Design of Cognitive Driven Adaptive e-Learning Environment using Individual Differences

Ph.D. Thesis

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DECLARATION

I sincerely declare that this thesis neither as a whole nor as part thereof has been copied out from any source. It is further declared that I have completed this thesis entirely on the basis of my personal effort, made under the sincere guidance of my supervisors. I also declare that the work presented in this report has not been submitted in support of any other application or degree or qualification in any other University or Institute.

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DEDICATION

This work is dedicated to my parents especially to my late Mother and family who always prayed, encouraged and supported me to achieve this endeavor.

ABSTRACT

The educational system of Pakistan surrounds with several problems. Among them, the most alarming issue is the poor learning outcomes of students. The predominant cause of such worst condition is weak traditional learning environment. To cater chronic educational issues the world around us strongly rely on technology because E-learning is being considered as widely recognized alternative to handle the shortcomings of traditional learning environment. Adaptive Educational Systems (AESs) are specialized class of e-learning which aimed to deliver individualized learning experience. The AESs integrate learner’s individual characteristics with the help of user modeling techniques to impart instruction to each individual in accordance to his/her learning needs. Numerous AESs have already been developed in the pursuit of quality learning experience. These systems consider single aspect of learner such as learning styles. The success rate of such systems is reasonably low as their impact in terms of improving learning outcomes is still unclear. The researchers affirmed that considering a single aspect of learner is not enough to positively impact the learning process. It is therefore suggested to conduct further research considering other effective parameters along with learning styles. In this thesis, an adaptive learning system is being proposed considering combination of multiple sources of personalization including prior knowledge, Working Memory Capacity (WMC) and learning styles.

An experiment has been conducted using sample size of (184) students to evaluate the impact of proposed approach in comparison to traditional learning environment. The student sample was equally divided into control and experimental groups. The control and experimental groups further consisted of subgroups formed on the basis of learners cognitive and non-cognitive characteristics identified using standard instruments. The experimental subgroups learned the subject contents with proposed adaptive learning system whereas control subgroups learned in traditional classroom environment. The results revealed that participants of experimental subgroups outperformed in terms of learning outcomes and learning efficiency than their counterparts of control subgroups.

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LIST OF ABBREVIATIONS

ICT	-	Information & Communication Technology
TLM	-	Teaching Learning Material
HCI	-	Human Computer Interaction
ITSs	-	Intelligent Tutoring Systems
AESs	-	Adaptive Educational Systems
AEHS	-	Adaptive Educational Hypermedia System
DM	-	Domain Model
SM	-	Student Model
AM	-	Adaptive Model
LS	-	Learning Style
CS	-	Cognitive Style
FSLSM	-	Felder Silverman Learning Style Model
PK	-	Prior Knowledge
WMC	-	Working Memory Capacity
ANN	-	Artificial Neural Network
BN	-	Bayesian Network
AR	-	Adaptive Rules
AE	-	Adaptive Engine
CAL	-	Computer Aided Learning
LMS	-	Learning Management System
ASSIST	-	Approaches and Study Skills Inventory for Students
WMTB-C	-	Working Memory Test Battery for Children
CLC	-	Collection of Learning Contents
SCH	-	Student Characteristics
ID	-	Individual Differences
NCC	-	Non Cognitive Characteristics

LIST OF PAPERS

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CHAPTER 1

INTRODUCTION

In this chapter, an overview of Adaptive Educational Systems (AESs) is provided as well as problem statement of this thesis and motivation of research study is discussed. Furthermore, the hypotheses are depicted and structure of thesis is defined.

Adaptive educational systems (AESs) are the most advanced form of educational software. It is a multidisciplinary research area which encompasses the interaction of different fields including education, cognitive science and computer science. Thus the design of such systems based on learning theories, educational psychology, domain knowledge and techniques related to Human Computer Interaction (HCI), machine learning and artificial intelligence. These systems attempt to dynamically modify behavior according to the changing state of learner in order to satisfy his/her individual learning needs. In general, the AESs are shown effective in imparting positive learning experience. Existing AESs have mainly focused on learning styles to provide adaptation effect. Previous research placed little emphasizes to take into account multiple learner characteristics for adaptive learning.

Learning is a complex process and requires involvement of different individual characteristics of learner to fully understand the subject matter. Literature reported various individual characteristics including cognitive and non-cognitive which make learners distinct from each other and played an important role in their learning. Specifically, the potential combination of cognitive and non-cognitive characteristics could have positive impact on student’s learning progress. Hence, incorporating combination of cognitive and non-cognitive characteristics in the design of learning content and in the development of AESs may reduce learning difficulties and improve learning outcomes.

1.1 Motivation

This research is conducted particularly considering educational perspectives of Pakistan. The Annual Statistics of Educational Report, 2013 (ASER) point out that school education sector of Pakistan surrounds with many serious issues. Among them the most depressing is the falling learning levels. The major cause behind falling learning outcomes is the shortage of teachers. It is confirmed by Pakistan Educational Statistics (2010-2011) that the teaching staff is low in public schools. Secondly, the teachers in public schools especially in rural areas of the country hold poor qualifications and teaching skills. The teaching function in public schools is not properly performed as the instruction predominantly imparted through oral communication and/or by reading poorly designed learning material. Conversely, if teaching function is being performed properly still traditional environment has some limitations. For example, teachers usually deliver an optimized instruction bearing in mind the general learning needs, preferences and capacities of students. In traditional setting, it is difficult for teacher to impart individualized instruction to the large number of students. It is not possible for teacher to keep pace of class considering the pace of each individual hence the performance of learners could be effected.

There is also dearth of learning resources relative to Information and Communication Technology (ICT) led environment which encompasses large variety of quality learning resources. Further, the constraints related to schedule and limited class time also create issues both for student and teacher. For example, student have to grasp maximum form the lecture as there is no opportunity to repeat the lesson. On the other hand, teachers also have limited time so bombard the material that may cause problem especially for students having slow cognitive processes. Above all, in traditional classroom, every student cannot learn all that taught in class because the learning material is not designed in accordance to their learning needs.

It is noticed that both developed and developing countries emphasizing on ICT led environment to deal with different kind of educational issues.

The main motivation behind this research is an attempt to provide an enabling environment to deal with the issue of poor learning outcomes. The solution presented in the form of adaptive e-learning environment premised on the belief of individualized learning. Individualized learning based on the philosophy of instructing each student individually considering his/her learning preferences and abilities. In (1984) a renowned educational psychologist Benjamin Bloom discovered that students whom instruction is imparted in one-on-one setting perform two standard deviation better than students who gets instruction in traditional learning setting (Evens & Michael, 2006). The provision of individualized or one-on-one tutoring through traditional environment is not practical as a personal teacher for each student requires huge budget. Hence, the ICT is a catalyst for individualized teaching. It is our main motivation to design an adaptive e-learning environment considering students individual differences in order to see impact of approach on students learning outcomes.

