2) Spatial reasoning test (SRT)
3) Abstract reasoning test (ART)
4) Cognitive load test (CLT)
5) Multimedia Instructional Package (MIP)
6) Retention test (RT)

3.6.1 Quantum Physics Pretest (QPPT)

This is a paper and pencil test which investigated the presence of prior knowledge of the students on quantum physics. The test consists of a paper-and-pencil test, of 60 multiple-choice items which combine verbal statements with diagrams. The test was administered to 42 SS III students since the topic quantum physics has been taught at this level.

Calculation of the reliability of QPPT, reported a reliability coefficient of 0.78 as found in appendix IB. Item analysis indicated a difficulty index of 0.47 and all items below 0.30 discrimination index were removed. Appendix V explains the establishment of the content validity of QPPT using the scheme of work for Physics to develop the items across the cognitive domains – knowledge, comprehension, application, analysis, synthesis and evaluation (Bloom, Madaus and Hastings, 1981).

3.6.2 Abstract Reasoning Test (ART)

This is a twenty-five (25) item test which required students to recognize patterns and similarities between shapes and figures in pattern recognition, figure grouping, icon grids, pattern completion, logical flowcharts and multiple operators. These test items were designed to use symbols arranged in a straight line or in a pattern and to identify the missing symbol or the next in the sequence. The twenty-five (25) item test was administered to 42 SS III students and it has a reliability co-efficient of 0.62 as indicated in appendix IIB

3.6.3 Spatial Reasoning Test (SRT)

This is a thirty (30) item test which assessed the student's understanding of visual relationships between spaces and shapes to elicit ability to mentally manipulate shapes, and interact with 3 dimension components. It also measured ability to think visually and solve spatial problems in two and three dimensions. It was administered to 42 SS III students and it has a reliability co-efficient of 0.74 as indicated in appendix IIIB

3.6.4 Cognitive Load Test (CLT)

This is an interactive test which only exists as a soft ware used to investigate the level of 'mental energy' required to process a given amount of information. It is founded on the cognitive load theory and has a strong relationship with retention. It is not a pencil and paper test like the others but a 'soft test' designed to interact with learners at the beginning of the intervention or treatment. It presented the student with an initial set of data (perhaps) numbers which the student was to memorize and recall after a set of distracting mental activities such as simple arithmetic questions. It was administered to 42 SS III students and it has a reliability co-efficient of 0.89 as indicated in appendix IVB. Find appended the software containing the cognitive load test.

3.6.5 Multimedia Instructional Package (MIP)

This is an interactive intervention instrument which only exists as a software containing instructional sounds, animations, graphics and pictures in quantum physics. It is an instructional software organised by the researcher to guide the Multimedia instructional strategy. The MIP was modified to fit the various treatment modalities and presented using the Microsoft power point application and macromedia flash slide presentation. Also accessories like a digital projector and a lap-top were used to create a classroom similitude. The MIP was also structured into three modules precluded with a pre-module. Each module was administered for forty minutes. Find appended the software containing the MIP

3.6.6 Retention Test in Quantum Physics

The retention test consists of a paper and pencil test which investigated the mastery of taught content on quantum physics. The retention test in quantum physics is the same as the quantum physics pretest. However it served also as posttest in the research. The test consists of a paper-and-pencil test, of 60 multiple-choice items which combine verbal statements with small parts of diagrams. A Table of Specification is appended in appendix V to indicate the basis for the development of items.

3.7 Treatment Procedure

The researcher resorted to the proficiency of one physics teacher (with teaching qualification degree in physics education and twenty one years of teaching experience in physics) as research assistant.

Two hundred and forty (247) senior secondary school students participated in the research and there was no attrition of participants.

Interaction Day I

On the first interaction day with the students, the quantum physics pre-test was administered. Then afterwards the abstract and spatial reasoning abilities tests were administered. To avoid the possible interaction of the tests creating further mental exertion and thereby increasing mental load, the treatment was administered on the second interaction day. The pre-module comprised slides 3 to 7 making a total of 4 slides in a user paced design, that is, the transition of slides was based on learners' discretion. The user paced design was conceded for this module since it was a preparatory module on exponential values with sizes and symbols of units which were assumed during modules 1 through 3.

Interaction Day II

The cognitive load test was administered first to investigate the presence of load and then the first module of the treatment was administered. This module comprised slides 8 to 59 making a total of 51 slides in a system paced design. The system paced design refers to the transition of slides based on the design of the module and this intervention lasted for 40 minutes.

Interaction Day III

The cognitive load test was administered again to investigate the presence of load and then the second module of the treatment was administered. This module comprised slides 61 to 120 making a total of 59 slides in a system paced design. This second module lasted for 40 minutes

Interaction Day IV

The cognitive load test was administered again to investigate the presence of load and then the third (last) module of the treatment was administered. This module comprised slides 123 to 186 making a total of 63 slides in a system paced design. This third module lasted for 40 minutes

Interaction Day V

The retention test in quantum physics was administered.

The description of the treatment used and its application in this study is as follows;

Design Condition A (DCA) – This applied the visual-verbal, the visual-nonverbal approach and auditory-verbal approach where learning materials were presented with a combination of narration, text, static graphical displays, and animated graphical displays. The informational text was integrated within graphical representations of material to be learned and narrated by a speaking agent (instructor). The instructor kept strictly to the procedures highlighted in the multimedia instructional package which is basically a duplicate of the information presented in DCB, so to avoid interaction effects possible if the instructor gave extra instructions not in the content.

Design Condition B (DCB) – This applied the visual-verbal, the visual-nonverbal approach and auditory-verbal approach where learning materials were presented with a combination of narration, text, static graphical displays, and animated graphical displays. The informational text was integrated within graphical representations of material to be learned and narrated by a digitized human voice.

Design Condition C (DCC) – This applied the visual-verbal and the visual-nonverbal approach where learning materials were presented with a combination of text, static graphical displays, and animated graphical displays. In this design condition, there was no auditory input and learners had to view static graphical and animated graphical displays while reading the text combined.

Notably, the researcher conducted the retention test two days after the treatment to avoid the recency effect of the working memory. Two days after the treatment was chosen as appropriate because extraneous load increase with time. Also the researcher benefitted from the concession of using regular and unvarying timing in the presentation of treatment. The average cognitive load value was taken across interaction II, III and IV.

3.8 Methodological Challenges

During the study, the following methodological challenges were experienced

1. The study did not make a case for pre-determined questions, hence the introduction of the pre-module to resolve entry behavior challenges in exponential values of sizes and symbols of units.

2. Time alteration of schedule in participants' availability posed a challenge however the researcher ensured scheduled timings were used in order to successfully complete modules.

3. Time alteration in learner versus system paced design issue was significant. However the researcher maintained the system paced design of the research. For further research, the learner paced design may be explored.

4. Electrification and power challenges were experienced during the research however, this challenge was manage with the use of a mini projector using alternative DC (direct currecnt) source.

3.9 Scoring of Instruments

The researcher manually scored the QPPT, SRT, ART, CLT and the Retention test in Quantum Physics. In the QPPT and the retention test in quantum physics, the 60-item multiple choice test attracted a score of 1 mark each making a total of 60 marks.

The 30 item of the SRT and the 25 item ART attracted a score of 1 mark each making a total of 30 and 25 marks respectively. The CLT attracted a total of 60 marks with each simple arithmetic item and every correct entry of the initial numbers supplied to be remembered weighing 1 mark each. The CLT, ART and SRT scores of all students were computed on percentile ranks to distinguish students according to designated categories with overload, partial load and no load for CLT, high and low for ART and considerable and little for SRT.

4.0 Analysis

Analysis of Co-Variance (ANCOVA) was conducted as statistical method of control to remove the effect of the known covariate thereby correcting initial differences among participants. Interaction effects of the independent variables were also revealed. The hypotheses were tested at the significant level ($p < 0.05$).

CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

This chapter outlines, examines and discusses the results of this study. The concern of this study was to investigate the effect of split-attention multimedia principle and cognitive load on retention in quantum physics while considering the moderating effects of abstract and spatial reasoning ability.

4.2 TESTING OF STATED NULL HYPOTHESES

The results are presented and discussed in relation to the hypotheses stated. The hypotheses were tested at the 0.05 significance level ($P < 0.05$) and the results interpreted accordingly.

Ho_1 : There is no significant main effect of treatment on students' retention in Quantum Physics

Analysis of covariance (ANCOVA) was calculated to examine the effect of treatment on students' achievement, covarying out the effect of the pretest. Table 4.1 presents the particulars of the analysis of covariance. The main effect of treatment was significant on students' retention in quantum physics [$F(2, 212) = 45.154$; $p<0.05$]

Since critical value of the F-ratio at 0.05 level of significance is less than the calculated value, the null hypothesis (Ho_1) is rejected.

1) Treatment accounted for 29.9% of the total variation in the retention scores in Quantum Physics as outlined in table 4.1 on the *partial eta squared* column.
2) Students who were exposed to DCA had the highest mean scores of 40. 344, DCB follows with 35.798 and DCC with 31.067 as outlined in table 4.2.

Table 4.1 Summary of Analysis of Covariance (ANCOVA) of Retention in Quantum Physics by treatment, cognitive load, abstract and spatial reasoning abilities.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	6158.162	34	181.122	7.358	.000	.541
Intercept	4507.373	1	4507.373	183.121	.000	.463
QPRETEST	1755.484	1	1755.484	71.320	.000	.252
TREATMENT	2222.865	2	1111.432	45.154	.000	.299
COGNITIVELOAD	173.569	2	86.785	3.526	.031	.032
ABSTRACT	44.323	1	44.323	1.801	.181	.008
SPATIAL	15.144	1	15.144	.615	.434	.003

TREATMENT * COGNITIVELOAD	211.841	4	52.960	2.152	.076	.039
TREATMENT * ABSTRACT	164.532	2	82.266	3.342	.037	.031
COGNITIVELOAD * ABSTRACT	5.563	2	2.781	.113	.893	.001
TREATMENT * COGNITIVELOAD* ABSTRACT	42.258	4	10.564	.429	.787	.008
TREATMENT * SPATIAL	13.043	2	6.521	.265	.768	.002
COGNITIVELOAD * SPATIAL	153.129	2	76.564	3.111	.047	.029
TREATMENT * COGNITIVELOAD* SPATIAL	29.458	4	7.365	.299	.878	.006
ABSTRACT * SPATIAL	24.317	1	24.317	.988	.321	.005
TREATMENT * ABSTRACT* SPATIAL	35.647	2	17.823	.724	.486	.007
COGNITIVELOAD * ABSTRACT * SPATIAL	227.910	2	113.955	4.630	.011	.042
TREATMENT * COGNITIVELOAD * ABSTRACT * SPATIAL	88.707	2	44.354	1.802	.167	.017
Error	5218.192	212	24.614			
Total	323084.250	247				
Corrected Total	11376.354	246				

a R Squared = .541 (Adjusted R Squared = .468)

*-significant at 0.05 level of significance

Table 4.2 Sets of means showing main effect of Treatment on students' retention test scores in physics

TREATMENT	Mean	Std. Dev.
DCA	40.344	6.11
DCB	35.798	6.36
DCC	31.067	6.32

To probe for sources of significant difference between treatment categories, Scheffe Post-hoc multiple range test was used in table 4.3. There was a significant difference at alpha level P<0.05

Table 4.3 :Post Hoc: Mean Difference Pairwise Comparisons of Treatment

TREATMENT	TREATMENT	Mean Difference	Sig.
DCA	DCB	4.546*	.000
	DCC	9.277*	.000
DCB	DCA	-4.546*	.000
	DCC	4.731*	.000
DCC	DCA	-9.277*	.000
	DCB	-4.731*	.000

Discussion

The findings of this study revealed a significant (main) effect of treatment (DCA, DCB, DCC) on students' retention in quantum physics. The learners exposed to DCA performed better in cognitive retention than those who received DCB, while learners who were exposed to DCB showed a higher ability to retain quantum physics concepts than DCC (the conventional method). This finding is in accord with similar findings where technological aids were harnessed for effective teaching and learning such as the findings of Brown (1991), Hofstetter (1995), Lewis (1996),Teo, Neo and Neo (2000), Ng and Komiya (2000), Wong (2000) Tan(2000).

DCA may have been more effective than DCB because technology can not entirely outdo human appropriate input. This means that technology is a supplement and not a substitute to instructor presence in teaching and learning. Chin (2007) follows this position in his emphasis that technology needs to support man, to function as an extension of our own innate abilities to accomplish a task. He further expresses his disenchantment in the unfortunate way human-computer disconnect forces users to reconcile the way they naturally work with how technology makes them work or, more cynically, how designers want them to work. This study affirms that the power of machines cannot eventually result in a society that lacks human self-reliance, uniqueness, and intelligence as society will always have the ability to be able to face crises and life without machines. The findings of this study agrees with split attention multimedia principle as students exposed to multiple and varying sources of integrated information DCA and DCB outperformed students exposed to DCC. In the DCC treatment, students tried to represent both the animation and the on-screen text in visual working memory. Although some of the visually-represented text eventually may be translated into an acoustic modality for auditory working memory, visual working memory was overloaded. Students paid full attention to on-line text and as such they missed some of the crucial images in the animation, and conversely when they paid full attention to the animation they missed some of the on-line text. Because they were not be able to hold corresponding pictorial and verbal representations in working memory at the same time, students in group DCC were less able to build connections between these representations. Therefore, our theory predicts that students in group DCC performed less successfully than students in group DCA/DCB on the retention tests.

This corroborates the findings of Chandler and Sweller (1992) who observed that the integration of text and diagrams reduces cognitive load and facilitates learning. They also discovered that students viewing integrated instruction spent less time processing the materials. DCA and DCB may have been more effective than DCC because they offer visual and auditory models which literature has identified as the factor responsible for 40% of what we remember

(Lindstrom, 1994). Ng and Komiya (2000) and Hofstetter (1995) confirm this result in their study that multimedia with auditory support elicits the highest rate of information retention and result in shorter learning time. Neo and Neo (2000) reiterate the position of this research result with the submission that multimedia offers a multi-sensory experience to the student as it becomes present not only to the cognitive stimuli like the conventional method may do but also incites the sensory stimuli.

$Ho_{2:}$ There is no significant main effect of cognitive load on students' retention in Quantum Physics

Analysis of covariance (ANCOVA) was calculated to examine the effect of treatment on students' retention in Quantum Physics, while treating Quantum pretest as the covariate. Table 4.1 presents the particulars of the analysis of covariance. The main effect of treatment was significant on students' achievement in physics [F (2, 212) =3.526 ; $p<0.05$]

Since critical value of the F-ratio at 0.05 level of significance is less than the calculated value, the null hypothesis (Ho_2) is rejected.

1) Cognitive Load accounted for 3.2% of the total variation in the retention scores of Quantum physics.

2) Students who entered the class with no cognitive load had the highest mean score of 37.8659, while students who entered the class with partial load had a less mean score of 35.1867. Students who entered the class with a cognitive overload had the lowest mean score of 33.5244.

Table 4.4 Sets of means showing main effect of Cognitive Load on students' retention test scores in physics

COGNITIVELOAD	Mean	Std. Dev.
Over Load	33.932	6.59073
Partial Load	35.184	6.59023
No Load	37.404	6.58236

To probe for sources of significant difference between categories of cognitive load, Scheffe Post-hoc multiple range test was used in table 4.5. There was a significant difference at alpha level $P<0.05$

Table 4.5 :Post Hoc: Mean Difference Pairwise Comparisons of Cognitive Load

COGNITIVE LOAD	COGNITIVE LOAD	Mean Difference	Sig.
Over Load	Partial Load	-1.252	.200
	No Load	-3.472*	.001
Partial Load	Over Load	1.252	.200
	No Load	-2.220*	.024
No Load	Over Load	3.472*	.001

	Partial Load	2.220*	.024

Discussion

The findings of this study revealed a significant (main) effect of cognitive load on students' retention in quantum physics. Learners who entered the class without cognitive load had a higher retention score than those who entered the class with partial load, while learners who experienced partial load showed a higher ability to retain quantum physics concepts than learners with cognitive overload. Chipperfield (2004) agrees with the findings of this study in his analogy of the ninth grade mathematics student suffering from cognitive load revealed how the presence of cognitive load may lead her to never understanding Algebra. He identified a number of factors that cause load such as her worry of the time limit on the assignment, her plans to go out with her friends that night, her anxiety not to have to do homework or stay late after school, her wish that the two students in front of her would stop whispering, the squeaky desk she sits on and her complex that her classmates were looking at her. Chipperfield revealed how these factors impeded her comprehension of the algebra content.

The relatedness of cognitive load and retention was also recorded in the work of Ke-Wen Huang (1996) who observed that learning achievement is affected by both intellectual factors and non-intellectual factors, where the former includes variables such as cognitive style, motivation, physical reaction and gender, all of which may influence cognitive load while the latter includes constructs such as anxiety, fears, worries, depression, among others. Similarly Pass and Van Merrienboer (1994) identified cognitive load to be a multi-dimensional notion, which involves causal factors and assessment factors. They viewed causal factors as the sources of cognitive load which include a) task/environment characteristics: which include task structures, task novelty, reward types, time pressure, noise, temperature, among others, all belonging to easily changed variables. b) subject characteristics: which include cognitive ability, cognitive style, prior knowledge and experiences, all belonging to relatively stable variables, and c) Interactions between the task and the learner: factors, such as performance, motivation and stimulation. These they concluded influence cognitive load before and during teaching and learning as well as eventual achievement.

Sweller et al. (1998) concur with the result of this study by identifying three separate sources of cognitive load, viz Intrinsic cognitive load (Intrinsic cognitive load is mainly affected by the degree of relevancy between instructional elements, i.e., the complexity of subject content, rather than by how instructional materials are presented), Extraneous cognitive load (The manner in which messages are presented as cause of different levels of cognitive burden) and Germane cognitive load(which involves the use of a particular instructional design to focus the learner's attention on the learning content or schema construction) which affect retention of content learned. Sweller noted further in accord with the result of this research that cognitive load is related to the quantity of elements that working memory is able to process and that putting a large quantity of instructional content or approaching an instructional content with a large quantity of extraneous load in the working memory will result in cognitive overload and learning will be difficult or impossible.

Ho_3 : There is no significant main effect of spatial reasoning ability on students' retention in Quantum Physics

To test whether spatial reasoning ability affects students' retention in quantum physics analysis of covariance (ANCOVA) was calculated, covarying out the effect of the pretest. Table 4.1 presents the particulars of the analysis of covariance. The main effect of spatial reasoning ability was not significant [F=1,212= .0.615, p>0.05] on students' retention of quantum physics. Since critical value of F-ratio at 0.05 level of significance is greater than the calculated value, therefore we do not reject the null hypothesis (Ho3).

Discussion

The findings of this study revealed that the main effect of spatial reasoning ability was not significant on students' retention in quantum physics. This disagrees with the findings of Hegarty and Kozhevnikov (2006) that performance is significantly affected by spatial visualisation ability. Shah and Miyake (1996) propose that test of spatial ability can provide a measure of spatial working memory capacity and therefore argue that high spatial individuals should be more successful in mentally animating mechanical systems. Indeed this is consistent with results of previous research (Hegarty and Sims, 1994; Hegarty and Steinhoff, 1997). In studies within the domain of geology, Kali and Orion (1996) found that high spatial participants were able to deduce the internal properties of structures while low-spatial participants were unable to mentally penetrate the structure and depended on patterns visible on external faces. Lord (1985) also lends credence that spatial ability predicts performance in inferring cross-sections of simple solids.

However, Schwartz and Black (1996) agree with the findings of this research partially in their discovery that spatial inference is not important in inferring motion of simpler machines, such as gear chains, possibly because these problems can also be solved with a verbal strategy. Kirsh and Maglio (1994) identified a reason why spatial reasoning may not be significant when they found that performance in relation to spatial reasoning is experience-based in their study of experienced players of Tetris who often rotated the Tetris pieces on the computer screen rather than mentally rotating them. Kirsh (2004) further attributed lack of significance in researches related to spatial reasoning to individual differences among participants.

Spatial reasoning ability from the result of this study is not a basic index to appreciation of conceptual scientific topics such as quantum physics. Where applications of physics concepts are studied, spatial reasoning ability may hold a fundamental role but for pure and conceptual issues in physics, spatial reasoning may be of little import. Working with gears, building of machineries, controlling auto-devices, among others which are characteristically applications of physics, spatial abilities maybe vital but for building of semionic inductors, miniaturised devices among others which characteristically require quantum physics foundations, spatial reasoning plays no helpful role.

Ho$_{4:}$ There is no significant main effect of abstract reasoning ability on students' retention in Quantum Physics

To test whether abstract reasoning ability affects students' retention in quantum physics analysis of covariance (ANCOVA) was calculated, covarying out the effect of the pretest. Table 4c presents the particulars of the analysis of covariance. The main effect of abstract reasoning ability was not significant [F=1,212= 1.801, p>0.05] on students' retention of quantum physics. Since critical value of F-ratio at 0.05 level of significance is greater than the calculated value, therefore we do not reject the null hypothesis (Ho4).

Discussion

The findings of this study revealed that the main effect of abstract reasoning ability was not significant on students' retention in quantum physics. This is not in consonance with the discovery of Virginia (2009) who compared performance of kindergarten children on abstract reasoning, visual-motor integration, and verbal development to achievement scores in kindergarten, second grade, and third grade. Her results disagree with the findings of this research as it showed relationships between abstract reasoning in kindergarten and achievement on two tests in second grade, but not between kindergarten visual-motor integration or verbal development and achievement.

Che and Che (2001) also found out that mathematics achievements were found to correlate strongly with abstract reasoning, logical thinking, and numerical computational abilities. The findings revealed that higher achievers were more oriented towards abstract conceptualisation and active experimentation modes of learning.

The results of this study differ completely from earlier researchers since the subject matter studied in those earlier researches would not be considered on the same difficulty plane with quantum physics. The results thereby outline distinctly the argument that quantum physics is inherently difficult because of its extremely high abstract content to the extent that mere abstraction ability cannot surmount the inherent difficulty. This is because quantum physics is a hypothetical system for understanding very small objects which relies heavily on the use of symbolic representations and deduction to apply quantum physics to a variety of situations. Symmetry arguments, and therefore transformations, are a significant part of many presentations of quantum physics. Therefore overall, we can assume that the traditional mode in which quantum physics is taught is very abstract and requires rather sophisticated formal operational procedures.

Significant research dating back to the 1970s has shown that many secondary school students have not yet developed formal operations (McKinnon and Renner 1971) adequate to handle matters in quantum physics. In fact Arons (1990) asserts that many people have concluded that learning quantum physics at a lower level is not possible and thus should not even be attempted. He argues that the students will only be able to memorize isolated facts and repeat things without true understanding. Thus, he advocates that the students are better served if more time is spent on classical physics where concrete learning experiences can more easily be constructed rather than attempting to teach them something that they could learn only with great difficulty, if at all.

Ho$_{5:}$ There is no significant interaction effect of treatment and cognitive load on students' retention in Quantum Physics

Analysis of covariance (ANCOVA) was calculated to examine the interaction effect of treatment and cognitive load on students' attitude to physics. Table 4.1 presents the particulars of the analysis of covariance. The two way interaction effect of treatment and cognitive load was not significant on students' retention in quantum physics [F (4,212) =2.152, p>0.05). Since critical value of F-ratio at 0.05 level of significance is greater than the calculated value, therefore we do not reject the null hypothesis (Ho5).

Discussion

The findings of this study revealed that the two way interaction effect of treatment and cognitive load was not significant on students' retention in quantum physics. This implies that the combination of treatment and cognitive load do not associate with students' retention in quantum physics. The interaction effect involving the two variables is not influential enough to contribute significantly towards the efforts of this study aimed at investigating retention of quantum physics content considering the effect of the split attention principle.

This gives a plausible explanation to the advantage of multimedia in inducing motivation even when students are cognitively burdened. Ryan and Deci (2000) observed that intrinsically motivated learners tend to behaviorally and cognitively engage with learning tasks and their contexts whereas amotivated learners do not. Paris and Turner (1994), also lend position to the effect of the motivation enkindled by appropriate multimedia instructions to extrinsically motivated students, who engage in the learning task or if its context appeals to them or has some perceived value, leading to a situated motivation. The results of this study also support Stefanou, Perencevich, DiCintio, and Turner (2004) that multimedia and computers have the capacity to allow for external regulation and autonomy support. Lowe (2004) prefers to purport that the naïve view of the power of animation has immense affective characteristics.

Technology through multimedia instructions therefore provides for context and variety in learning tasks that theoretically could be exploited to situate motivation even in cognitively burdened learners.

Ho$_6$: There is no significant interaction effect of treatment and spatial reasoning ability on students' retention in Quantum Physics

Analysis of covariance (ANCOVA) was calculated to examine the interaction effect of treatment and spatial reasoning ability on students' retention in quantum physics. Table 4.1 presents the particulars of the analysis of covariance. The two way interaction effect of treatment and spatial reasoning ability was not significant on students' retention in quantum physics [F (4,212) =2.152, $p>0.05$). Therefore, we do not reject the null hypothesis (Ho6).

Discussion

The findings of this study revealed that the two way interaction effect of treatment and spatial reasoning ability was not significant on students' retention in quantum physics. This implies that the combination of treatment and spatial reasoning ability do not associate with students' retention in quantum physics. The interaction effect involving the two variables is not influential enough to contribute significantly towards the efforts of this study aimed at investigating retention of quantum physics content considering the effect of the split attention principle. This finding agrees with the discovery of Zheng and Zhou (2006) where forty-five college students were recruited and assigned to two groups in an interactive multimedia environment, viz, synchronized and unsynchronized interactive multimedia groups based on their spatial ability score. Results indicated that low spatial ability learners in the synchronized interactive multimedia showed an improvement in problem solving than high spatial ability learners. While this research of Zheng and

Zhou (2006) recorded a significant negative direction, this study did not find a significant interaction effect between treatment and spatial reasoning.

The findings afore-presented accrue from the lack of significance associated with spatial reasoning ability on retention. It also exposes the sharp contrast between the spatial contiguity multimedia principle and the split attention multimedia principle. Mayer (2001) distinguished between both multimedia principles in his findings that students learn better from animation and narration than from animation and on-screen text while contrasting that with the spatial contiguity principle that students learn better when corresponding words and pictures are presented near rather than far from each other on the page or screen. Since this study deals more with the split attention multimedia principle rather than the spatial contiguity principle, it is logically appropriate that spatial reasoning ability plays a less significant role

Ho$_7$: There is no significant interaction effect of treatment and abstract reasoning ability on students' retention in Quantum Physics

Analysis of covariance (ANCOVA) was calculated to examine the interaction effect of treatment and abstract reasoning ability on students' retention in quantum physics. Table 4.1 presents the particulars of the analysis of covariance. The two way interaction effect of treatment and abstract reasoning ability was significant on students' retention in quantum physics (F (2,212) =3.342, $p<0.05$). Therefore, we reject the null hypothesis (Ho7). These effects are illustrated graphically in figure 4.1 which is a plot of the cell means in table 4.6. The graph shows that students with high and low abstract reasoning ability exposed to DCA scored highest in the test of retention in quantum physics than students exposed to DCB. Students exposed to DCA whether with high or low reasoning ability scored lowest in the retention test.

Table 4.6: Sets of means showing the interaction effect of treatment and abstract reasoning ability on students retention test scores in physics

TREATMENT	ABSTRACT REASONING	Mean
DCA	Low	38.614
	High	42.419
DCB	Low	35.400
	High	36.275
DCC	Low	31.823
	High	30.311

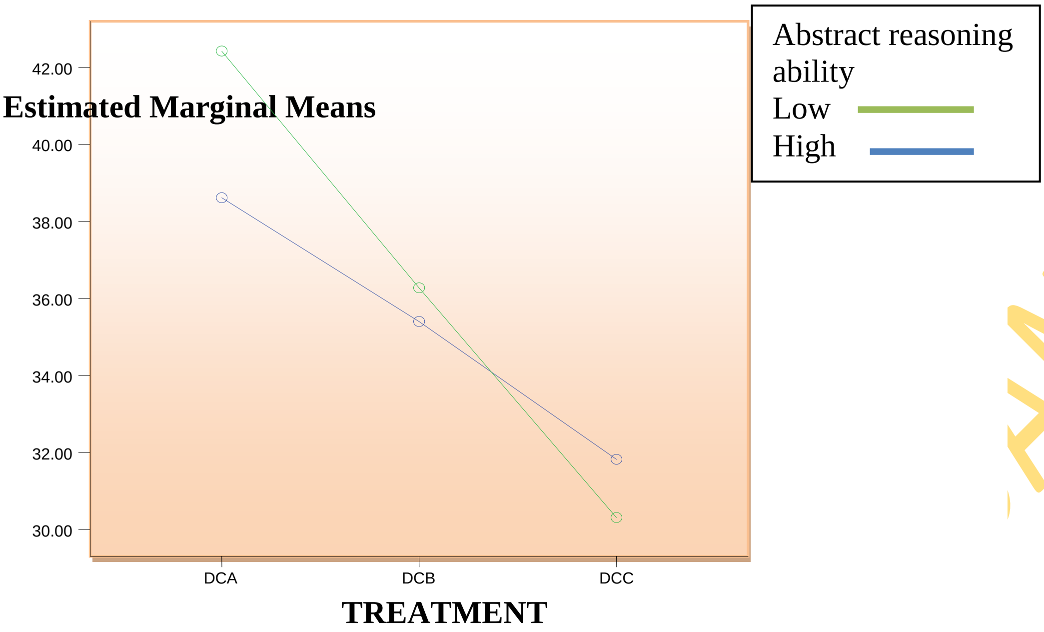


Figure 4.1 Interaction Effect Of Treatment And Abstract Reasoning Ability On Students Retention

Discussion

The findings of this study revealed that the two way interaction effect of treatment and abstract reasoning ability was significant on students' retention in quantum physics. This implies that the combination of treatment and abstract reasoning ability has a propensity with students' retention in quantum physics. The interaction effect involving the two variables is influential to contribute significantly towards the efforts of this study aimed at investigating retention of quantum physics content considering the effect of the split attention principle. Learners with high abstract reasoning and at same time exposed to DCA outperformed learners exposed to the other design conditions in the retention test score. This result is highly probable as abstract reasoning assesses ability to understand complex concepts and assimilate new information beyond previous experience and DCA the most minimal error in the application of the split attention principle.

It is a plausible result as active learning environment makes it feasible for students to simulate unobservable phenomena as experienced in quantum physics thereby igniting their inquiry ability and increased wonder for the subject matter. In fact while it may be cognitively impossible to build schema from quantum physics since it deals with discrete, indivisible units of energy, and therefore requiring extreme use of abstraction which rarely contribute significantly, multimedia instructions have the capacity to simulate these infinitesimal particles into observable phenomena. In fact studying the five main ideas represented in quantum physics below, it is impossible for mere abstractions to extract the pith of the concept but where these phenomena can be made observable, learners may begin to build appropriate structures of comprehension. The five main theses of quantum physics include;

1. Energy is not continuous, but comes in small but discrete units.
2. The elementary particles behave both like particles *and* like waves.
3. The movement of these particles is inherently random.
4. It is *physically impossible* to know both the position and the momentum of a particle at the same time. The more precisely one is known, the less precise the measurement of the other is.
5. The atomic world is *nothing* like the world we live in.

This is in accord with Stelzer, Brookes, Gladding, and Mestre (2006) who observed that in addition to a modest increase in exam performance, the use of multimedia introduced changes which dramatically improved student attitudes toward the course in general and lectures in particular.

Ho$_8$: There is no significant interaction effect of cognitive load and abstract reasoning ability on students' retention in Quantum Physics

Analysis of covariance (ANCOVA) was calculated to examine the interaction effect of cognitive load and abstract reasoning ability on students' retention in quantum physics. Table 4.1 presents the particulars of the analysis of covariance. The two way interaction effect of cognitive load and abstract reasoning was not significant on students' retention in quantum physics [F (2,212) =0.113, $p>0.05$]. Therefore, we do not reject the null hypothesis (Ho8).

Discussion

The findings of this study reveal that the two way interaction effect of cognitive load and abstract reasoning ability was not significant on students' retention in quantum physics. This implies that the combination of cognitive load and abstract reasoning ability do not associate with students' retention in quantum physics. The interaction effect involving the two variables is not influential enough to contribute significantly towards the efforts of this study aimed at investigating retention of quantum physics content considering the effect of the split attention principle.

This finding is feasible in the instance where the abstract reasoning test and cognitive load test were conducted in the same learning unit. In fact if the abstract reasoning test is administered prior to the cognitive load test, it may be observed that the mental exertion expended on tackling the abstract reasoning test may have increased the cognitive load of the learner. This reveals a reversal effect on the research as the abstract reasoning test creates cognitive load across the learners, making it almost impossible to distinguish between learners who attended the class interaction with cognitive load from learners who did not.