1.2 Problem Statement

Numerous AESs have been developed to impart effective learning experience through computer assisted technology. Among many, initial systems provided adaptivity merely on the basis of student's domain knowledge and interaction history. These systems created student's model using domain knowledge to provide adaptation effect while delivering instruction related to domain. Later research focused on Learning Style (LS) based AESs but so far careful studies are rare and success stories are very few (Akbulut & Cardak, 2012; Brusilovsky & Millan, 2007). In reality, LS based AESs have been failed in improving learning outcomes. The prior research studies considered frequently only few learning style models (i.e.) rather than exploring other learning style models using different studies to see their impact.

However, existing research studies also did not took into account cognitive and non-cognitive characteristics for adaptive learning. It is already highlighted that students differ from each other in many ways so the integration of potential combination of learner's cognitive and non-cognitive characteristics in AESs considerably impact students learning (Nakic, Granic, & Glavinic, 2015). Hence, it is believed that AES ability to deliver learning content considering learner's strengths and weaknesses can significantly improve their learning outcomes and learning efficiency.

Another issue related to this research area is the lack of empirical investigation. Many studies were conducted without finding any significant differences. Although several AESs have been developed but only few statistically significant empirical studies have been conducted to prove the effectiveness of such systems and their impact on students learning performance, motivation, self-regulation and attitude. Therefore, further empirical studies are required to justify the benefits of adaptive e-learning systems which may help to promote the use of such systems outside the research community.

Following is the concrete problem statement for this thesis. (Details are discussed in Chapter-3)

In general, the adaptive educational systems provides adaptivity through student models which predominantly based either on knowledge or learning styles. However they do not consider potential combinations of cognitive and non-cognitive characteristics of individual students to impart adaptive learning experience.

To test the proposed idea in terms of student's learning improvement according to the combination of cognitive and non-cognitive parameters including learning styles, cognitive styles, Working Memory Capacity (WMC) and prior knowledge. Following hypothesis are defined.

HYP-1: Students with different level of background knowledge, WMC and specific learning/cognitive style when exposed to lecture contents as per their learning needs can achieve equal or better learning outcomes as compared to those who are not given contents according to their individual needs.

- When students with low prior knowledge, low WMC, deep learning style along with serialist/holist cognitive style are exposed learning content which explain basics of the concepts in smaller chunks given with details in sequential steps along with appropriate illustrations, they can outperformed than their counterpart for whom learning content are not designed considering their learning needs and preferences.
- When students with low prior knowledge, low WMC and surface learning style are presented with learning content that is designed to impart basic of concepts using simple, short and plain language they can perform better than their counterparts for whom learning content are not designed according to their learning needs.

HYP-2: Students with high WMC when presented learning content according to their capacity can learn efficiently relative to students with low WMC to whom learning content also delivered according to their memory capacity.

HYP-3: Students who learn course using adaptive e-learning environment are more satisfying, having better understanding and retention of concepts than those who have not such facility.

1.3 Scope and Domain of Study

The scope of thesis in terms of student modeling parameters is defined as follows:
The student model was created on the basis of potential combination of student's cognitive and non-cognitive characteristics which includes student's prior knowledge of English preposition, WMC, Entwistle's deep vs. surface learning style along with Pask's holist and serialist cognitive style. The cognitive parameters (WMC, learning/cognitive style) were acquired through psychometric questionnaire whereas non-cognitive parameter (prior knowledge) using self-designed tool. The prior knowledge and WMC of students were classified into *low* and *high* categories. The classification may further be broken into sub or medium level that's out of the scope of this study.
In this project the preposition topic of English grammar has been picked up as domain knowledge. Following concepts related to preposition topic have been selected.

- Basics of Preposition of time
  - Introduction to preposition
  - Difference between preposition of time & place
  - Basic usage of preposition of at
  - Basic usage of preposition of in
  - Basic usage of preposition of on
  - Comparison & contrast of preposition words
  - Comparison of preposition words (at, in, on)
  - Contrast in preposition words (at, in, on)
- Basics of Preposition of place
  - Basic usage of preposition of at
  - Basic usage of preposition of in
  - Basic usage of preposition of on
  - Comparison & contrast of preposition words
- Advance usage of preposition time
  - Introduction to preposition of time/place
  - Advance usage of preposition of time
  - Advance usage of preposition of at
  - Advance usage of preposition of in
  - Advance usage of preposition of on
  - Comparison & contrast

  - Compound concepts
  - Other related concepts
- Advance usage of preposition of place
  - Advance usage of preposition of at
  - Advance usage of preposition of in
  - Advance usage of preposition of on
  - Comparison & contrast
  - Compound concepts

The order in which different preposition knowledge elements were taught, recognized after consulting various recent international standard English grammar books used to teach English at elementary and secondary level. These resources are available in the library of Directorate of Staff Development (DSD) Lahore, delivered by British Council under Punjab Education and English Language Initiative (PEELI) project.

1.4 Research Methodology

For the verification of proposed approach, the methodology we adopted is depicted below in multiple stages.

- *Development of Prototype:* The prototype of adaptive e-learning system was developed to teach concepts related to the usage of preposition. The system consists of different components including domain model, student model, adaptive model and evaluation, feedback and user interface modules which interact with each other to carry out system functionality.
- *Experiment Planning Phase:* This phase was about the preparation of experiment. Initially, related instruments were deployed among students of local public schools. The collected data was processed using SPSS and students were categorized into twelve possible subgroups which were further divided into control and experimental groups.
- *Experiment Execution Phase:* This phase was about the execution of experiment. In this phase the experimental sub groups were taught through adaptive learning system. The system delivers learning content in accordance to the profile of student that's consists of cognitive and non-cognitive parameters. And further it provided adaptation effect on the basis of students learning performance. On the other hand, control subgroups learnt same learning material in traditional classroom environment.
- *Evaluation Phase:* The most important aspect of learning process was to enable learners to correctly apply preposition words in new context. Evaluation phase test this aspect of learning. Hence, the students of both experimental and control groups were assessed through post-tests in order to know the impact of proposed approach in improving their learning performance.
- *Analysis Phase:* The results received from evaluation phase were analyzed to look into success of proposed approach. The idea is that an Adaptive e-

learning system developed around the potential combination of cognitive and non-cognitive parameters of students is more useful in terms of increasing learning curve of students as compared to traditional learning environment.