Ho$_9$: There is no significant interaction effect of cognitive load and spatial reasoning ability on students' retention in Quantum Physics

Analysis of covariance (ANCOVA) was calculated to examine the interaction effect of cognitive load and spatial reasoning ability on students' retention in quantum physics. Table 4.1 presents the particulars of the analysis of covariance. The two way interaction effect of cognitive load and spatial reasoning ability was significant on students' retention in physics (F (2,212) =3.111, $p<0.05$). Therefore, we reject the null hypothesis (Ho9).

These effects are illustrated graphically in figure 4.2 which is a plot of the cell means in table 4.7. The graph shows that students with almost no cognitive load irrespective of their spatial reasoning ability scored highest in the test of retention in quantum physics.

Table 4.7: Sets Of Means Showing The Interaction Effect Of Cognitive load and Spatial Reasoning Ability on Students Retention Test Scores In Physics

COGNITIVELOAD	SPATIAL REASONING	Mean
Over Load	Little	32.011
	Considerable	35.852
Partial Load	Little	34.538
	Considerable	35.830
No Load	Little	38.663
	Considerable	36.144

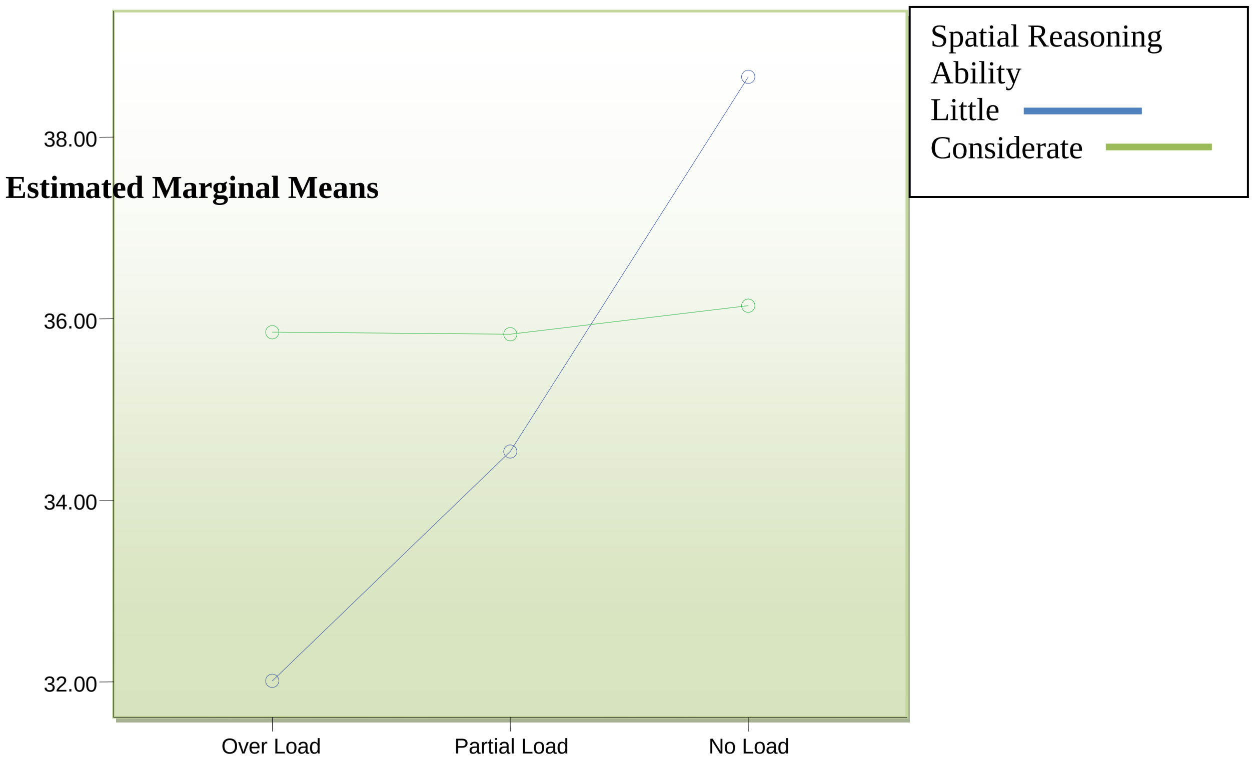


Fig. 4.2 Interaction effect of cognitive load and spatial reasoning ability on students' retention

Discussion

The findings of this study revealed that the two way interaction effect of cognitive load and spatial reasoning ability was significant on students' retention in quantum physics. This implies that the combination of cognitive load and spatial reasoning ability has a propensity with students' retention in quantum physics. The interaction effect involving the two variables is influential to contribute significantly towards the efforts of this study aimed at investigating retention of quantum physics content considering the effect of the split attention principle. Learners without load (minimal load) and high spatial reasoning outperformed others learners in same categories in the retention test score.

In fact this result accords with reason if we consider the everyday spatial event of driving a car with complexities of issues in the mind of the driver. High cognitive load may affect the safety of driving and thereby endanger the life of the driver. This elaborates why people learning to drive cars have minor or even major accidents at the beginning stage of learning. This is because the multiple functions to be carried out create a cognitive load as such the learning driver disconnects from the cognitive map of the route. If the intrinsic cognitive load therefore is high (difficult content) and the extraneous cognitive load is also high, then total cognitive load will exceed mental resources and learning may fail to occur. This explains simply again why a learning driver would do well if there is minimal extraneous cognitive load such as the impatience of the tutor, among others.

Ho_{10}: There is no significant interaction effect of abstract reasoning ability and spatial reasoning ability on students' retention in Quantum Physics

Analysis of covariance (ANCOVA) was calculated to examine the interaction effect of abstract reasoning ability and spatial reasoning ability on students' retention in quantum physics. Table 4c presents the particulars of the analysis of covariance. The two way interaction effect of abstract reasoning ability and spatial reasoning ability was not significant on students' retention in quantum physics [F (4,212) =2.152, p>0.05). Therefore, we do not reject the null hypothesis (Ho10).

Discussion

The findings of this study revealed that the two way interaction effect of abstract reasoning ability and spatial reasoning ability was not significant on students' retention in quantum physics. This implies that the combination of abstract reasoning ability and spatial reasoning ability do not associate with students' retention in quantum physics. The interaction effect involving the two variables is not influential enough to contribute significantly towards the efforts of this study aimed at investigating retention of quantum physics content considering the effect of the split attention principle. Spearman (1920) had observed using factor analysis to examine relationships between people's scores on different tests or sub-tests of intelligence that people who do well on some intelligence tests also do well on others (e.g. vocabulary, mathematics, spatial abilities). Yong (2006) differs from Spearman and partly agrees with the position of this research in his findings that achievement in physics is very much affected by spatial reasoning ability but not at all by abstract reasoning.

This finding accedes to the autonomy of different forms of intelligence and declines Spearman's factor analysis of relatedness of intelligence. This explains why a student may have intelligent motor skills but lack emotional intelligence, or a professor having high cognitive ability but lacking emotional intelligence. However, it is vital to clarify that this finding does not describe an inverse relationship between different forms of intelligence but refuses to consider a direct relationship between different forms of intelligence.

Ho_{11}: There is no significant interaction effect of cognitive load, abstract reasoning ability and spatial reasoning ability on students' retention in Quantum Physics

Analysis of covariance (ANCOVA) was calculated to examine the interaction effect of cognitive load, abstract reasoning ability and spatial reasoning ability on students' retention in quantum physics. Table 4.1 presents the particulars of the analysis of covariance. The three way interaction effect of cognitive load, abstract reasoning ability and spatial reasoning ability was significant on students' retention in physics (F (2,212) =4.630, $p<0.05$). Therefore, the null hypothesis (Ho11) is rejected. The interaction effects of cognitive load, abstract reasoning ability and spatial reasoning ability accounted for 4.2% of the total variation in the retention scores of Quantum physics.

These effects are illustrated graphically in figure 4.3 which is a plot of the cell means in table 4.8. The graph shows that students without cognitive load having high and low abstract reasoning ability as well as high and low spatial reasoning ability scored highest in the test of retention in quantum physics. Students with an overload in cognition whether with high or low reasoning ability as well as high and low spatial reasoning ability scored lowest in the retention test.

Table 4.8: Sets of means showing the interaction effect of cognitive load, abstract reasoning ability and spatial reasoning ability on students retention test scores in physics

COGNITIVELOAD	ABSTRACTREASONING	SPATIALREASONING	Mean
Over Load	Low	Little	32.686
		Considerable	36.702
	High	Little	30.999
		Considerable	34.578
Partial Load	Low	Little	33.296
		Considerable	36.026
	High	Little	35.780
		Considerable	35.633
No Load	Low	Little	39.957
		Considerable	33.008
	High	Little	37.370
		Considerable	39.280

Discussion

The three way interaction effect of cognitive load, abstract reasoning ability and spatial reasoning ability was significant on students' retention in quantum physics. This implies that the combination of cognitive load, abstract reasoning ability and spatial reasoning ability has a strong association with students' retention in quantum physics. The interaction effect involving the three variables contributes significantly to the retention test scores. Learners without cognitive load generally scored high in the retention test. Even the difference in abstract and spatial reasoning abilities hardly diminished the scores of the retention test. This finding agrees with Spearman (1920) in his assertion that people who do well on some intelligence tests also do well on others (e.g. vocabulary, mathematics, spatial abilities). However, this is in stark contrast to the earlier findings of this work that disagree with Spearman's theory on the 'g' factor in intelligence.

Ho$_{12}$: There is no significant interaction effect of treatment, abstract reasoning ability and spatial reasoning on students' retention in Quantum Physics

Analysis of covariance (ANCOVA) was calculated to examine the interaction effect of treatment, abstract reasoning ability and spatial reasoning ability on students' retention in quantum physics. Table 4.1 presents the particulars of the analysis of covariance. The three way interaction effect of abstract reasoning ability and spatial reasoning ability was not significant on students' retention in quantum physics [F (2,212) =0.724, p>0.05]. Therefore, we do not reject the null hypothesis (Ho12).

Discussion

The three way interaction effect of treatment, abstract reasoning ability and spatial reasoning was not significant on students' retention in quantum physics. This implies that the combination of treatment, abstract reasoning ability and spatial reasoning has very insignificant propensity with students' retention in quantum physics. The interaction effect involving the three variables does not contribute significantly to the retention test scores.

The lack of significance of this finding accrues from the insignificant interaction effect of treatment and abstract reasoning ability as well as treatment and spatial reasoning ability earlier presented.

Ho$_{13}$: There is no significant interaction effect of treatment, cognitive load and abstract reasoning ability on students' retention in Quantum Physics

Analysis of covariance (ANCOVA) was calculated to examine the interaction effect of treatment, cognitive load and abstract reasoning ability on students' retention in quantum physics. Table 4.1 presents the particulars of the analysis of covariance. The three way interaction effect of treatment, cognitive load and abstract reasoning ability was not significant on students' retention in quantum physics [F (2,212) =0.724, p>0.05). Therefore, we do not reject the null hypothesis(Ho13).

Discussion

The three way interaction effect of treatment, cognitive load and abstract reasoning ability was not significant on students' retention in quantum physics. This implies that the combination of treatment, cognitive load and abstract reasoning ability has very insignificant propensity with students' retention in quantum physics. The interaction effect involving the three variables does not contribute significantly to the retention test scores. The lack of significance of this finding accrues from the insignificant interaction effect of treatment and abstract reasoning ability earlier presented.

Ho_{14}: There is no significant interaction effect of treatment, cognitive load and spatial reasoning ability on students' retention in Quantum Physics

Analysis of covariance (ANCOVA) was calculated to examine the interaction effect of treatment, cognitive load and spatial reasoning ability on students' retention in quantum physics. Table 4.1 presents the particulars of the analysis of covariance. The three way interaction effect of treatment, cognitive load and spatial reasoning ability was not significant on students' retention in quantum physics [F (4,212) =0.299, p>0.05). Therefore, we do not reject the null hypothesis(Ho14).

Discussion

The three way interaction effect of treatment, cognitive load and abstract reasoning ability was not significant on students' retention in quantum physics. This implies that the combination of treatment, cognitive load and abstract reasoning ability do not associate with students' retention in quantum physics. The interaction effect involving the three variables does not contribute significantly to the retention test scores.

The lack of significance of this finding accrues from the weight of the insignificant interaction effect of treatment and spatial reasoning ability earlier presented.

Ho_{15}: There is no significant interaction effect of treatment, cognitive load, spatial reasoning ability, and abstract reasoning ability on students' retention in Quantum Physics

Analysis of covariance (ANCOVA) was calculated to examine the interaction effect of treatment, cognitive load and spatial reasoning ability and abstract reasoning on students' retention in quantum physics. Table 4.1 presents the particulars of the analysis of covariance. The four way interaction effect of treatment, cognitive load and spatial reasoning ability and abstract reasoning was not significant on students' retention in quantum physics [F (4,212) =0.299, p>0.05). Therefore, we do not reject the null hypothesis(Ho15).

Discussion

The four way interaction effect of treatment, cognitive load spatial and abstract reasoning ability was not significant on students' retention in quantum physics. This implies that the combination of treatment, cognitive load, spatial and abstract reasoning ability has very insignificant propensity with students' retention in quantum physics. The interaction effect involving the four variables does not contribute significantly to the retention test scores.

The lack of significance of this finding accrues from the weight of insignificant interaction effect of treatment and abstract reasoning ability as well as treatment and spatial reasoning ability earlier presented.

CHAPTER FIVE

5.0 SUMMARY OF FINDINGS, IMPLICATIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

The principal findings of this study as presented in chapter four with their educational implications and recommendations are summarized in this chapter. Also, the limitations of this study and suggestions for further research are highlighted.

5.1 SUMMARY OF FINDINGS

The research findings, in accord with data obtained from the study sample are presented as follows;

1. The main effect of treatment was significant on students' retention in quantum physics

2. The main effect of cognitive load was significant on students' retention in physics

3. The main effect of spatial reasoning ability was not significant on students' retention of quantum physics.

4. The main effect of abstract reasoning ability was not significant on students' retention of quantum physics.

5. The two way interaction effect of treatment and cognitive load was not significant on students' retention in quantum physics

6. The two way interaction effect of treatment and spatial reasoning ability was not significant on students' retention in quantum physics

7. The two way interaction effect of treatment and abstract reasoning ability was significant on students' retention in quantum physics

8. The two way interaction effect of cognitive load and abstract reasoning was not significant on students' retention in quantum physics

9. The two way interaction effect of cognitive load and spatial reasoning ability was significant on students' retention in physics

10. The two way interaction effect of abstract reasoning ability and spatial reasoning ability was not significant on students' retention in quantum physics

11. The three way interaction effect of cognitive load, abstract reasoning ability and spatial reasoning ability was significant on students' retention in physics

12. The three way interaction effect of treatment abstract reasoning ability and spatial reasoning ability was not significant on students' retention in quantum physics

13. The three way interaction effect of treatment, cognitive load and abstract reasoning ability was not significant on students' retention in quantum physics

14. The three way interaction effect of treatment, cognitive load and spatial reasoning ability was not significant on students' retention in quantum physics

15. The four way interaction effect of treatment, cognitive load and spatial reasoning ability and abstract reasoning was not significant on students' retention in quantum physics

5.2 EDUCATIONAL IMPLICATIONS

The findings of this study have implications for stakeholders in the education sector.

The government

The findings of this study are relevant to the government in the following ways;

1) The government should subsidize the sale of computers in order that they may be easily affordable by schools for further explorations on its benefit to education.

2) There is the need for the government to promote and use computer programs created and developed within Nigeria schools.

3) Technology in education needs to be explored as apparently the next generation of Nigerian students would be confronted with the fast moving use of computer technology.

4) The government should expose teachers to seminars, workshops and courses on the design of multimedia instructional materials so as not to leave the design of multimedia course content to computer proficient persons who only see from lucrative dimension rather than the educative perspective.

The Teachers

1) Multimedia instructional strategy can simulate phenomena which otherwise would not be feasible and observable. Multimedia learning materials do not necessarily lead to better learning outcomes. Teachers should use multimedia in a supportive and not decorative way by studying the learning defects inherent in poorly organised, designed and presented instructions

2) Teachers should avoid the disregard of the underlying cognitive architecture of the learner in the design, organization, technique and presentation of multimedia instructions can make multimedia less effective.

3) Multimedia presentations must employ visual and auditory formats so as not to create an overload on the visual working memory

The Students

1) Students: This may also cognitively de-mystify the gaps between theory and application in quantum physics

2) Students should be made to undergo abstract pre-instructions before a class on quantum

physics as a cognitive entry characteristic.

Parents

1) Parents should endeavour to purchase computers in their homes and monitor its usage so as to introduce and guide their children in harnessing the use of computers in education.

2) Parents in the PTA associations should endeavour to empower schools with computers which can facilitate learning.

Curriculum Developers

1) There is a need to build into the curriculum for teacher education and other related disciplines the appropriate use of recent technology in education.

2) Curriculum developers should introduce courses on abstract reasoning in secondary school to improve the development of formal reasoning at this stage

5.3 LIMITATIONS

The limitations of this study are highlighted below;

1) The designing of the multimedia package was time-consuming and required considerable effort therefore inhibiting the pace of the researcher.

2) The study made use of relatively small sample of private boarding schools in Ijebu and Remo educational zones of Ogun state, thus limiting the generalizability of the study.

3) The content coverage was also limited to quantum physics.

4) This study was dependent on electrical power supply and as such outage of power hampered the progress of the study.

5.4 SUGGESTIONS FOR FURTHER RESEARCH

Results of this study have highlighted the following areas to be charted for further investigation.

1) Similar study should be conducted however using the learner paced system design rather than the user paced system design used in this study.

2) Further research needs to be carried out on other senior secondary school physics classes(SS 2 and SS3) as the generalizability of the study is limited.

3) Further research should be conducted on its wide variety of formats such as text, graphics, sound, film, video, hypermedia, and other interactive formats which are considered to engage more senses than conventional teaching methods so to determine which is more effective.

4) Further research on the effectiveness of multimedia may also consider other variables (Independent, moderator and dependent) other than those used in this study to investigate further interactions.

5) In this research, cognitive load was examined indirectly by investigating students’ mental effort on entering the class. Further research may adopt a more scientific and direct measurement by cooperating with medical centers on the possibility of applying medical engineering technology like functional magnetic resonance imaging (fMRI) for measuring the cognitive load. This may give further information when neural signs are studied.

REFERENCES

Ainsworth, S. 1999. The Functions of Multiple Representations. *Computers & Education*, 33(2-3), 131-152.

Ainsworth, S., & VanLabeke, N. 2004. Multiple forms of dynamic representation. *Learning and Instruction*, 14(3), 241-255.

Anderson, John R. 2004. *Cognitive psychology and its implications* (6th ed.). Worth Publishers. p. 519. ISBN 978-0-7167-0110-1.

Ansari, D; Garcia, N; Lucas, E; Hamon, K; Dhital, B. 2005. "Neural correlates of symbolic number processing in children and adults". *Neuroreport* **16** (16): 1769–1773. doi:10.1097/01.wnr.0000183905.23396.f1. PMID 16237324.

Arieli R., 2001. *Visual Quantum Physics* (Hebrew). Rehovot, Israel, Weizmann Institute of Science.

Arons A., 1990 *A Guide to Introductory Physics Teaching*, New York, John Wiley and Sons,.

Ayres and Sweller, 2005. The split-attention principle in multimedia learning. R.E. Mayer (Ed.), *The Cambridge handbook of multimedia learning*, Cambridge University Press, New York. 134-146

Ayres, P. 2006. Cognitive load theory at UNSW. Sydney, Australia: University of New South Wales (UNSW). Retrieved on November 10, 2008 from *http://education.arts.unsw.edu.au/research/*

Baddeley, A. D. 1986. *Working memory*. Oxford, England: Oxford University Press.

Balaban, N. 1995. "Seeing the Child, Knowing the Person." In Ayers, W. *To Become a Teacher*. Teachers College Press. p. 52

Bennett, S. J. 1995. The Use of Interactive Multimedia in the Communication of Science. Unpublished thesis, The Australian National University.

Berk, L & Winsler, A. 1995. "Vygotsky: His life and works" and "Vygotsky's approach to development". In *Scaffolding children's learning: Vygotsky and early childhood learning*. Natl. Assoc for Educ. Of Young Children.

Biferno, M. A. 1985. *Mental workload measurement: Event-related potentials and ratings of workload and fatigue* (NASA CR 177354). Moffett Field, CA: NASA Ames Research Center.

Blake, T. 1977 Motion in instructional media: Some subject-display mode interactions. *Perceptual and Motor Skills*, 44, 975–985.

Blinn, J. 1989. The making of The Mechanical Universe. Paper presented at the Spatial displays and spacial instruments: *Proceedings of a conference sponsored by NASA Ames Research Center, and the School of Optometry*, University of California, Asilomar, California

Bruning, R. H., et. al. 2004. *Cognitive psychology and instruction*. 4th ed. New Jersey: Prentice hall.

Bruer, J. T. 1997. "Education and the brain: A bridge too far". *Educational Researcher* **26**: 4–16.

Chandler, P., and Sweller, J. 1992. The split-attention effect as a factor in the design of instruction. *British Journal of Educational Psychology*, 62, 233-246 *Cognitive Sciences*. (2nd Ed), Englewood Cliffs, NJ: Educational Technology Publications.

Che D., Che A. H. 2001. Factors Influencing the Achievement in Mathematics of Malay Secondary School Students. Unpublished Masters Thesis, Universiti Putra Malaysia

Chipperfield B. 2004. Cognitive Load Theory and Instructional Design University of Saskatchewan Press, Saskatchewan Retrieved on November 7, 2008 from *http://www.usask.ca/education/coursework/802papers/chipperfield/chipperfield.pdf*

Chipperfield, B. 2006. Cognitive Load Theory and Instructional Design Saskatoon. Saskatchewan, Canada: University of Saskatchewan (USASK). Retrieved on November 7, 2008 from *http://www.usask.ca/education/coursework/802papers/chipperfield/chipperfield.pdf*

Choi, B., & Gennaro, E. 1987. The effectiveness of using computer simulated experiments on junior high students' understanding of the volume displacement concept. *Journal of Research in Science Teaching, 24* (6), 539-552.

Clark, R. E. 1983. Reconsidering Research on Learning from Media. *Review of Educational Research*, 53(4), 445-459.

Clark, R. E. 1989. The future of technology in educational psychology. M. Wittrock & F. Farley (Eds.), *The future of educational psychology*. Hillsdale, NJ: Laurence Erlbaum Associates.

Clark, R. E. 1994. Media Will Never Influence Learning. Educational Technology, *Research and Development*, 42(2), 21-29.

Clark, R. E., & Estes, F. 1998. Technology or Craft: What Are We Doing? *Educational Technology*, 38(5), 5-11.

Clark, R. E., & Estes, F. 1999. The Development of Authentic Educational Technologies. *Educational Technology*, 39(2), 5-16.

Clark, R. C., and Mayer, R. E. 2003. E-Learning and the Science of Instruction. Does Practice Make Perfect? In *e-Learning and the Science of Instruction,*149-171 San Francisco: Pfeiffer.

Clark, R.C., Nguyen, F., and Sweller, J. 2006. *Efficiency in learning: evidence-based guidelines to manage cognitive load*. San Francisco: Pfeiffer.

Clement, J. 1982. Students Preconceptions in Introductory Physics, *American Journal of Physics*, 50, 66-71 *Cognitive Science* 12 (1): 257–285

Conole, G. 2002. Systematising Learning and Research Information. *Journal of Interactive Media in Education* (7).

Cooper, L. A. 1982. Strategies for visual comparison and representation: Individual differences. In R. J. Sternberg (Ed.), *Advances in the psychology of human intelligence* (pp. 77-124). Hillsdale, NJ: Erlbaum.

Cooper, G. 1990. Cognitive load theory as an aid for instructional design. *Australian Journal of Educational Technology*, 6(2), 108-113.

Cooper, G. 1998. Research into Cognitive Load Theory and Instructional Design at UNSW. Sydney, Australia: University of New South Wales (UNSW). Retrieved on November 10, 2008 from *http://education.arts.unsw.edu.au/staff/sweller/clt/index.html.*

Cuban, L. 1986. *Teachers and machines: The classroom use of technology since 1920*. New York: Teachers College Press.

Dalgarno, B. J. 2004. Characteristics of 3D environments and potential contributions to spatial learning. Wollongong : University of Wollongong.

deGroot A., Thought and Choice in Chess The Hague: Mouton, 1965. cited by Herbert A. Simon, "How Big Is a Chunk?" *Science*, Vol. 183 (1974), 487.This discussion draws on Francis S. Bellezza, "Mnemonic Devices: Classification, Characteristics, and Criteria" Athens, Ohio: Ohio University, pre-publication manuscript, January 1980.

Dehaene, S; Spelke, E; Pinel, P; Stanescu, R; Tsivkin, S. 1999. "Sources of mathematical thinking: behavioral and brain-imaging evidence". *Science* (AAAS) **284** (5416): 970–974. doi:10.1126/science.284.5416.970. PMID 10320379.

de Raedt, H. 2008 “Event by Event Simulation of Quantum Phenomena” *Brazilian Journal of Physics* 38, (1) 26 - 36

Egbugara, O. U. 1989. An investigation of aspects of students’ problem-solving difficulties in ordinary level Physics. Journal of the Science Teachers Association of Nigeria, 26(1), 57-67.

Faraday, P. 2000, Visually critiquing Web pages, *6th Conference on Human Factors & the Web*.

Faraday, P. and Sutcliffe, A, 1997. Designing effective multimedia presentations, *Proceedings of CHI* '97, 272-278.

Fluck, A. 2001. The rise and rise of computers in education. In M. Robertson & R. Gerber (Eds.), *Children's Ways of Knowing: Learning Through Experience*. 144-157. Melbourne: Australian Council for Educational Research.

Fonteneau, E; van der Lely, HKJ; Pinker, Steven. 2008. Pinker, Steven. ed. "Electrical Brain Responses in Language-Impaired Children Reveal Grammar-Specific Deficits". *http://www.plosone.org/article/info:doi/10.1371/journal.pone.0001832*

Friesen, N., Roberts, A., & Fisher, S. 2002. CanCore: Metadata for Learning Objects. *Canadian Journal of Learning and Technology*, 28(3), 43-53.

Garg, A. X., Norman, G., and Sperotable, L. 2001. How medical students learn spatial anatomy. *The Lancet*, 357, 363–364.

Goleman, D. 1995. *Emotional intelligence*. New York, Bantam Books.

Goswami, U. 2004. "Neuroscience and education". *British Journal of Educational Psychology* **74** 1: 1–14. doi:10.1348/000709904322848798. PMID 15096296.

Guttorm, TK; Leppänen, PH; Poikkeus, AM; Eklund, KM; Lyytinen, P; Lyytinen, H. 2005 "Brain event-related potentials (ERPs) measured at birth predict later language development in children with and without familial risk for dyslexia". *Cortex* (Elsevier Science) **41** 3: 291–303. doi:10.1016/S0010-9452(08)70267-3. PMID 15871595

Halloun, I and Hestenes, D, 1985. Common Sense Concepts About Motion, *American Journal of Physics*, 53, 1056-1065

Han Fang. 2004. Multimedia teaching problems and countermeasures. Chongqing Institute of Technology, 18: 143.

Hart, S., and Staveland, L. 1988. Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P. Hancock & N. Meshkati (Eds.), Human mental workload. 139-183. Amsterdam: North Holland.

Hart. S. G., Battiste. V., Chesney. M. A., Ward. M. M., and McElroy, M. 1986. Comparison of workload, performance, and cardiovascular measures: Type A personalities vs. Type B. Working paper. Moffett Field, CA: NASA Ames Research Center.

Hays, T. A. 1996 Spatial abilities and the effects of computer animation on short-term and long-term comprehension. *Journal of Educational Computing Research*, 14, 139–155.

Hegarty, M., and Kriz, S. 2008 Effects of knowledge and spatial ability on learning from animation. R. Höffler, T. N., Sumfleth, E., & Leutner, D. 2006. The role of spatial ability when learning from an instructional animation or a series of static pictures. J. Plass (Ed.), *Proceedings of the NYU Symposium on Technology and Learning*, April 2006. New York: New York University.

Hegarty M. and Kozhevnikov M. 2006. *Spatial Abilities, Working Memory, and Mechanical Reasoning*, Santa Barbara: UCSB Press,

Hegarty, M., Shah, P & Miyake, A. 2000. Constraints on using the dual-task methodology to specify the degree of central executive involvement in cognitive tasks. *Memory & Cognition, 28*: 376-385.

Hegarty, M. & Steinhoff, K.1997. Use of diagrams as external memory in a mechanical reasoning task. *Learning and Individual Differences, 9:* 19-42.

Hegarty, M. & Sims, V. K. 1994. Individual differences in mental animation during mechanical reasoning. *Memory & Cognition, 22*: 411-430.

Hestenes, D. 1992. Force Concept Inventory. Physics Teacher, 30.3:141-158.

Heyneman, S. P. 2001. The growing international commercial market for educational goods and services. *International Journal of Educational Development*, 21: 345-359.

Hofstetter, F. T. 1995. *Multimedia Literacy*, New York: McGraw-Hill.

Huk, T. 2006. Who benefits from learning with 3d models? The case of spatial ability. Journal of illusion. *Journal of Experimental Psychology: Human Perception and Performance*, 21, 1391– 1408. Instruction, 4: 295–312.

James, W. 1890. *The Principles of Psychology*. New York: Henry Holt, Vol. 1: 403-404.

Jensen and J Adrion (Eds.).2004. *Proceedings of the Third Symposium on Aviation Psychology*. 263-270. Columbus, OH: OSU Aviation Psychology Laboratory.

Jeung, H., Chandler, P., and Sweller, J. 1997. The role of visual indicators in dual sensory mode instruction. *Educational Psychology*, 17: 329-343.

Jinyan, Z. 1998. *Introduction to Quantum Physics*. Beijing: Beijing University Press.

Johnson, G. 1992. *In the Palaces of Memory: How We Build the Worlds Inside Our Heads*. Vintage Books, xi.

Jonassen, D. 1988 The future of technology in education: A post-modern problem with a transformative solution or whoever controls the technology creates the reality. *Proceedings of ASCILITE98*. In Coderoy (Ed.) UOW Press. 29-36.

Josephson, M. 1992, Edison: A Biography. New York: McGraw-Hill,

Kali, Y., and Orion, N. 1996. Spatial abilities of high school students in the perception of geologic structures. *Journal of Research in Science Teaching*, 33:369-391.

Kalyuga, S. 2000. When using sound with a text or picture is not beneficial for learning. *Australian Journal of Educational Technology*, 16:161–172

Kalyuga, S., Chandler, P., and Sweller, J. 2000. Managing split-attention and redundancy in multimedia instruction. *Applied Cognitive Psychology*, 13, 351-371.

Kearsley, G. 2006 in J. Sweller 2006. Cognitive Load theory. Retrieved on November 15, 2008, from the *Explorations in Learning & Instruction: The Theory into Practice Database* Website: http://tip.psychology.org/sweller.html

Kintsch, W., & Greeno, J. G. (1985). Understanding and solving word arithmetic problems. *Psychological Review*, *92*.1:109-129.

Kirsh, D. 1997. Interactivity and multimedia interfaces. *Instructional Science*, 25: 79-96.

Kirsh, D. 2004. Metacognition, distributed cognition and visual design. P. Gardinfors And P. Johansson (Eds). *Cognition, Education, and Communication Technology*. Lawrence Erlbaum.

Kozma, R. 2000. Reflections on the State of Educational Technology Research and Development. *Educational Technology Research and Development*, 48.1: 5-15.

Kozma, R. B.1994. Will Media Influence Learning? Reframing the Debate. Educational Technology, Research and Development, 42.2: 7-19.

Kozma, R. B., & Russell, J. 1997. Multimedia and Understanding: Expert and Novice Responses To Different Representations of Chemical Phenomena. *Journal of Research in Science Teaching*, 34.9: 949-968.

Kucian, K; Loenneker, T; Dietrich, T; Dosch, M; Martin, E; von Aster, M (2006). "Impaired neural networks for approximate calculation in dyscalculic children: a functional MRI study". *Behavioral and Brain Functions* (BioMed Central Ltd.) 2 .1: 31. doi:10.1186/1744-9081-2-31. PMC 1574332. PMID 16953876.

Kuti, J.B. 2006, Effect of Multimedia Instructional Strategy on Senior Secondary School Students' Learning Outcomes in Physics. Unpublished M.Ed. Thesis, University of Ibadan.

Landerl, K; Bevan, A; Butterworth, B. 2004. "Developmental dyscalculia and basic numerical capacities: a study of 8-9-year-old students". *Cognition* (Elsevier Science) 93.2: 99–125. doi:10.1016/j.cognition.2003.11.004. PMID 15147931.

Large, A., Beheshti, J., Breuleux, A., and Renaud, A. 1996 Effect of animation in enhancing descriptive and procedural texts in a multimedia learning environment. Journal *of the American Society for Information Science*, 47:437–448.

Lee, A. Y. and Bowers, A. N. 1997. The effect of multimedia components on learning, *Proceedings of the Human Factors and Ergonomics Society*, 340-344.

Lee, H. 2007. Instructional design of web-based simulations for learners with different levels of spatial ability. *Instructional Science*, 35:467–479.