1.5 Structure of the Thesis

The thesis report is organized in 8 chapters. In next chapter (Chapter 2) the ICT integration in education specifically in developing countries is reviewed to know *(i)* the process of ICT integration in education *(ii)* ICT interventions taken by Asian countries to resolve educational issues and to improve quality of learning process. *(iii)* impact of such ICT based interventions on learning. *(iv)* Impact of ICT integration in education over economy and society. *(v)* The room for further improvements to advance the concept of ICT in education is highlighted. *(vi)* Finally, for successful integration of ICT in education some guidelines are suggested.

Chapter 3 provides literature review of adaptive learning based on individual differences. The shortcomings of previous research are identified and problem statement is framed on such basis. Further, the solution is proposed to address research issue(s).

Chapter 4 generally describes the major components of AESs, student modeling approaches and techniques used to provide adaptivity are discussed. Some example AESs are discussed in detail to show their working and evaluation results.

Chapter 5 highlights the issue(s) related to adaptive contents and presents the design of adaptive learning contents. The guidelines related to the development of adaptive content and process used to ensure content validity is discussed.

Chapter 6 discusses the concept of user/student modeling and describes major machine learning techniques used for such modeling. The architecture of system is presented along with detailed explanation of each component.

Chapter 7 discusses phases of experiment conducted to verify proposed approach. The results of evaluation are explained.

Chapter 8 is about conclusion and future work.

CHAPTER 2

REVIEW OF ICT INTEGRATION IN EDUCATION

Overview

The potential of Information and Communication technology (ICT) has been widely seen as a key enabler to deliver quality education. This chapter examines the progress of ICT within education primarily in terms of hardware infrastructure, e-learning resources, teachers ICT capacity development and ICT based educational practices in schools of four Asian countries namely Singapore, Malaysia, India and Pakistan. It further analyses the positive impact of ICT integration over the learning outcomes and growth of economy in these countries. Through an extensive literature review the state of each country regarding integration of ICT in education has been analyzed. The Singapore and Malaysia has completely revamped their educational system through official policy and strong commitment of Government to furnish ICT led teaching and learning environment in all public schools. India has also taken many ICT initiatives in different states to cope up chronic educational problems. The education system of Pakistan is facing many issues but the country so far did not realized the benefits of ICT to improve education. The result indicates that ICT is an effective mechanism to deliver quality education and has potential to deal with different educational issues.

2.1 Introduction

The chapter refers to the utilization and analysis of computer and Internet based technologies for teaching and learning. In present information society the nature of learner and demands of education are changing. The traditional education system cannot effectively cater to emerging demands and prevailing educational problems like issues of quality, access and equity (Reddi, 2004). The traditional system revolves around the textbooks, sometimes written many years ago. The teachers deliver instructions through an oral presentation combined with lesson and learning activities designed largely to memorize the contents, while the modern times challenges expect creativity and problem solving capabilities in students. They should be able to apply knowledge rather than simply know what the information is. ICT is a powerful tool that can help to cater these demands. ICT means such as audio, visuals, multimedia, interactive learning material and diverse collection of learning activities to develop a better understanding of the concepts, retention on long term basis and provide a particular context to apply that knowledge (Noor-Ul-Amin, 2013).

It is commonly believed that the use of ICT in education helps to develop higher order thinking skills, transcend cognitive limitations, engage students in learning, provide quality learning experience, motivate and nurture a culture of learning among students

& teachers. It helps to make the teaching-learning process more effective and efficient (Singh, 2013; Devi, Rizwaan, & Chander, 2012; Lim, 2007). Moreover, ICT has a potential to increase participation rate, access of education to out of school children, reducing dropout rate, address issues of unavailability of qualified teachers, quality learning and distance barrier (Singh, 2013; Devi et al., 2012).

It is a well-established fact that a skilled and well educated workforce is critical to enhance the work and economic performance of any country (Awang, 2004). Globally ICT in education is viewed as a catalyst for educational change, to develop skills among learners and make them ready for the global economy and information society (Kong, Chan, Huang, & Cheah, 2014; Kozma, 2005). The education sector in both developed and some developing countries are making heavy investments to integrate ICT in school education to ascend standard of teaching and learning, access of education to children of marginalized and remote communities, to boost economy for the better development of society (Singh, 2013; Kozma, 2005). The key factor to successfully bring application of ICT in classrooms and preparation of students to learn and operate in the information age is highly reliant on the preparation and ability of teachers to use ICT in teaching-learning process. Furthermore, their belief, commitment and positive attitude towards ICT is important to transform learning in positive direction (Singh & Chan, 2014; Boon & Gopinathan, 1965).

In the light of above literature this research derive an analysis framework to look into the development of ICT integration in education, its success/failure, educational and economic impact in four Asian countries i.e. Singapore, Malaysia, India and Pakistan. The ICT dimensions we analyze include the availability of ICT infrastructure (computers, classroom equipment, network & Internet), e-learning resources (CD based and web based), revision of curriculum, teachers ICT capacity development and the educational & economic impact of ICT in selected countries. The rest of the chapter describes the case of each country on the basis of above mentioned dimensions.

2.2 The Case of Singapore

Background

After independence, the education system of Singapore has experienced numerous structural changes and led to different development stages. The first stage was *survival driven education* (1965-1978) which focused on rapid construction of schools, teacher's recruitment and training, universal primary education and bilingual policy *(English & Malay)*. The Government also established vocational schools in 1968 to accommodate those students who failed in primary leaving examination. This stage showed an impressive progress. The enrolment in primary education reached to 100% in 1965. Similarly tremendous progress was seen in secondary education enrollment, from 48,723 in 1959, 114,736 in 1965 and 161,371 in 1972. The enrollment in English stream schools also increased (Morris, 1996; Boon &