Liboff R. 1980. *Introductory Quantum Physics*, San Francisco: Holden-Day

Lohman, D. F. 1979 Spatial ability: review and re-analysis of the correlational literature. Tech. Rep. No. 8, Stanford University.

Lord, T. R. 1985. Enhancing the visuo-spatial aptitude of students. *Journal of Research in Science Teaching*, 22:395-405.

Lowe, R. K. 2004. Animation and learning: Value for money? Beyond the comfort zone: *Proceedings of the 21st ASCILITE Conference, Perth 5-8 December.* http://acilite.org.au/conferences/perth04/procs/lowe-r.html

Mackey, W.E. 2004. The Interactive Thread: Exploring Methods for Multi-disciplinary Design. In *Proc. ACM Conference on Designing Interactive Systems* (DIS 2004), Cambridge (USA). ACM Press, 103-112.

Maduekwe, O. 2003 Maduekwe Seeks Emergence of "Policy Leadership". *This Day* Retrieved March 3, 2007 from http://fr.allafrica.com/

Marton, F. 1986. *Phenomenology- A Research Approach to Investigating Different Understandings of Reality* .J. Thought 21.3: 28-49.

Mayer, R. E. 1997 Multimedia learning: Are we asking the right questions? *Educational Psychologist*, 32:1–19.

Mayer, R. E., 2001. *Multimedia Learning,* Cambridge University Press, Cambridge.

Mayer, R. E. 2005. *The Cambridge Handbook of Multimedia Learning*. New York: Cambridge University Press.

Mayer R.E. 2009. *Multimedia Learning: Second Edition.* New York: Cambridge University Press

Mayer, R. E. and Anderson, R. B. 1992. The instructive animation: Helping students build connections between words and pictures in multimedia learning. *Journal of Educational Psychology*, 84:444-452.

Mayer, R. E. and Moreno, R. 1998. A split-attention effect in multimedia learning: Evidence for dual processing systems in working memory. *Journal of Educational Psychology*, 90:312-320.

Mayer, R.E. and Moreno R. 2002. Animation as an Aid to Multimedia Learning *Educational Psychology Review* 14.1: 87-99

Mayer, R. E., and Sims, V. K. 1994 For whom is a picture worth a thousand words? Extensions of a dual-coding theory of multimedia learning. *Journal of Educational Psychology*, 82:715–726.

Mayer, R. E. 2003. The promise of multimedia learning: using the same instructional design methods across different media. *Learning and Instruction*, 13.2:125-139.

McLuhan, M. 1964. *Understanding media: the extensions of man*. London: Routledge & Kegan Paul.

McDermott, L. 1984. Research on Conceptual Understanding in Physics. *Physics Today*, 37.7: 24.

Mc Dermott L.1990 a view from physics in towards a scientific practice of science education, M. gardner, J.G Greeno, F. Reif,A.H. Schoenfeld, A. Diessa and E. Stage, 3-30 hillsdale, N.J. Erlbaum 1990

McDermott L. and Redish, E. 1999. Resource Letter PER-1: *Physics Education Research American Journal of Physics* 67: 755-767.

McMurry, S. 1994. *Quantum Physics,*Wokingham: Addison-Wesley Pub, Co.

Miller, G.A. 1956 "The magic number seven plus or minus two: some limits on our capacity to process information". *Psychological Review* 63: 81–97.

Miller, M. 2006. Cognitive Load Theory. San Diego, California: San Diego State University, Retrieved on November 7, 2008 from the *Encyclopedia of Educational Technology Website: http://coe.sdsu.edu/eet/Articles/cogloadtheory/index.htm.*

Miller, R, C, and Hart, S. G. 1984. Assessing the subjective workload of directional orientation tasks. In *Twentieth Annual Conference on Manual Control* pp. 85-95. Washington, D.C.: NASA Conference Publication 2341.

Moreno, R., and Mayer, R. E. 1999. Cognitive principles of multimedia learning. *Journal of Educational Psychology*, 91:358-368.

Moreno, R. and Mayer, R. E. 2000. A coherence effect in multimedia learning: The case for minimizing irrelevant sounds in the design of multimedia instructional messages. *Journal of Educational Psychology*, 97: 117-125.

Moore, D. M., Burton, J. K., & Myers, R. J. 2004. Multiple-channel Communication: The theoretical and Research Foundations of Multimedia. D. H. Jonassen (Ed.), *Handbook of research on educational communications and technology*. 979-1005. Mahwah, N.J.: Lawrence Erlbaum.

Mousavi, S.Y., Low, R., and Sweller, J. 1995. Reducing cognitive load by mixing auditory and visual presentation modes. *Journal of Educational Psychology*, 87, 319-334.

Muller, D. A., & Sharma, M. D. 2005. Video Physics Education: Falling Cats and Terminal Velocity. *Paper presented at the Australian Institute of Physics: Physics for the Nation*, Canberra.

Muller, DA, Eklund, J. and Sharma, MD. 2006. “The future of multimedia learning: Essential issues for research Retrieved May 24, 2007, from http*://www.aare.edu.au/05pap/mul05178*

Najjar, L. J. 1998. Principles of educational multimedia user interface design, *Human Factors*, 41.2: 311-323.

Narayanan, N. H., and Hegarty, M. 2002. Multimedia design for communication of dynamic information. *International Journal of Human-Computer Studies*, 57: 279–315.

Neo, M & Neo, T. K. 2000. “Multimedia Learning: Using multimedia as a platform for instruction and learning in higher education”. *Proceedings of the Multimedia University International Symposium on Information and Communication Technologies 2000* (M2USIC’2000), PJ Hilton, October 5-6, 2000, S3-1.1 - 1.4.

Ng, K. H. & Komiya, R. 2000. Introduction of Intelligent Interface to Virtual Learning Environment. *Paper presented at the Multimedia University International Symposium on Information and Communication Technologies 2000 (M2USIC’2000),* October 5-6, 2000, Petaling Jaya, Malaysia.

Nigerian National Computer Policy. 1988. Federal Ministry of Education, Lagos, Nigeria

Obukhova, L. F., & Korepanova, I. A. 2009. The Zone of Proximal Development: A Spatiotemporal Model. *Journal of Russian & East European Psychology*, 47.6: 25-47. doi:10.2753/RPO1061-0405470602

Odogwu, H. 2000 Survey of Computer Education in Secondary Schools ASUU- UNILAG. *Journal of Contemporary Issues*, 1.1.

Ogundipe ,B.D (2004):The effects of peer-tutoring assisted instruction,class size and test anxiety on senior secondary students' achievement in physics. Unpublished Ph.D thesis. University of Ibadan.

Paas, F. and van Merrienboer, J. J. G. 1993. The efficiency of instructional conditions: An approach to combine mental-effort and performance measures. *Human Factors*, 354:737-743.

Paas, F. van Merriënboer, J. J. G., and Adam, J. J. 1994. Measurement of cognitive load in instructional research. *Perceptual and Motor Skills*, 79: 419-430.

Paas, F., Tuovinen, J. E., Tabbers, H. K., and Van Gerven, P. W. M. 2003. Cognitive load measurement as a means to advance cognitive load theory. *Educational Psychologist*, 38.1: 63–71.

Paivio, A. 1971. *Imagery and verbal processes*. New York: Holt.

Paivio, A. 1986. *Mental representation: A dual coding approach*. Oxford, England: Oxford University Press.

Paris, S. G., & Turner, J. C. 1994. Situated Motivation. In P. Pintrich, D. Brown & C. E. Weinstein (Eds.), *Student motivation, cognition, and learning: Essays in honor of Wilbert J. McKeachie*. Hillsdale, NJ: Lawrence Erlbaum.

Park, I., and Hannafin, M. J. 1994. Empirically-based guidelines for the design of interactive multimedia. *Educational Technology, Research and Development*, 41:66-85.

Piaget, J., 1983 "Piaget's theory". In P. Mussen (ed). *Handbook of Child Psychology*. 4th edition. Vol. 1. New York: Wiley.

Piaget, J., 2001. *Studies in Reflecting Abstraction*. Hove, UK: Psychology Press.

Piaget, J., & Inhelder, B. 1948. *The child's conception of space*. New York: Norton.

Pinker, S; Jackendoff, R .2005. "The faculty of language: what's special about it?". *Cognition* (Elsevier Science) 95.2: 201–236. doi:10.1016/j.cognition.2004.08.004. PMID 15694646.

Pollock, E. Chandler, P. and Sweller, J. 2002. Assimilating complex information. *Learning and Instruction*. 12:61-86.

Rebello NS, Cumaranatunge C, Escalada L, Zollman D, 1998. Simulating the spectra of light sources, *Computers in Physics*, 12: 28-33.

Rebello NS, Sushenko K, Zollman D, 1997. Learning the physics of the scanning tunnelling microscope using a computer program, *European Journal of Physics*, 18, 456-61.

Reimann, P. 2003. Multimedia learning: Beyond modality. *Learning and Instruction*, 13.2, 245-252.

Ridd, P. 2005. It's not rocket science. *The Australian*, 43.

Rieber, L. P. 1990. Animation in computer-based instruction. *Educational technology Research and Development*, 38:77-86.

Ryan, R. M., & Doci, E. L. 2000. Self-determination theory and the facilitation of intrinsic motivation, source development, and well-being. *American Psychologist*, 55: 68-78.

Santrock, J., 2008. A Topical Approach to Life Span Development. New York, NY: McGraw-Hill.

Salovey, P. and D.J. Sluyter. 1997..*Emotional development and emotional intelligence: Educational implications.* Basic Books.

Schaller, R. R. 1997. Moore's Law: Past, present, and future. *IEEE Spectrum*, 34.6:52-59.

Schwartz, D. L. & Black, J. B. (1996) Shuttling between depictive models and abstract rules: Induction and fallback. *Cognitive Science.* 20:457--497. Manifold sub-theories of "the two factors."

Semrau, P., & Boyer, B. A. 1994. Using interactive video in education. Boston: Allyn and Bacon.

Sequeira, M and Leite, L.(1991) “Alternative conceptions and history of science in physics teacher education” *Science Education* 75 (1) 45–56, DOI: 10.1002/sce.3730750105

Shah, P. and Miyake, A. 1996 The separability of working memory resources for spatial thinking and language processing: An individual differences approach, *Journal of Experimental Psychology: General*, 125, 4-27.

Shankar, R., 1994. Principles of Quantum Physics, 2nd Ed., New York: Plenum Press.

Shepard, R. N. 1978 Externalization of mental images and the act of creation, in B. S. Randawa and W. E. Coffman (eds), *Visual Learning, Thinking and Communication*. San Diego: Academic Press.

Shixun, Z. 1979. *Quantum physics tutorial*. Beijing: Higher Education Press.

Sims, V. K and Hegarty, M. 1997 Mental animation in the visual-spatial sketchpad: Evidence from dual-task studies, *Memory and Cognition*, 25, 321-332.

Smith, I. M. (1964). *Spatial ability: Its educational and social significance.* London: University of London Press.

Spearman, C. *Psychological Review*, Vol 27(3), May 1920, 159-172.doi: 10.1037/h0068562

Strayer, DL; Drews FA & Johnston WA (2003). "Cell phone induced failures of visual attention during simulated driving". *Journal of Experimental Psychology: Applied* 9.1: 23–32.doi:10.1037/1076-898X.9.1.23. PMID 12710835.

Sweller, J. 1998. Cognitive architecture and instructional design. *Educational Psychology Review* 10. 251-296.

Sweller, J. 1988. Cognitive load during problem solving: Effects on learning. *Cognitive Science*, 12. 257-285.

Sweller, J. and Chandler, P. 1994 Why some material is difficult to learn. *Cognition and Instruction*, 12:185-233.

Stefanou, C. R., Perencevich, K. C., DiCintio, M., & Turner, J. C. 2004. Supporting Autonomy in the Classroom: Ways of Teachers Encourage Student Decision Making and Ownership. *Educational Psychologist*, 39.2: 97-110.

Sweller, J. 1994. Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction*, 4:295-312.

Tan, O. S. 2000. Thinking Skills, Creativity and Problem-Based Learning. *Paper presented at the 2nd Asia Pacific Conference on Problem - Based Learning: Education Across Disciplines*, December 4-7, 2000, Singapore.

Tang Lijun. 2005. Multimedia teaching [J]. Jilin University Radio, 69: 1. UNSW *Cognitive Load Theory Conference* - Sydney Australia 24-26 March, 2007

Tharp, R and Gallimore, R. 1988. *Rousing Minds to Life*. Cambridge University Press.

Tinsley, R. & Lebak, K. 2009. Expanding the Zone of Reflective Capacity: Taking separate journeys together. *Networks, 11*.2.

Tomblin, JB and Zhang, X. 2006. "The dimensionality of language ability in school-age children". *Journal of Speech, Language, and Hearing Research* 49.6: 1193–1208. doi:10.1044/1092-4388(2006/086). PMID 17197490.

Van Gerven, Pascal W. M. 2003. The efficiency of multimedia learning into old age. *British journal of educational psychology*, 73.4: 489-505

Van Merriemboer J.J.G. and Paas F. 1993 "The efficiency of instructional conditions: an approach to combine mental effort and performance measures" *Human Factors* 35: 737-743

Van Merriënboer, J.J.G. and Sweller, J. 2005. Cognitive load theory and complex learning: Recent developments and future directions. *Educational Psychology Review*, 17.2: 147-177

Viennot, L, 1979. Spontaneous Reasoning in Elementary Dynamics, *European Journal of Science Education* 1, 205-221

Vygotsky, L.S. 1978. *Mind and society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

West African Examination Council, 2008. *Chief examiners' report (Nigeria)*, May/June 2008. Lagos: WAEC.

Weiner, B. 1990. History of Motivational Research in Education. *Journal of Educational Psychology*, 82(4), 646-622.

Wells, G. 1999. *Dialogic Inquiries in education: Building on the legacy of Vygotsky*. Cambridge: Cambridge University Press.

Wetzel, C. D., Radtke, P. H., & Stern, H. W. (1994). Instructional effectiveness of video media. Hillsdale, N.J.: Lawrence Erlbaum Associates.

Whitehead, A. 1929. Process and Reality. New York:The MacMillan Company.

Willingham, DT 2009. "Three problems in the marriage of neuroscience and education". *Cortex* (Elsevier Science) **45**.4: 544–545. doi:10.1016/j.cortex.2008.05.009. PMID 18644588.

Yang, E. M., Andre, T., and Greenbowe, T. Y. (2003). Spatial ability and the impact of visualisation/animation on learning electrochemistry. *International Journal of Science Education*, 25:329–349.

Zago, L; Pesenti, M; Mellet, E; Crivello, F; Mazoyer, B; Tzourio-Mazoyer, N (2001). "Neural correlates of simple and complex mental calculation". *Neuroimage* (Elsevier Science 2001) **13** .2: 314–327. doi:10.1006/nimg.2000.0697. PMID 11162272.

Zheng, R. and Zhou, B. (2006). Recency Effect on Problem Solving in Interactive Multimedia Learning. *Educational Technology & Society*, 9.2: 107-118.

Zaretskii, V. K. (November–December 2009). "The Zone of Proximal Development What Vygotsky Did Not Have Time to Write". *Journal of Russian and East European Psychology* **47** (1061–0405/2010 $9.50 + 0.00.): 70–93. doi:10.2753/RPO1061-0405470604. Retrieved 21 November 2011.

Zollman D, 2010. Learning Cycles in a Large Enrollment Class, *The Physics Teacher*, 28: 20-5.

INSTITUTE OF
EDUCATION
UNIVERSITY OF IBADAN

APPENDIX IA

INSTITUTE OF EDUCATION, UNIVERSITY OF IBADAN

QUANTUM PHYSICS PRE-TEST [QMPT]

1. The equation E= hν was deduced by: (a) Heisenberg (b) de Broglie (c) Einstein (d) Planck

2. The velocity of a photon is:
(a) Independent of its wavelength (b) Depends on its wavelength(c) Depends on its source (d) Equal to square of its amplitude

3. Which is not characteristic of Planck's quantum theory of radiation?
(a) Radiation is associated with energy
(b) Energy is not absorbed or emitted in whole number or multiples of quantum
(c) The magnitude of energy associated with a quantum is proportional to the frequency
(d) Radiation energy is neither emitted nor absorbed continuously but in small packets called quanta

4 . Light, a well known form of energy, is treated as a form of matter, by saying that it consists of:
(a) Photons or bundles of energy (b) Electrons or a wave like matter(c) Neutrons, since electrically neutral (d) None of the above

5. Which is not electromagnetic radiation? (a) Infrared rays (b) X-rays (c) Cathode rays (d) y-rays

6.Which wave property is directly proportional to energy of electromagnetic radiation:(a) Velocity (b) Frequency (c) Wave number (d) All of these

7. Photoelectric effect is the phenomenon in which:
(a) Photons come out of a metal when it is hit by a beam of electrons
(b) Photons come out of the nucleus of an atom under the action of an electric field
(c) Electrons come out of a metal with a constant velocity which depends on the frequency and intensity of incident light wave
(d) Electrons come out of a metal with different velocities not greater than a certain value which depends only on the frequency of the incident light wave and not on its intensity

8. Einstein's theory of photoelectric effect is based on:
(a) Newtons corpuscular theory of light
(b) Huygen's wave theory of light
(c) Maxwell's electromagnetic theory of light
(d) Planck's quantum theory of light

9. In photoelectric effect, the photo-current:
(a) Increases with increase of frequency of incident photon
(b) Decreases with increase of frequency of incident photon ~
(c) Does not depend on the frequency of photon but depends only on the intensity of incident light
(d) Depends both on intensity and frequency of the incident photon

10. In photoelectric effect the number of photo- electrons emitted is proportional to:
(a) Intensity of incident beam
(b) Frequency of incident beam
(c) Velocity of incident beam
(d) Work function of photo cathode

11. Increase in the frequency of the incident radiations increases the:
(a) Rate of emission of photo-electrons
(b) Work function
(c) Kinetic energy of photo-electrons
(d) Threshold frequency

12. Threshold wavelength depends upon:
(a) Frequency of incident radiation
(b) Velocity of electrons
(c) Work function
(d) None of the above

13. The study of photoelectric effect is useful in understanding:
(a) Conservation of energy
(b) Quantization of charge
(c) Conservation of charge
(d) Conservation of kinetic energy

14. The work-function for photoelectric effect:
(a) Depends upon the frequency of incident light
(b) Is same for all metals
(c) Is different for different metals
(d) None of the above

15 . Einstein's photoelectric equation states that $Ek = hv - W$. In this equation, Ek refers to:
(a) Kinetic energy of all ejected electrons
(b) Mean kinetic energy of emitted electrons
(c) Minimum kinetic energy of emitted electrons
(d) Maximum kinetic energy of emitted electrons

16. A photon is:
(a) A quanta of light (or electromagnetic) energy
(b) A quanta of matter
(c) A positively charged particle
(d) An instrument for measuring light intensity

17. Photoelectric effect can be caused by:
(a) Visible light but not by X-rays
(b) Gamma-rays but not by X-rays
(c) Ultraviolet light only
(d) Visible light, ultraviolet rays, X-rays and gamma rays also

18. If $E1$, $E2$ and $E3$ represent respectively the kinetic energies of an electron, an alpha particle and a proton each having same de Broglie wavelength then:

(a) E1>E3>E2 (b) E2>E3>E1 (c) E1 > E2> E3 (d) E1= E2= E3

19. The best metal to be used for photoemission is:
(a) Potassium (b) Sodium (c) Ceasium (d) Lithium

20. A quanta will have more energy if:
(a) The wavelength is larger
(b) The frequency is higher
(c) The amplitude is higher
(d) The velocity is lower

21. The minimum energy required to eject an electron from an atom is called:
(a) Kinetic energy (b) Electrical energy (c) Chemical energy (d) Work function

22. When light is directed at the metal surface, the emitted electrons:
(a) Are called photons
(b) Have random energies
(c) Have energies that depend upon intensity of light
(d) Have energies that depend upon the frequency of light

23. The photoelectric effect occurs only when the incident light has more frequency than a certain minimum:
(a) Frequency
(b) Wavelength
(c) Speed
(d) Charge

24. The Planck's constant has a unit of: (a) Work (b) Energy (c) Angular momentum (d) Linear momentum

25. In photoelectric emission the energy of the emitted electrons is:(a) Larger than that of incident photon (b) Smaller than that of incident photon(c) Same as that of incident photon (d) Proportional to intensity of incident light

26. When the frequency of light incident on a metallic plate is doubled, the KE of the emitted photoelectrons will be:(a) Doubled (b) Halved (c) Increased but more than doubled of the previous KE (d) Unchanged

27. The energy of electromagnetic radiation depends on:(a) Amplitude and wavelength (b) Wavelength (c) Amplitude (d) Temperature of medium through which it passes

28. The threshold frequency for photoelectric effect depends on the
(a) frequency of incident light (b) intensity of incident light (c) p.d. between the cathode and the anode (d) material of the photocathode

29. In which of the following is the photoelectric effect not applicable?
(a) Smoke detectors (b) Burglar Alarms (c) Movie soundtrack production (d) Transistors

30. The frequency of a green light is 6×10^{14} Hz. Its wavelength is:(a) 500 nm(b) 5 nm (c)50,000nm (d) None of these

31. The maximum wavelength of light that can excite an electron from first to third orbit of hydrogen atom is:(a) 487 nm (b) 170 nm (c) 103 nm (d) 17 nm

32. The specific charge of a proton is 9.6 x 10^{7}C kg^{-1}, then for an α-particles it will be:(a) 2.4 x 10^{7} Ckg^{-1} (b) 4.8x 10^{7} Ckg^{-1} (c) 19.2 x 10^{7} Ckg^{-1} (d) 38.4 x 10^{7} C Kg^{-1}

33. The work function for a metal is 4 eV. To emit a photo electron of zero velocity from the surface of the metal, the wavelength of incident light should be: (a) 2700 Å (b) 1700 Å (c) 5900 Å (d) 3100 Å

34. Ultraviolet light of 6.2 eV falls on aluminium surface (work function = 4.2 eV). The kinetic energy (in joule) of thefastest electron emitted is approximately: (a) 3 x 10^{-21} (b) 3 x 10^{-19} (c) 3 x 10^{-17} (d) 3 x 10^{-15}

35. The threshold wavelength for photoelectric effect on sodium is 5000 Å. Its work function is:(a) 4 x 10^{-19}J (b) 1 J (c) 2 x 10^{-19}(d) 3 x 10^{-10}J

36. Photons of energy 6 eV are incidented on a potassium surface of work function 2.1 eV. What is the stoppingpotential?(a) -6V (b) -2.1V (c) -3.9V (d) -8.1V

37. Suppose 10^{-17} J of light energy is needed by the interior of human eye to see an object. The photons of green light(λ = 550 nm) needed to see the object are: (a) 27 (b) 28 (c) 29 (d) 30

38. A photon of 300 nm is absorbed by a gas and then reemits two photons. One reemitted photon has wavelength496 nm, the wavelength of second reemitted photon is:(a) 757 (b) 857 (c) 957 (d) 657

39. An atom emits energy equal to 4x 10^{-12} erg. To which part of electromagnetic spectrum it belongs:(a) UV region (b) Visible region (c) IR region (d) Microwave region

40. The energy Δ E corresponding to intense yellow line of sodium of λ=589 nm is:(a) 2.10 eV (b) 43. 37 eV (c) 47.12 eV (d) 2.11 kcal

41. The momentum of a photon of frequency 5 x 10^{17}s^{-1} is nearly:(a) 1.1 x 10^{-24} kg ms^{-1} (b) 3.33 x 10^{-43} kg ms^{-1} (c) 2.27 x 10^{-40}kg ms^{-1} (d) 2.27 x 10^{-38}kg ms^{-1}

42. In a photocell, light energy is converted to (a) electrical energy (b) chemical energy (c) heat energy (d) mechanical energy

43. When a metal surface is irradiated, photoelectrons may be ejected from the metal. The kinetic energy of the ejected electrons depends on the
(a) Source of radiation (b) Intensity of radiation (c) amplitude of radiation (d) Frequency of radiation

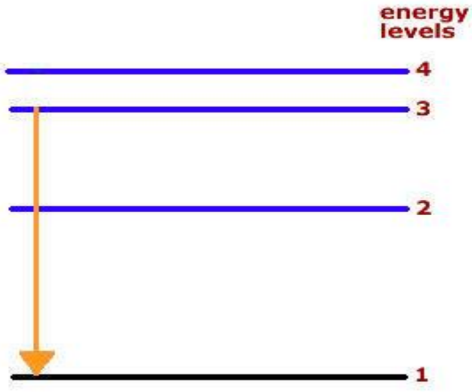
44. The Kinetic Energy of a photoelectron ejected from a metal surface illuminated with radiation depends on the
(I) Wavelength of the radiation
(II) intensity of the radiation
(III) source of the radiation
(IV) nature of the surface
I only b) I and IV only c) II and III only d) I,II and IV only

45. Protons have ___ charge, neutrons have ___ charge, and electrons have ___ charge.
(a) negative; positive; no
(b) positive; no; negative
(c) positive; negative; no
(d) negative; no; positive

46. In the photoelectric effect, electromagnetic rays incident upon a metallic surface can result in electrons being emitted from the metal. Which of the following will result in more electrons being emitted per second?
(a) Using a different metal
(b) Using the same intensity of radiation but of a shorter wavelength
(c) Using the same intensity of radiation but of a greater frequency
(d) Using more intense radiation of the same wavelength

47. Put the following in order of increasing energy.
(a) the energy of one photon of an ultra violet lamp.
(b) the energy of one photon of a gamma ray.
(c) the energy of one photon of a microwave.
(a) a then b then c
(b) a then c then b
(c) c then a then b
(d) b then a then c

48. If the speed of light is c and Planck's constant is h, what is the wavelength of electromagnetic radiation produced if an electron makes a transition from a higher energy level, E2, to a lower one, E1?
(a) $\frac{hc}{(E_2 - E_1)}$ (b) $\frac{hc}{(E_1 - E_2)}$ (c) $\frac{E_2 - E_1}{hc}$ (d) $\frac{h(E_2 - E_1)}{c}$



49. The diagram shows four electron energy levels in an atom. The transition of an electron from level 3 to level 1 as shown in the diagram produces a photon in the visible light range. Which transition is most likely to produce a photon in the ultra-violet range?
(a) level 2 to level 1 (b) level 4 to level 1 (c) level 3 to level 2 (d) level 4 to level 2

50. In the photoelectric effect, When the frequency of the incident light is increased, the number of released photons
(a) increases (b) becomes excited (c) decreases (d) does not change

51. In the photoelectric effect, when the frequency of the incident light is increased the energy of the released photons
(a) Increases (b) becomes excited (c) decreases (d) does not change

52. In the photoelectric effect, when the brightness of the incident light is decreased, the number of released photons
(a) Increases (b) becomes excited (c) decreases (d) does not change

53. In the photoelectric effect, when the brightness of the incident light is decreased, the energy of the released photons
(a) increases (b) becomes excited (c) decreases (d) does not change

54. Which of the following expressions depicts Eistein's conversion of matter into energy
(a) $E= \Delta mc$ (b) $E=\Delta mc^2$ (c) $E=h\lambda$ (d) $E=h\lambda^2$

The transitions occur between the following energy levels
n= 5: -.54ev
n=4: -.85ev
n=3: -1.5ev
n=2: -3.4ev
n=1: -13.6ev

55. Which transition will produce photons of the greatest energy?
(a) 1 to 2 (b) 1 to 3 (c) 1 to 4 (d) 1 to 5

56. Which transition will produce photons of the greatest wavelength?
(a) 1 to 2 (b) 1 to 3 (c) 1 to 4 (d) 1 to 5

57. Electromagnetic waves consists of a stream of energy particles called
(a) electrons (b) protons (c) photons (d) quanta

58. The strength of current produced during photo electricity is proportional to
(a) Intensity of incident rays (b) Kinetic energy of incident rays (c) Potential energy of incident rays (d) frequency of incident rays

59. A bombarding electron has energy 8.8.eV. To what level will the mercury atom be excited? (assuming the ionization energy of mercury is 10.4eV)
(a) 1 (b) 2 (c) 3 (d) 4

60. The threshold frequency for lithium is 5.5×10^{14} Hz. Calculate the work function for lithium, if a lithium surface is illuminated by light of wavelength 450nm, calculate E*k(max)* of the emitted photoelectrons. (Take $1eV=1.6 \times 10^{-19}J$, $1nm=10^{-9}$)
(a)0.49 eV (b) 0.69eV (c) 0.99eV (d)1.09eV

APPENDIX IB
RELIABILITY CO-EFFICIENT FOR QUANTUM PHYSICS PRE-TEST

Case Processing Summary

		N	%
Cases	Valid	42	100.0
	Excluded(a)	0	.0
	Total	42	100.0

a Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.782	60

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
ITEM01	36.7381	52.735	.335	.775
ITEM02	36.8095	51.914	.443	.772
ITEM03	36.7381	51.710	.482	.770
ITEM04	36.7857	55.099	.006	.786
ITEM05	36.5238	54.938	.051	.783
ITEM06	36.7381	52.930	.307	.776
ITEM07	36.7381	52.198	.411	.773
ITEM08	36.7381	52.393	.384	.774
ITEM09	36.3571	55.552	-.077	.783
ITEM10	36.4048	55.369	-.010	.783
ITEM11	36.8333	52.289	.390	.773
ITEM12	36.8333	53.362	.241	.778
ITEM13	36.5238	54.060	.202	.779
ITEM14	36.4524	54.351	.194	.780
ITEM15	36.5952	56.198	-.150	.789
ITEM16	36.8571	53.101	.277	.777
ITEM17	36.8571	53.394	.237	.778
ITEM18	36.3810	55.168	.057	.782
ITEM19	36.4286	54.544	.175	.780
ITEM20	36.4286	55.373	-.014	.784
ITEM21	36.7381	54.881	.037	.785
ITEM22	36.8571	53.882	.170	.781
ITEM23	36.8333	54.484	.088	.783
ITEM24	36.5000	54.256	.180	.780
ITEM25	36.5238	54.695	.093	.782
ITEM27	36.7381	51.808	.468	.771
ITEM28	36.7143	52.258	.408	.773
ITEM29	36.8571	51.150	.552	.768
ITEM30	36.6429	53.162	.296	.777

ITEM31	36.6905	53.292	.264	.778
ITEM32	36.9286	51.970	.444	.772
ITEM33	36.8571	51.589	.489	.770
ITEM34	36.8095	50.987	.576	.767
ITEM35	36.5238	53.865	.236	.779
ITEM36	36.5952	54.198	.153	.781
ITEM37	36.8095	52.792	.320	.776
ITEM38	36.8571	55.247	-.014	.786
ITEM39	36.8571	53.150	.270	.777
ITEM40	36.5238	53.914	.227	.779
ITEM41	36.5000	54.890	.065	.783
ITEM42	36.9286	54.019	.155	.781
ITEM43	36.9524	54.242	.126	.782
ITEM44	36.9524	52.876	.319	.776
ITEM45	36.6429	53.113	.303	.776
ITEM46	36.5476	54.839	.063	.783
ITEM47	36.7619	53.503	.224	.779
ITEM48	36.9524	53.510	.229	.779
ITEM49	36.9048	52.674	.340	.775
ITEM50	36.6429	54.918	.038	.784
ITEM51	36.6905	57.243	-.283	.794
ITEM52	36.5476	54.351	.143	.781
ITEM53	36.6667	53.496	.240	.778
ITEM54	36.8810	53.961	.160	.781
ITEM55	36.7857	54.807	.045	.785
ITEM56	36.8571	54.955	.025	.785
ITEM57	36.6429	54.479	.101	.782
ITEM58	36.5952	52.979	.343	.775
ITEM59	36.9286	53.775	.189	.780
ITEM60	36.8810	54.937	.028	.785
ITEM26	36.7857	54.075	.144	.781

INSTITUTE OF EDUCATION
UNIVERSITY OF IBADAN
IBADAN, NIGERIA

APPENDIX IIA

ABSTRACT REASONING TEST [SRT]

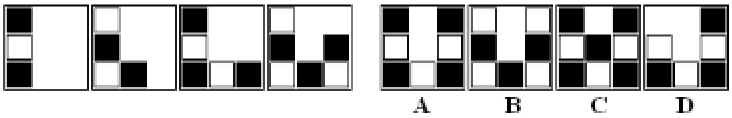
Dear Respondent,

This is a test to measure your ability to perceive relationships and then to work out any co-relationships without you requiring any knowledge of language or mathematics. Abstract reasoning tests use diagrams, symbols or shapes instead of words or numbers. They involve identifying the underlying logic of a pattern and then determining the solution. Because they are visual questions and are independent of language and mathematical ability, they are considered to be an accurate indicator of your general intellectual ability as well as being 'culturally fair'

INSTRUCTIONS:

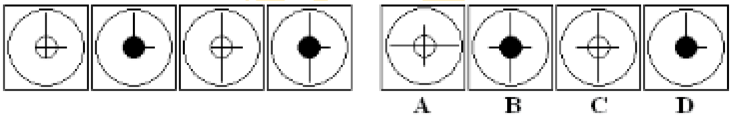
1. *Answer as many items as possible in 20mins*
2. *Circle the letter on the right which corresponds to the correct answer.*
3. *Do not CIRCLE more than one OPTION in same item*

1) Which figure completes the series?