Gopinathan, 1965). This phase emphasized on the quantitative dimensions to provide educational opportunities to all young Singaporeans. Although during this phase literate and numerate manpower was produced for industrial development, but the quality of education was very low. The passing rate was low, 20% of the students entering primary one and leave school after nine years without obtaining any qualification or skill. The proficiency in English language was also low which resulted in the overall low education standard. Out of 1,000 pupils entering in Primary-1, only 440 reached Secondary-4 after 10 years and of this number, only 106 obtained three or more "Ordinary" level passes at the Cambridge Schools Examinations. Moreover there was an acute shortage of local expertise in the field of science and technology. To overcome these deficiencies the government re-structured the education system through efficiency driven education. The *efficiency driven education* (1978-1997) premised on the belief that children have different level of intelligence and abilities. This new system provided three streams in both primary and secondary school, to allow pupils to progress at a pace more suited to their abilities. The student's academic results were found better than before. By 1984, the overall percentage passes at the Primary School Leaving Certificate (PSLC) in English and the second language was 85.5 and 98.7% respectively. The attrition rate for secondary schools decreased significantly from 19% in 1980 to 3.5% in 1999. The efficiency driven education showed positive outcomes but the global rapid technological advances shifted focus towards knowledge based economy (KBE) which depends on innovation and creativity. To cater the demands of KBE the education system of Singapore was entered into *ability driven education* phase during 1997 which incorporated the educational vision *"Thinking Schools Learning Nations" (TSNL)*. The TSNL based on the idea that the Singapore completely lacking in natural resources so the national wealth and future growth of the country is based on the capacity of its people to learn throughout the life. Learning should be culture of the nation where innovation and creativity grow at every level of society. The integration of ICT in education was realized as a major resource to foster innovation, creativity, research and lifelong learning. Hence for the integration of ICT into education three successive master plans known as MP 1, MP 2 and MP 3 were launched (Singapore, 2010; Morris, 1996; Boon & Gopinathan, 1965).

History of ICT in Education

Singapore had a long history of ICT in education. In 1980 Ministry of education started ICT projects in schools including *school link project*, *computer appreciation clubs*, *professional computing support program and computer applications* (CPA) to raise computer literacy and ICT awareness among students. In mid-1990 some projects had initiated to explore the use of ICT in classroom such as *accelerating the use of ICT in primary schools program* (AITP), *Student's and Teacher's workbench* (STW) and JCNet. These pilot studies found helpful in improving student learning and led ICT integration at wider level in schools using best practices and lesson learnt from the implementation of AITP, STW and JCNet (Koh & Lee, 2008).

2.2.1 First ICT Master Plan-MP1 (1997-2002)

Under MP1 strong technological foundation was established in education for effective use of ICT in teaching and learning. The MP1 was not working in isolation, Singapore initiated four national IT plans between 1998 and 2002 to develop ICT infrastructure and ICT oriented mindset of public. These IT plans had complemented MP1 in the widespread injection of ICT into education. The MP1 had emphasized on the following dimensions to promote ICT in education (Kong et al., 2014; Toh & So, 2011; Lim, 2007; Johari, Looi, Hung, Bopry, & Koh, 2004).

Curriculum &Assessment: The curriculum was revised with the 30% integration of ICT at all levels *(primary school, secondary school and junior colleges)* in almost all subjects. The revised curriculum emphasized over the wider use of internet, learning applications, learning management systems and other tools such as word processing, spreadsheet and mind mapping packages. The use of ICT was encouraged among students to shift learning merely from information receiving towards acquiring, analyzing and applying information to solve problems (Singh & Chan, 2014).

Physical and Technological Infrastructure: All schools were enriched with ICT infrastructure including three computer laboratories in every primary school and four in every secondary school. The student computer ratio in primary schools was 6.6:1, in secondary 5:1 and teacher computer ratio was 2:1. In addition to computers, the classrooms had equipped with data projectors; pull down projector screen and printers. The school wide networks were developed for the access of learning material at all learning areas including classroom, library and special room for the effective integration of ICT into curriculum. Every school was inked with wide area network which in the end was linked to high speed backbone of Singapore ONE (Kong et al., 2014; Koh & Lee, 2008; Johari et al., 2004).

e-Learning Resources: Initially MOE selected commercially available CD-ROM based learning packages including *Math Blaster, ZARC CD-ROMs* for mathematics, *I-Micro* and *Robo Lab* for Science, *Midisaurus* for music, *Crayola* for art and many other for various subjects which were relevant to pedagogy and curricular objectives (Noor-Ul-Amin, 2013). Later, MOE encouraged local industry to develop wide range of e-learning resources. Consequently a large number of learning applications were developed and many of them got international recognition like *active primary mathematics series*. A clearing house was established within MOE to evaluate and recommend e-learning resources to schools. Moreover schools and teachers had autonomy (ESPS) to procure suitable learning applications under Educational Software Procurement Scheme (Koh & Lee, 2008).

Teachers Training: The Educational Technology Division (ETD) within MOE had conducted 30 hours school based training sessions to equip all teachers with sufficient knowledge and skills for the effective use of ICT in classroom. They were furnished with various examples regarding the use of ICT tools i.e. word processor, spreadsheets and Internet. Further the creative and advance use of ICT in classroom was encouraged through reward schemes (Koh & Lee, 2008).

Research & Development (R&D): The researchers were encouraged to conduct experiments on different subject domains in real classroom setting. The objective was to explore pedagogical aspects on e-learning to improve the technological innovations with the help of industry partners (Koh & Lee, 2008).

The MP1 ended up with a positive note. During this phase a strong foundation of ICT in education was established, ICT culture was nurtured with core ICT competencies among teachers and students (Toh & So, 2011).

2.2.2 Second ICT Master Plan -MP2 (2003-2008)

After the success of MP1the MP2 was launched which had underlying philosophy similar to MP1, which was to equip students with such ICT knowledge and skills useful to meet emerging demands of workplace and society.

The main objective of MP2 was the effective and seamless integration of ICT and advent of innovation in education to foster MOE's overarching aim *"Teach less learn more".* The following areas were emphasized during MP2 (Kong et al., 2014; Toh & So, 2011; Koh & Lee, 2008; Johari et al., 2004).

ICT Infrastructure: Under MP2 the ICT infrastructure was advanced with wireless network technology and access of higher bandwidth internet. The student's computer ratio was also improved at greater degree. All secondary schools and almost 90 % of primary schools were furnished with Learning Management Systems (LMSs) in order to access custom built and commercially available learning contents. The interoperability in LMSs made possible through MOE *"Inter Cluster Sharing of Resources" (iSHARE)* project to encourage ICT based resource sharing among various schools (Koh & Lee, 2008).

Web Based Learning Resources: In MP2 the focus was shifted towards interactive web based learning resources instead of CD-ROM based learning. The teachers were developing their own learning objects and shared them with each other. The sharing of e-learning resources was encouraged through *edu.Mall,* a web based repository. The *edu.Mall* is a mechanism for teachers to access information, share their ideas, experiences and setbacks. The access to highly customizable and reusable learning objects promoted varied learning using student's learning styles. The availability of web based learning resources facilitated anytime and anywhere learning using range of devices and platforms (Koh & Lee, 2008).