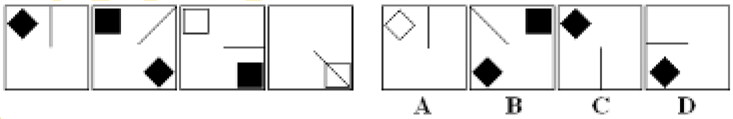
A B C D

2) Which figure completes the series?



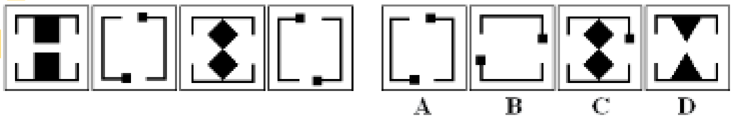
A B C D

3) Which figure completes the series?



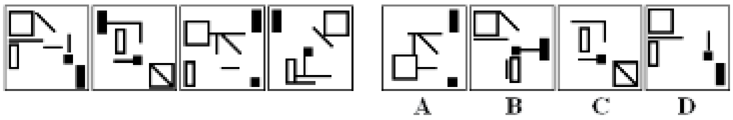
A B C D

4) Which figure completes the series?



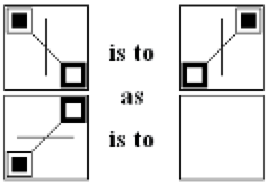
A B C D

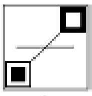
5) Which figure completes the series?

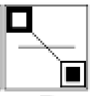


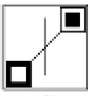
A B C D

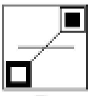
6) Which figure completes the statement?




A

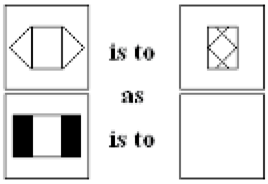

B

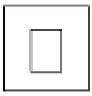

C

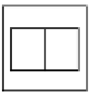

D

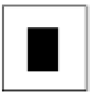
A B C D

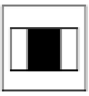
7) Which figure completes the statement?




A

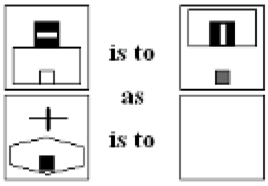

B

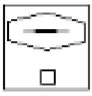

C

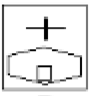

D

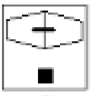
A B C D

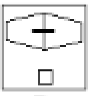
8) Which figure completes the statement?




A

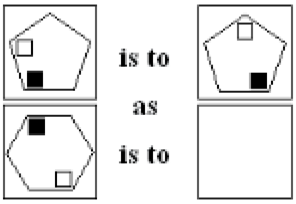

B

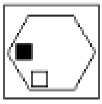

C

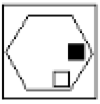

D

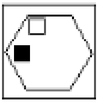
A B C D

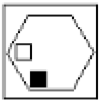
9) Which figure completes the statement?




A

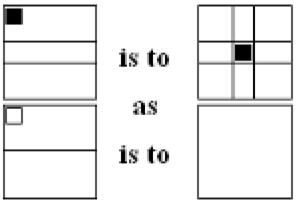

B

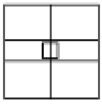

C

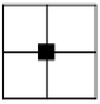

D

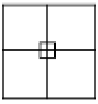
A B C D

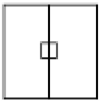
10) Which figure completes the statement?




A

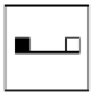

B

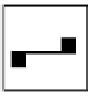

C

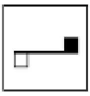

D

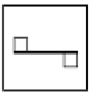
A B C D

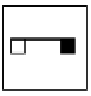
11) Which figure is the odd one out?


A


B

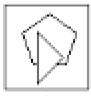

C

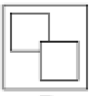

D

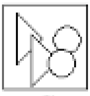

E

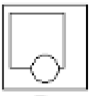
A B C D E

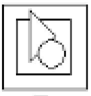
12) Which figure is the odd one out?


A


B

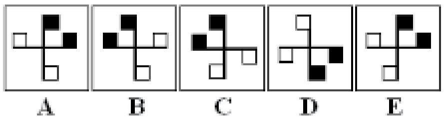

C


D


E

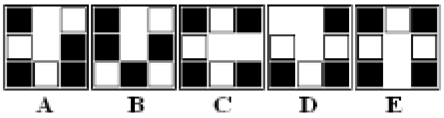
A B C D E

13) Which figure is the odd one out?



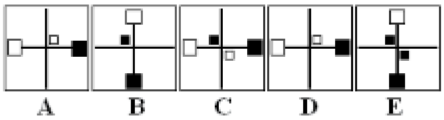
A B C D E

14) Which figure is the odd one out?



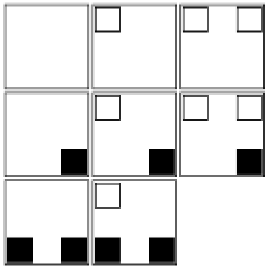
A B C D E

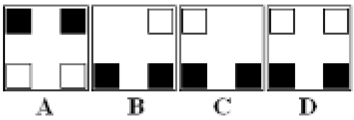
15) Which figure is the odd one out?



A B C D E

16) Which figure completes the series?

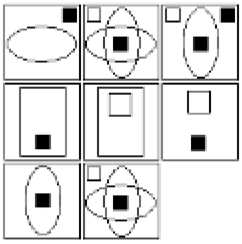


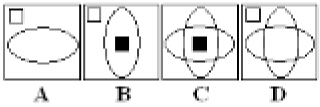


A B C D

17)) Which figure completes the series?

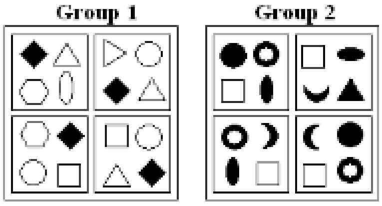
A B C D

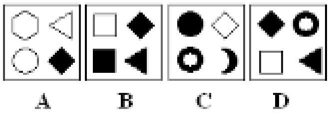




18) Which figure belongs in neither group?

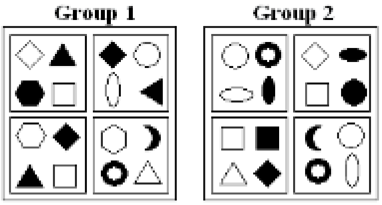
A B C D

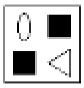


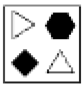


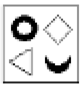
19) Which figure belongs in neither group?

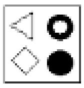
A B C D




A

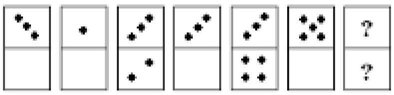

B

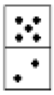

C

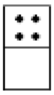

D

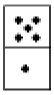
20) Which figure is next in the series?

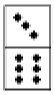
A B C D




A

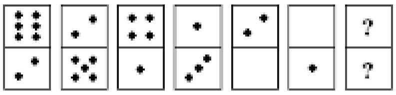

B

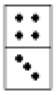

C

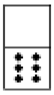

D

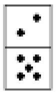
21) Which figure is next in the series?

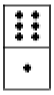
A B C D



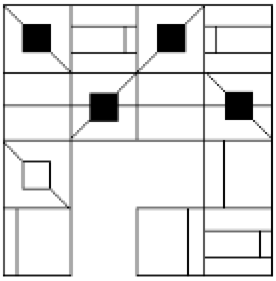

A

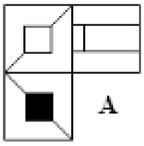

B

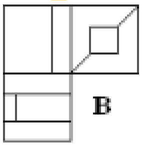

C

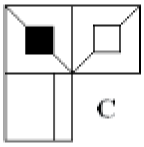

D

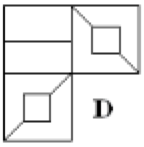
22) Which figure completes the grid?




A


B

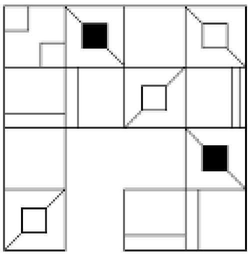

C

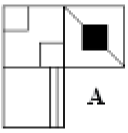

D

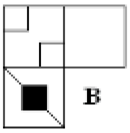
A B C D

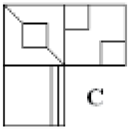
23) Which figure completes the grid?

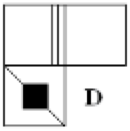
A B C D



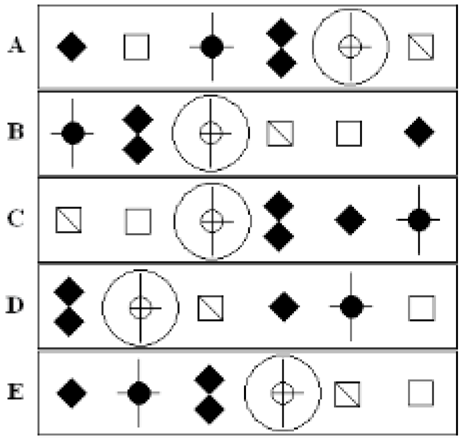

A


B


C

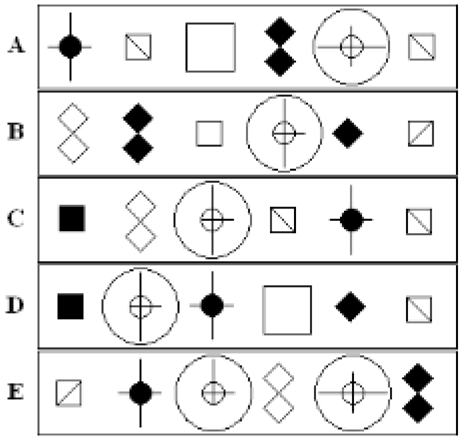

D

24) Which figure is the odd one out?



A B C D E

25) Which figure is the odd one out?



A B C D E

APPENDIX IIB

RELIABILITY CO-EFFICIENT FOR ABSTRACT REASONING ABILITY TEST

Case Processing Summary

		N	%
Cases	Valid	42	93.3
	Excluded(a)	3	6.7
	Total	45	100.0

a Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.620	25

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
ITEM01	12.2381	25.942	.305	.603
ITEM02	12.1429	27.443	-.022	.629
ITEM03	11.9762	26.316	.194	.611
ITEM04	11.8810	25.620	.350	.599
ITEM05	12.0238	24.804	.498	.585
ITEM06	11.8810	25.229	.433	.592
ITEM07	12.0000	26.976	.065	.622
ITEM08	11.7143	26.063	.333	.603
ITEM09	11.9286	25.044	.459	.589
ITEM10	11.8810	24.546	.581	.579
ITEM11	12.0952	24.625	.543	.582
ITEM12	12.1429	24.613	.557	.581
ITEM13	11.9286	26.068	.248	.607
ITEM14	11.9286	25.629	.337	.600
ITEM15	11.5714	18.885	.162	.726
ITEM16	12.0714	25.970	.263	.606
ITEM17	12.1905	26.256	.223	.609
ITEM18	12.1667	26.289	.211	.610
ITEM19	12.1429	27.491	-.031	.629
ITEM20	12.1905	26.646	.142	.616
ITEM21	12.0952	27.210	.021	.625
ITEM22	12.1429	27.930	-.115	.636
ITEM23	12.1429	26.906	.083	.620
ITEM24	12.0952	26.771	.106	.619
ITEM25	12.0000	26.049	.246	.607

INSTITUTE OF EDUCATION
UNIVERSITY OF IBADAN
IBADAN, NIGERIA

APPENDIX IIIA

SPATIAL REASONING TEST [SRT]

Dear Respondent,

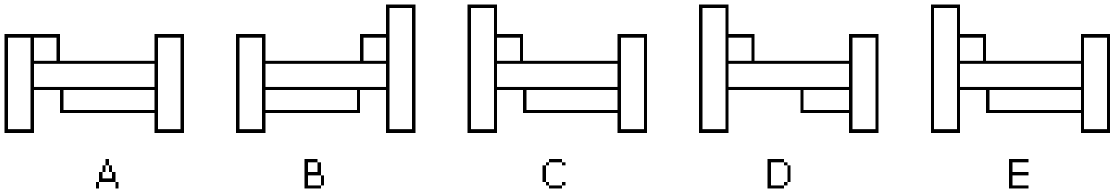
This is a test to measure your ability to think visually and solve spatial problems in two and three dimensions. It contains items such as shape matching, group rotation, shapes combination, views in 2 and 3dimensions, maps and plans.

INSTRUCTIONS:

1. ***Answer as many items as possible in 15mins***
2. ***Shade the correct option in the box supplied in the answer sheet***
3. ***Do not shade more than one box in same item***

Example:

Which two pictures are identical?



a) A and D b) B and E c) C and E d) D and E

Answer

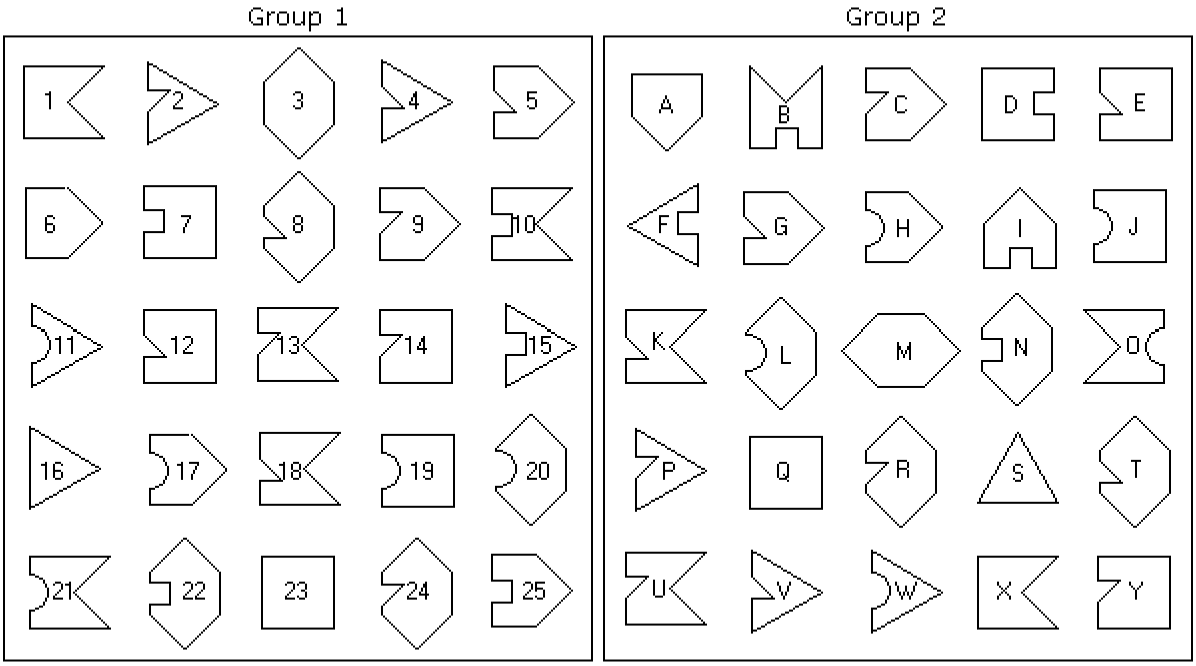
c) C and E are the only two pictures which are identical

Answer as many items as possible in 15mins

[1-25] *Below are two groups of simple, flat objects. Find pairs that are exactly the same size and shape. Each group has about 25 small drawings of these 2-dimensional objects. The objects in the first group are labeled with numbers [1-25] and are in numerical order. The objects in the second group are labeled with letters [A-Y] and are in random order. Each drawing in the first group is exactly the same as a drawing in the second group. The objects in the second group have been moved and some have been rotated.*

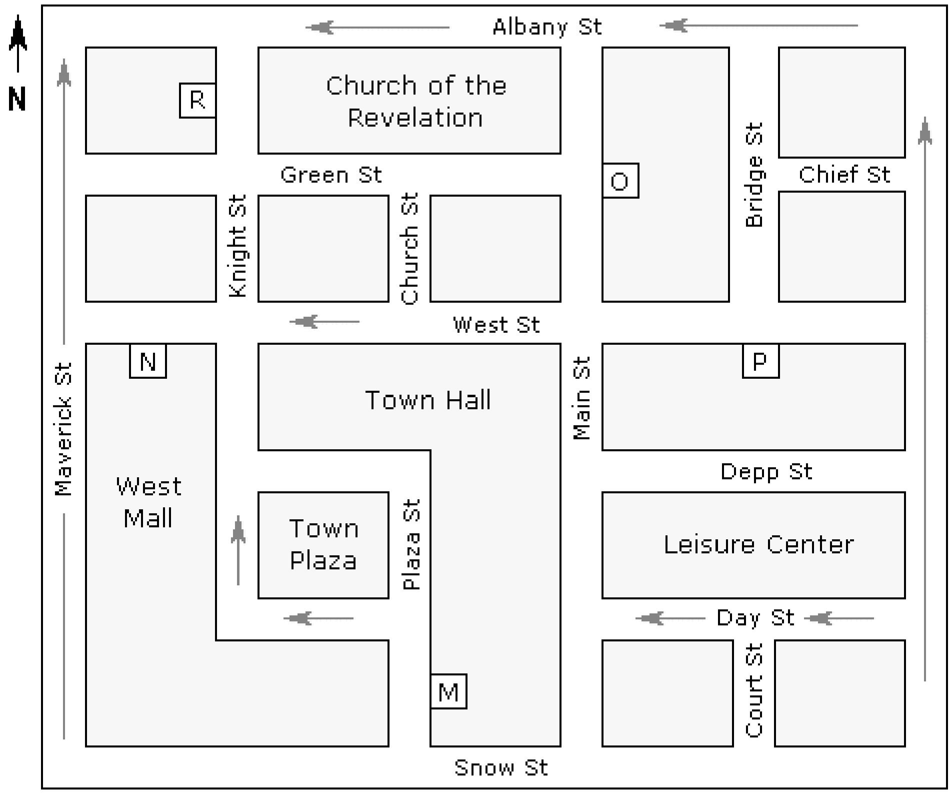
Spatial matching

Which shape in Group 2 corresponds to the shape in Group 1?