Teacher's Professional Development: MP2 had emphasized on the customized professional development of teacher. The schools had privilege to decide their training requirements. The trainings were offered to schools or cluster basis to cater specific requirement of a particular subject. These programs encouraged the value added use of ICT in the process of teaching and learning (Koh & Lee, 2008).

School Autonomy in ICT Programs: The MOE provided greater autonomy to schools allocating funds on annual basis to implements ICT programs as per their specific needs. The MOE consultancy teams supported them in the effective use of ICT in teaching and learning. The schools were encouraged to experiment advance technologies including tablet, mobile devices and 3-D virtual learning environment to promote advance use of ICT (Koh & Lee, 2008).

Research & Development: The research center had established in MOE to experiment with innovative ICT based pedagogical practices and Learning Science Lab (LSL) in National Institute of Education (NIE) to embark on basic research on ICT based learning. LSL presents effective ideas and prototypes among school stakeholders to enhance learning through ICT. The MOE has launched LEAD ICT scheme in 15% technologically advanced schools in order to experiment with existing and emerging ICT based pedagogies. In 2007 *FutureSchools@Singapore* project (FS@SG) started to support 5% exemplar schools with state of the art technology and advanced ICT enabled learning environment to nurture innovation across all the subjects and educational levels. Upon successful completion of these projects the technology will be replicated to other schools as well. The LEAD ICT schools achieved the higher use of ICT in at least one subject across one level (Toh & So, 2011; Koh & Lee, 2008; Johari et al., 2004).

2.2.3 ICT Master Plan 3-MP 3 (2009-2014)

The 3rd ICT master plan was aimed at larger integration of ICT in curriculum, assessment and pedagogy to equip students with critical ICT competencies such as communication & collaborative skills and self-directed learning to succeed in the 21st century. The focus was on following key areas.

ICT Standards: A set of baseline ICT standards were established to ensure that certain level of ICT competency will be achieved by every student.

School Leadership on e-Learning: The peer coaching approach was adopted to develop skills among school leaders/principals to implement innovative e-learning programs in all schools. The coaches were chosen from FS@SG and Lead ICT schools to share their experiences, lessons learnt and practical guidelines for the successful integration of innovative ICT resources. This approach was found fruitful by the community of principals (Kong et al., 2014; Toh & So, 2011).

ICT mentor program: Under this program four teachers per school were trained as ICT mentor. They were equipped with in-depth knowledge and skills regarding the actual use of ICT in teaching and learning. After successfully completing training each ICT mentor was responsible to mentor at least one peer during the academic year (Kong et al., 2014).

Innovative teaching and learning practices: MP3 has emphasized on innovative school practices established through FS@SG program. Under FS@SG, various key innovative initiatives were taken in 15% elementary schools. Such initiatives include interactive virtual learning environment, canberra LIVE, i-CONNECT learning spaces, VL trek, artificial intelligence chat bots and scaffolded algorithmic inquiry-based learning. (MOE, Singapore).

Table 1: Summary of Singapore ICT master plans

	MP 1	**MP 2**	**MP 3**
ICT Infrastructure	Basic infrastructure and provisions	Enhanced ICT infrastructure (wireless technology)	1:1 computing and ubiquitous technology
Learning sources	Printed material and CD-ROM based learning resources	Web based learning repositories in the form of learning objects	Intelligent learning environment
Teacher's professional development	Develop basic ICT competencies to integrate ICT in curriculum	Customized training programs, provide wider repertoire of competencies for the integration of ICT in curriculum	Peer coach program ICT mentor program
Pedagogy	Teachers centered	Learner centered	Personalized Learner centric
ICT approach	Centralized approach	Provided greater autonomy	Research based educational innovation
Learning approach	One size fit all approach	Adopted customization and ability driven plans to cater different groups in schools	Alternative learning paths
Student ICT capacity building	Basic ICT skills (applications & internet)	Sophisticated ICT skills (internet & web)	Self-directed learner Collaborative
Outcomes	ICT culture	Research based pedagogical practices	Innovation

2.2.4 Impact of ICT

Learning Performance

The Singapore students are among the world top performers. According to Programme for International Student Assessment (PISA) 2009 results, Singapore students graded second in mathematics, fourth in science and fifth in reading outcome of 65 participating Organization for Economic Cooperation and Development (OECD) countries. In reading Singapore students outperformed than English speaking countries including Australia, United States and United Kingdom. The major contributing factor towards Singapore's such remarkable performance is the availability of quality e-learning resources in schools and at home. Singapore has the highest index of availability of school resources. The majority *(90%)* of Singaporean students has computers and access of educational resources at home as compared to 60% international average (Toh & So, 2011; PISA, 2009). The massive access of ICT based learning resources at schools and homes enabled independent learning and inspired capable students to broaden their horizons beyond the standard curriculum. On the other hand rich media and interactive capability of ICT resources has motivated and engaged weaker students to facilitate them in learning at their own pace (Lim, 2007).

Critical Thinking Skills

The international assessments revealed that Singaporean students have ability to think critically and solve real-life problems. The students of mathematics were capable to work with mathematical models for complex situations. They have well-developed thinking and reasoning skills and can effectively communicate their interpretations and reasoning. Likewise science students were able to identify scientific mechanisms of many complex life situations and can apply scientific ideas to such situations. Moreover, they could use well-developed inquiry abilities and make arguments on the basis of their critical analysis (Toh & So, 2011). The findings affirm that ICT based learning environment furnished students with such valuable skills which are requisite for 21st century life and workplace.

Student's Engagement

The multiple case studies have reported that ICT mediated learning environment along with different scaffolding strategies including orienting strategies, peer interaction, modeling to guide and prompts were more likely to engage students in learning tasks and higher order thinking (Lim, 2007).

Information Literacy

Tan et al., (2011) evaluation study showed that students were proficient in the use of different ICT tools required at a certain level. The primary level students were more competent with the Internet and MS Word but have low proficiency with spreadsheet and communication tools. The secondary schools students were more proficient with communication tools, office productivity tools and information tools but relatively less competent in collaboration tools, reflection tools, multimedia editing, immersive virtual environments and educational games. Thus an appropriate level of ICT competencies among students engage them in self-directed learning (SDL) and collaborative learning (CoL) which promotes deep learning, self-regulation and metacognition skills essential to succeed in 21st century (Timothy et al., 2010; Tan et al., 2011). The teacher's reported that they regularly engage their students in SDL and

CoL activities such as internet search, access of learning resources using learning management system, group work and project work (Tan et al., 2011).

Teacher's ICT Competency and Attitude towards ICT

The majority of the teachers found at ease in the use of available ICT tools and resources to support classroom teaching. Most of the lessons (85%) were delivered using ICT resources including Internet, CD-ROM, data logger and other open tools such as word processor, spreadsheet, Geometric Sketchpad, and presentation application. The Second Information Technology in Education Study (SITES 2) affirms that Singapore's teaching community is highly competent in ICT and much interested towards the use of ICT in teaching learning process and fully supported by Government and school leaders in this regard (Tan et al., 2011).

Knowledge Workers

Singapore possesses an excellent indigenous pool of scientific and technological workers which would be a source of future growth of the country. The PISA results showed that Singapore has second highest ratio (35.6%) of top performers in mathematics, third highest ratio (15.7%) of top performers in reading as well as second highest proportion (19.9%) of top performers in science. Overall the country has the second highest ratio (12.3%) of students who were top performers in all three domains after Shanghai (14.6%) whilst the average percentage of top performers among OECD countries was simply 4.1% (Toh & So, 2011; PISA, 2009). The widespread uses of ICT in education help Singapore to build a stronger base for knowledge creation, acquisition, dissemination as well as knowledge application capabilities to develop creative industries and attract major multinational enterprises (MOE, Singapore).

Economic performance

Among other facets, the availability of technologically literate workforce and large pool of creative pool is one of the key factor in attracting almost 4000 high tech international companies in Singapore to start their operations which resulted in technology transfer, a well-functioning of financial markets, flourishing market for SMEs as well as remarkable growth in GDP at about 3.5% during 1990-2003 (Wong, Millar, & Ju Choi, 2006; Kozma, 2005). Moreover, only the educational services significantly contributed in country's GDP from 3% to 5% and raise the standard of living with an adjusted per capita GDP of US$24,481 (Wong et al., 2006; Kau, 2005).

2.3 The Case of Malaysia

Background

The former Malaysian Prime Minister Dr. Mahathir Muhammad historical speech entitled *"Malaysia-The way forward"* delivered in 1991 had led to the widely recognized Malaysian vision 2020. He was aspiring to achieve the status of fully developed nation by the year 2020 (Ong, 2006). To accomplish vision 2020 it was imperative to prepare scientifically and technologically literate workforce with critical thinking skills which enable them to contribute effectively in the global economy of 21st century. The vehicle to deliver such desired workforce was the education system of the country. The issue related to education system was the rote learning environment and examination oriented culture. The enrollment in science subjects was very low even having educational policy to achieve the ratio of 60:40 for science versus arts based enrollment. The low percentage of science enrolment threaten the government that the Malaysia's vision of becoming developed country may be endangered by a scarcity of scientific and technical human capital (Ong, 2006; Lee, 1999). Therefore the reinvention of education system was realized in support of vision 2020. The ICT was recognized as a catalyst to transform the rote learning based education into a system that can stimulate thinking, creativity, quality learning and equitable access (Hassan, n.d.). Resultantly, MOE started to conceptualize Smart Schools in 1996, which was originally conceived by David Perkins in 1984 at Harvard University. The smart school was an innovative idea which based on the use of ICT in education. The Malaysian smart school can be defined as a "a learning institution that has been systematically reinvented in terms of teaching learning practices and school management in order to prepare children for information age". The most distinct aspect of the smart school is the teaching and learning atmosphere that's based on the world's best practices. This entails mutually supporting and consistent alignment of the following four dimensions (Malaysian Smart School, 1997).

- *Curriculum:* This includes four types of knowledge areas namely content knowledge, problem solving knowledge, epistemic knowledge and inquiry knowledge.
- *Pedagogy:* Pedagogy should be student centered in smart schools.
- *Assessment:* Assessment shall be criterion-referenced to present more holistic and accurate picture of student performance and it can be in various forms such as classroom based assessment; school based assessment and centralized.
- *Teaching-Learning material:* The teaching learning material should meet curricular and instructional objectives and provide cognitively challenging contents to motivate students towards learning.

The Malaysian smart school implementation was scheduled to go through four phases namely; the pilot (1999-2002), the post-pilot (2002-2005), making all schools smart (2005-2010), and consolidation and stabilization (2010-2020) (Hassan, n.d.). The Malaysian government had embarked on various ICT initiatives within education to enhance the effectiveness of learning environment.

2.3.1 ICT Infrastructure

The following ICT based facilities were provided in government schools (Hassan, n.d.).

Computer Laboratories: The Government of Malaysia developed computer laboratories in 6633 schools including rural areas in order to bridge digital divide.

These laboratories were equipped with basic ICT facilities such as PCs, Local Area Network (LAN), printers and servers.

SchoolNet: The access of Internet was provided with 4Mb/s in 9654 locations.

1BestariNet: It is a virtual learning platform which applies high-speed Internet connection and access to integrated education system. This new expansion introduced a novel learning environment to facilitate provision of learning material with 4G Internet access anywhere and anytime.

School Access Centers: To provide access of computers to the students after school hours access centers have been installed in 3029 schools with 70% in rural schools and 30% in urban schools.

WebTV: WebTV was another way to provide access of learning material to teachers and school community. They can access on-line streaming as long as they have the availability of Internet.

Teacher's Training

The MOE had initiated various ICT training programs to furnish with necessary knowledge and skills to utilize ICT in teaching process (Shaharuddin & Abiddin, 2009; Lubis et al., 2009). The government successfully developed ICT trained teaching force. Almost 70% teachers asserted their comfort level in various aspects of smart instruction. They felt that ICT facilities enhanced their productivity but the lack of support from school leaders hampered their use of ICT in classroom (Lubis et al., 2009).

2.3.2 Teaching/Learning Material (TLM)

To make learning environment interesting and meaningful the MOE developed a diverse range of teaching and learning material. The learning materials were available in different forms including audio CDs, video CDs, interactive CD ROMs and web-based multimedia contents. Furthermore teachers and students were provided with online access of learning material. The 3778 titles of TLM were produced and distributed widely at schools from 1999 – 2008 (Hassan, n.d.).