Spatial Locating

[26-28] *Study the map extract and answer questions 26-28*



[26] **Susan is in Depp St and can see the Town Hall to her right. What direction is she facing?**

a) North b) South c) East d) West

[27] **She turns and walks to the junction with Main St. She turns left and proceeds two blocks before turning right, then taking the next right, and walking half a block. Which location is nearest to her current position?**

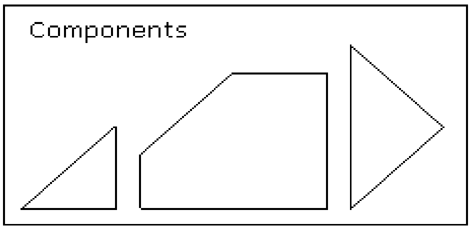
a) M b) N c) R d) P

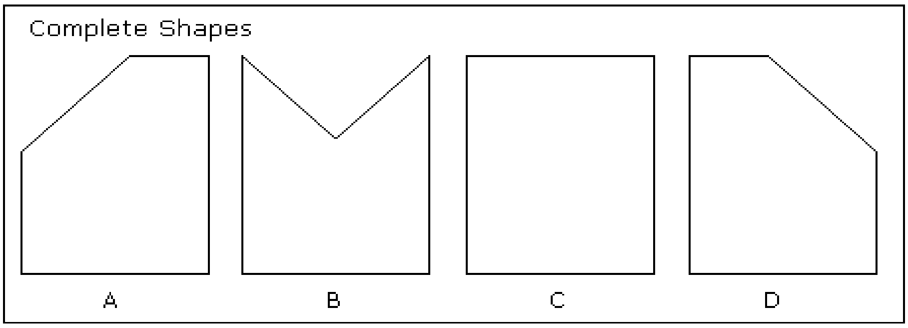
[28] **Ade starts from location 'N' and proceeds as follows: right onto West St - heading East, fourth left - heading North, first right - heading East, first right - heading South, third right – heading West. He proceeds West for one block. Where is location 'P' in relation to his current position?**

a) North b) South East c) North East d) North West

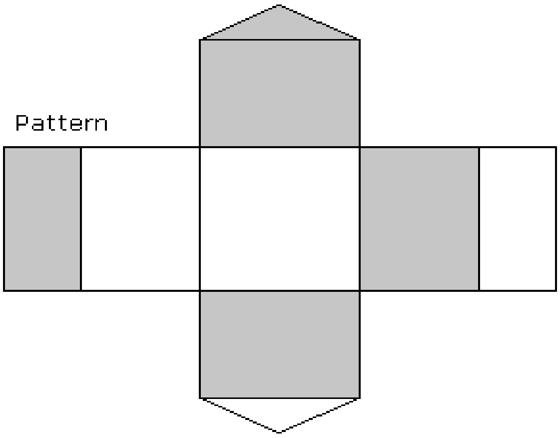
Spatial orientating

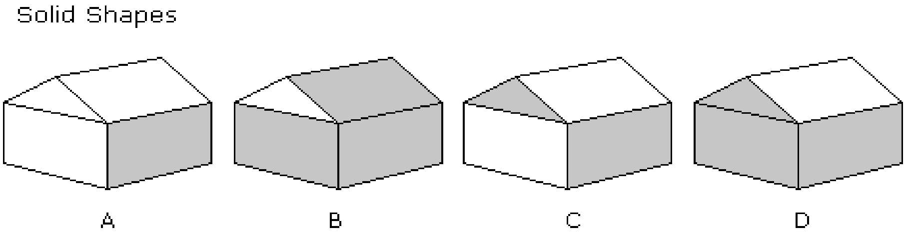
[29] **The 2-dimensional shapes below that have been cut-up into pieces. Match the pieces to the shape that they came from. Which of the complete shapes can be made from the components shown?**





[30] **Which of the solid shapes shown could be made from the pattern?**





APPENDIX IIIB

RELIABILITY CO-EFFICIENT FOR SPATIAL REASONING ABILITY TEST

Case Processing Summary

		N	%
Cases	Valid	42	100.0
	Excluded(a)	0	.0
	Total	42	100.0

a Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.740	30

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
ITEM01	15.3333	24.179	.258	.733
ITEM02	15.3095	24.756	.140	.740
ITEM03	15.2381	24.527	.190	.737
ITEM04	15.2619	24.100	.276	.732
ITEM05	15.3095	23.634	.372	.726
ITEM06	15.1667	24.093	.292	.731
ITEM07	15.3095	24.024	.290	.731
ITEM08	15.3810	23.949	.310	.729
ITEM09	15.3810	24.144	.269	.732
ITEM10	15.3571	24.723	.148	.739
ITEM11	15.4048	23.710	.364	.726
ITEM12	15.3333	23.203	.464	.720
ITEM13	15.3333	24.813	.129	.740
ITEM14	15.2143	25.246	.045	.745
ITEM15	15.2381	23.503	.405	.724
ITEM16	15.2857	24.404	.212	.735
ITEM17	15.1429	24.077	.302	.730
ITEM18	15.0952	24.088	.317	.729
ITEM19	15.1905	24.792	.140	.739
ITEM20	15.5238	25.914	-.087	.751
ITEM21	15.2619	23.564	.389	.725
ITEM22	15.3333	23.935	.309	.729
ITEM23	15.3810	24.193	.259	.733
ITEM24	15.1190	23.620	.413	.724
ITEM25	15.2381	23.893	.322	.729
ITEM27	15.4286	25.373	.021	.746
ITEM28	15.1667	24.093	.292	.731
ITEM29	15.3095	23.926	.310	.729
ITEM30	15.3571	24.138	.268	.732
ITEM26	15.0714	24.848	.152	.738

INSTITUTE OF
EDUCATION
UNIVERSITY OF IBADAN

APPENDIX IVA

COGNITIVE LOAD TEST [CLT] RECORD SHEET

Dear Respondent,

The following test explores your memory capacity under cognitive load by distracting you between remembering and reproducing. These items are measured in terms the largest meaningful unit you can recognize.

Your Task: *Remembering a fixed set of arbitrary digits*.

You will be shown a set of N arbitrary digits in sequence. Try to remember all digits. After this the script will distract you by asking you to solve some simple arithmetic problems. Afterwards it will ask you to reproduce all digits in correct order. N shall be increased to see how many digits you can reproduce reliable.

Record the answers to the simple arithmetic problems in the boxes underneath the numbers

N=5	1	2	3	4	5
Simple arithmetic					
Problems answer					

REPRODUCE DIGITS IN CORRECT ORDER ___ ___ ___ ___ ___

N=6	1	2	3	4	5
Simple arithmetic					
Problems answer					

REPRODUCE DIGITS IN CORRECT ORDER ___ ___ ___ ___ ___ ___

N=7	1	2	3	4	5
Simple arithmetic					
Problems answer					

REPRODUCE DIGITS IN CORRECT ORDER ___ ___ ___ ___ ___ ___ ___

N=8	1	2	3	4	5
Simple arithmetic					
Problems answer					

REPRODUCE DIGITS IN CORRECT ORDER

___ ___ ___ ___ ___ ___ ___ ___

N=9	1	2	3	4	5
Simple arithmetic					
Problems answer					

REPRODUCE DIGITS IN CORRECT ORDER

___ ___ ___ ___ ___ ___ ___ ___ ___

APPENDIX IV B

RELIABILITY CO-EFFICIENT FOR COGNITIVE LOAD TEST

Case Processing Summary

		N	%
Cases	Valid	42	100.0
	Excluded(a)	0	.0
	Total	42	100.0

a Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.890	60

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
ITEM01	43.5238	102.548	.416	.888
ITEM02	43.6429	101.552	.423	.888
ITEM03	43.5238	102.695	.394	.888
ITEM04	43.6667	103.350	.207	.890
ITEM05	43.5000	102.841	.413	.888
ITEM06	43.5238	102.548	.416	.888
ITEM07	43.5714	101.714	.468	.888
ITEM08	43.7381	100.247	.517	.887
ITEM09	43.4286	103.909	.472	.889
ITEM10	43.5000	102.841	.413	.888
ITEM11	43.7143	102.453	.290	.889
ITEM12	43.6429	104.528	.080	.891
ITEM13	43.6667	101.447	.421	.888
ITEM14	43.5000	103.085	.372	.889
ITEM15	43.5000	103.963	.225	.890
ITEM16	43.1667	102.630	.013	.911
ITEM17	43.7143	104.014	.124	.891
ITEM18	43.6905	101.682	.382	.888
ITEM19	43.6667	102.520	.300	.889
ITEM20	43.4762	102.987	.447	.888
ITEM21	43.6905	101.926	.356	.889
ITEM22	43.8333	102.533	.260	.890
ITEM23	43.7619	103.113	.210	.890
ITEM24	43.6190	100.681	.548	.887
ITEM25	43.6190	101.803	.411	.888
ITEM27	43.5000	104.988	.056	.891
ITEM28	43.6667	102.520	.300	.889
ITEM29	43.7619	100.479	.484	.887
ITEM30	43.5952	101.222	.505	.887
ITEM31	43.5476	102.888	.335	.889
ITEM32	43.6429	101.455	.435	.888

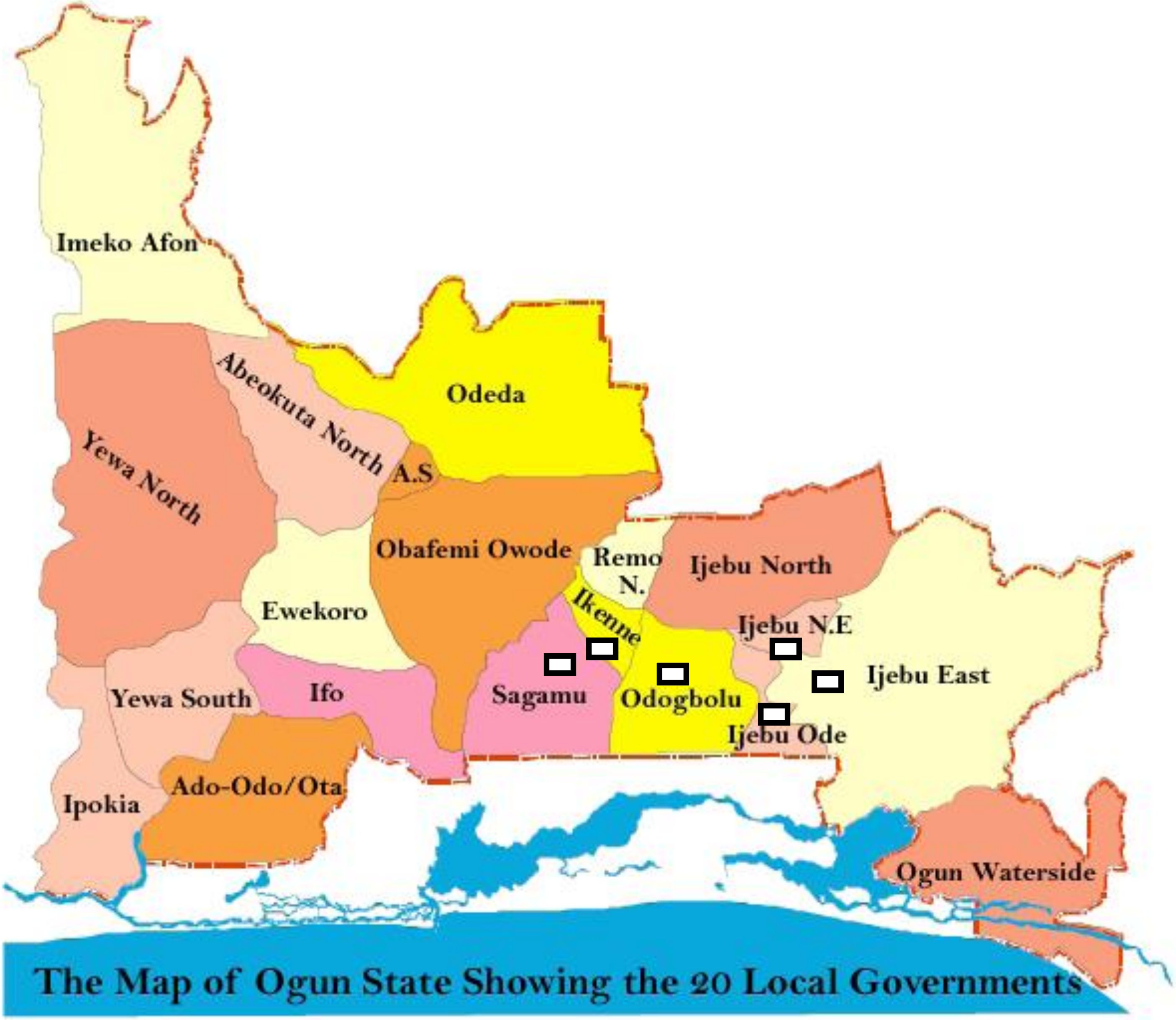
ITEM33	43.7143	100.551	.495	.887
ITEM34	43.8333	99.459	.571	.886
ITEM35	43.7619	100.576	.474	.887
ITEM36	43.5238	102.402	.438	.888
ITEM37	43.5714	102.641	.345	.889
ITEM38	43.8571	101.199	.391	.888
ITEM39	43.8333	100.435	.471	.887
ITEM40	43.7143	101.721	.368	.888
ITEM41	43.5000	104.354	.161	.890
ITEM42	43.7143	101.429	.400	.888
ITEM43	43.8571	99.930	.520	.886
ITEM44	43.8810	98.546	.659	.885
ITEM45	43.7619	100.088	.525	.886
ITEM46	43.4762	104.938	.077	.891
ITEM47	43.6667	104.081	.125	.891
ITEM48	43.8571	101.735	.337	.889
ITEM49	43.8333	100.923	.422	.888
ITEM50	43.6905	101.487	.404	.888
ITEM26	43.5952	103.954	.161	.891
ITEM51	43.5000	104.354	.161	.890
ITEM52	43.7381	102.149	.315	.889
ITEM53	43.9524	99.851	.528	.886
ITEM54	43.9762	98.463	.674	.884
ITEM55	43.8571	100.028	.510	.887
ITEM56	43.4762	104.938	.077	.891
ITEM57	43.6905	104.512	.075	.892
ITEM58	43.8810	102.156	.294	.889
ITEM59	43.8571	101.345	.377	.888
ITEM60	43.7143	101.916	.347	.889

APPENDIX V

QUANTUM PHYSICS TABLE OF SPECIFICATION

	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation	Total
Physics of light	7	5	-	2			14
Photoelectric Effect	8	4	2	5			19
Energy Quanta	4	3	6	2			15
Atomic Physics	3	5	1	3			12
Total	22	17	9	12	-	-	60

APPENDIX V



The Map of Ogun State Showing the 20 Local Governments

▭ = Locations on the map where sample schools where selected from