Browser Based Courseware: The major component of smart school was browser-based courseware designed to deliver lessons efficiently and effectively. The courseware design aimed to build student's capabilities and supports them in independent learning. The analysis revealed that courseware integrated all media such as text (76.2%), images & illustrations (64.1%) were dominantly used while interactive images (41.9%), animation (31.4%) and sound (31.9%) were also incorporated into some pages in an effort to represent students a rich learning environment. In terms of pedagogical dimensions 82.6 % of the total web pages supported individual instruction and rest of the pages constituted collaborative learning. The prevailing instructional model was traditional, hierarchical and direct instruction mode whereas only 36% pages supported inquiry based learning. The major cognitive processes elicited by learning activities were lowest level such as information retrieval (48.8%) and memorization (47.1%). Very few pages encompassed high level processes such as problem solving, creation and invention (Halim, Zain, Luan, & Atan, 2005).

The fully equipped smart school consisted of computer laboratory, network/internet, and classroom with multimedia courseware and presentation facilities, media center, multimedia development center, studio/theatre for centralized teaching and videoconferencing and teacher's room with access of courseware and online resources (Omidinia, Masrom, & Selamat, 2013).

2.3.3 Impact of ICT

Learning Performance

Ong & Kenneth research examined the teaching of science subjects in terms of *attitude of student's towards science subjects, academic performance and science process skills* both in smart and traditional schools. The research revealed that smart schools used ICT based resources and student centered approaches in science teaching. The notes giving by teacher or notes copying was a dominant practice in traditional schools while it was rare in smart schools. The teachers in smart schools used ICT resources in a way which would be interesting, motivating and illuminating to students. For example, software qualities such as visualization and graphical representation hold student's attention. The graphics and animations enrich student's comprehension of concept and grasp of scientific phenomena. The evaluation showed statistically significant results favoring smart schools over traditional ones in terms of all three above mentioned outcomes (Ong & Ruthven, 2009; Ong & Ruthven, 2010). The findings were consistent to the results of another comparative study which revealed that smart school students outperformed across all national exams in core subjects like Mathematics, Science and English. The academic score increased by 11.4% after the launch of smart school. Another study showed that majority of the students (97%) perceived ICT based learning as an interesting and joyful experience as well as helpful in improving the understanding of concepts (Halim, 2005). Moreover, the enrolment in science and technical courses has also increased in science subjects. It was 52% of total enrolment in year 2000 compared to only 40.7% in 1995. Similarly, enrolment in IT courses increased from 3,770 students in 1995 to 15,050 students in 2005.

Information Literacy

Information literacy skills were emphasized in the Malaysian smart school project (MSSP) to prepare students for the Information age. *"Information literacy"* defined as the knowledge and skills which contribute to student's personal empowerment and freedom to learn (Malaysian Smart School, 1997). The most of the Malaysian smart school students (92.8%) were capable to use computers and to access learning materials from either courseware or Internet and many students were also able to use basic communication tools such as e-mail and chat. They use computers to do their homework (84.9%), (92.6%) to type reports, (75.3%) to make presentations, (97.5%) to search information and (54 %) to make drawings. The low percentage of students used to compose music (16.9%), (16.2%) create movies and 34.9% used to create web pages (Lau and Sim, 2008). These results indicate the good level of ICT competencies among students so they are independent learners which lead them in developing critical thinking and problem solving skills.

Teacher's ICT Competency and Attitude towards ICT

The teachers were found competent in the use ICT based application including multimedia courseware, presentation tools, internet browsing and spreadsheets. They rely on the use of these applications in classroom to impart instruction. Their attitude towards ICT in education was positive. They concurred that ICT resources enrich their lessons and brought variety into teaching material which amplify student's interest and motivate them towards learning. The teachers found reluctant in the use of graphical visualizing tools, hypermedia/multimedia and simulation programs due to the lack of advanced level training in these specialized kind of learning applications (Lau & Sim, 2008).

Knowledge Workers & Economic Performance

During 1996 the percentage of knowledge workers in the labor force was low (11.1%). There was a substantial increase in the employment of knowledge workers in labor force from 2800 in 1997 to almost 32000 in 2001, which tended to increase further. The availability of ICT literate workforce encouraged manufacturing sector and wholesale sector in Malaysia to rely on the use of ICT products to handle various business processes efficiently which ultimately improved productivity and economic growth. An empirical analysis revealed that every 1% increase in ICT investment in the manufacturing sector improved the economy by 0.27% in the short term and by 0.91% in the long run. Similarly, in wholesale sector every 1% ICT investment boost the economy by 0.6% in the short term and 1.9% in the long term (Kuppusamy, Raman, & Lee, 2009; Awang, 2004).

2.4 The Case of India

Background

Education in India is provided both by the public and private sector. The control and funding coming from three levels: central, state, and local. The public sector is the largest provider of education (80%) in the country. The public sector schools consist of Government and Government aided schools. The Government schools were not delivering quality education (Dangwal & Gope, 2011). The several efforts have been by the Government to reform and revitalize the existing education system including District Education Revitalization Program (DERP). Under DERP almost 160000 new schools were opened and the staffing requirement has also been improved which has positively impacted the enrollment ratio but the access to quality education remained a concern to address (Patra, 2014). For example, in India during 2004 – 05, the Gross Enrolment Ratio was 97% for Grade I to VIII and the drop ratio for the children of same classes was as high as 46%. The same situation was found at secondary level education (Grade IX and X). The government recognizing the issue of quality in education has embarked on various initiatives (Price Waterhouse Coopers, 2010). The ICT interventions were viewed as a major catalyst to positively impact the learning environment. Therefore over the last decade various ICT based initiatives have been taken in education which are as follows.

2.4.1 School Computerization Project

The scheme was aimed at ICT integration in government high schools, a pilot project was initiated in 140 rural schools of seven districts of India during 1999. These schools were equipped with one computer laboratory consisting of 10 multimedia personal computer with web cam, a server, a hard disk, a network printer, a flat screen color TV and uninterrupted power supply (UPS) along with MS-Office package having multi-lingual support, visual studio, Encarta reference suite, online deluxe and web hosting software. The broadband facility was also provided for intra and Internet connectivity in all 140 schools. The seven training centers were set up at district level. The trainings in the use of computer, Internet browsing, development of learning material was provided to all school principals' and 950 teachers (Arora, 2007).

Impact

Through this computerization project schools managed to improve student's attendance rate and diminish the rate of drop out. The teacher and students were found interested in the use of ICT resources for teaching and learning and they felt pride on the access of such ICT facilities (Computer Aided Learning, n.d).

2.4.2 Computer Aided Learning (CAL) Program

Up till 2009, Under CAL program 67188 public elementary schools were covered with necessary ICT arrangements including computers, printers, UPS system and multimedia based learning resources in the form of CDs. These CDs consists of selected hard spots *(topics)* related to Science, Mathematics and language *(English, Hindi)* subjects using state specific languages to impart quality education. The 2 million teachers have been trained in the use of these e-learning resources and around 10.2 million children have been benefitted from these learning resources (Computer Aided Learning, n.d.).

Impact

The teachers across all states had positive view about CAL. They perceived that multimedia based CDs enhanced student's attention, imagination and supported slow learner in improving their learning. Moreover it promoted self-learning, self-evaluation and collaborative learning. Similarly, majority of the students showed positive attitude towards CAL mainly due to the use of images, graphics and animations in lessons which supported them in memorizing and comprehending concepts (Azim Premji Foundation, 2008).

Unfortunately, the school environment was found biased in terms of providing access to CAL for an appropriate time period. So the students who were given opportunity to access CAL on regular basis under the supervision of teachers had shown significant improvement in all subjects during exams (Gupta & KPN, 2012).

2.4.3 HiWEL Learning Station

Hole in the wall learning station *(HiWEL-LS)* consists of two to four computers fixed on a wall facing outside at public places such as boundary walls of government schools and playgrounds. Almost 200 learning stations were set up in slum, rural and remote areas across the India to evaluate its positive impact on elementary education. The learning stations were accessible free of cost to the children of 6-14 years age group. The *HiWEL-LSs* were fully equipped with educational learning material including stimulating games and multimedia & video based contents. The contents were in English language and covered courses like English, Mathematics and Social Sciences, etc. The learning stations provided supporting environment for self-regulatory and self-paced learning (Dangwal, Sharma, & Hazarika, 2014; Dangwal & Thounaojam, 2011; Dangwal & Gope, 2011).

Impact

***Out-of-School Children* (OOSC)**

The *HiWEL-LS* yielded remarkable results that in a period of two years 20% of the OOSC belonging to Delhi were enrolled in Government schools. On the other hand the government even after spending millions of rupees has been able to bring down drop out merely by 2% during last 10 years (Dangwal & Thounaojam, 2011).

Academic Performance

An empirical study showed that the students who studied through *HiWEL* learning station increased score by 19% in English and by 13% in Mathematics while those students who studied in traditional learning environment did not exhibit any significant increase in academic scores [43]. Other evaluation studies conducted to assess the academic performance of *HiWEL-LSs* showed similar results. The findings also revealed that *HiWEL-LSs* foster discovery learning, collaborative learning and enable children to become computer literate on their own. Moreover this innovative intervention has promoted social cohesion among students of different background (Dangwal & Thounaojam, 2011; Dangwal & Gope, 2011; Dangwal, 2005).

Community& Teachers Perception

The Government of Delhi reported that local community believed that *HiWEL* learning stations are useful in spreading basic literacy, computer literacy, improving social cohesion and academic performance. The teachers observed that due to learning stations students' takes more interest in learning and their presence has increased in classes (Maftuh, 2010).

2.4.4 CALtoonz

CALtoonz was a specialized computer aided learning program deployed in all Government schools of Delhi for a joyful, interesting and meaningful learning experience. The main objectives were to reduce the drop out ratio, engage students and enhance the quality of learning. The learning contents consist of animation and multimedia presentations to make learning fun for children. Additionally games, puzzles and challenging tasks were used to stimulate interest. The program allows students to practice on their own and accesses the lesson for revision of concepts taught in class (Price Waterhouse Coopers, 2010).

Impact

Dropout Rate

The program assisted in reducing the dropout rate by 7.51% in Delhi Government schools. The decrease in dropout rate was greater than those schools which have not a facility of *CALtoonZ* program. Owing to the technology and fun elements students became more interested in education. The success of program with large number of schools has provoked an expansion to more schools (Price Waterhouse Coopers, 2010).

2.4.5 KYAN

The Government of West Bengal has introduced an e-learning system called KYAN in 115 state schools. The objective was to impart quality education to marginalized segment of society specifically schedule caste & schedule tribe (SC/ST) children. The KYAN content comprises on 1090 lessons on various difficult to teach topics related to all subjects from Kindergarten to class X (Maftuh, 2010).

Impact

Student's Attendance Rate

The students using KYAN felt classes more interesting than traditional classroom which forced them stay in school and attend class. Hence KYAN supports state schools in improving the student's attendance rate (Price Waterhouse Coopers, 2010).

2.4.6 ICT @ School

ICT @ School project was initiated in all schools located in 14 districts of Kerala state during 2001. The major objectives were to deal with the issues of access, equity, quality education and to raise student's ICT literacy. The computer *(ratio 1:15)* and broadband connectivity was provided in all schools of sate. The teachers ICT capacity was also developed. Around 900 titles of educational CDs have been developed to cover all subjects offered at elementary and secondary level education. The audio/visual contents have also been created which are broadcasted using FM Radio *(Gyanvani)* and other educational channels such as *Doordarshan & victers*.

Furthermore the web portal *(www.sietkerala.gov.in)* has been developed for the access of learning material to students via Internet. The work on digital textbooks on tablet is underway (Ministry of HRD, n.d.).

2.5 The Case of Pakistan

The school system of Pakistan comprises over public and private schools. The government schools are the main source of delivering educational services. In spite of huge quantities of educational institutions (72%) the public sector is accommodating lower number of students (66%) than private sector due to poor quality of education in such schools (Banerji, Bhattacharjea, & Wadhwa, 2013). The ASER survey 2013 revealed that the student learning levels are falling especially across the rural Pakistan. Almost more than 50 % grade 5th students cannot read grade 2nd *English* sentences, cannot do two digit division and unable to read simple grade 2nd level story text in Urdu/Sindhi/Pashto. The survey reported that in Pakistan 30% of school aged children (6-16) were not in schools. The majority of OOSC (23%) belongs to rural areas. Among 23 % OOSC, the drop out ratio was 5% and rest of the 18% were never enrolled. The share of girls in OOSC found greater than boys (Qadir & Hameed, 2014). The Pakistan educational statistics confirmed that there is a shortage of teaching staff in government schools and those who are available to teach are not well qualified and well trained especially in rural areas (Banerji et al., 2013; Statistics, 2013).

The results indicate that the educational system is not delivering effectively. The ICT interventions have also been ignored to strengthen the system and to resolve the prevalent problems. At government level the most visible effort so far is computer laboratory project initiated by the Government of Punjab. The ICT initiatives experienced so far are as.

2.5.1 Computer Laboratories Project

Under this project 4286 computer laboratories *(each consists of 16 computers)* were established in Government secondary schools. These labs were mainly used by the students of grade 9th and 10th enrolled in computer studies course. Only the Microsoft word and GW BASIC were being taught to students. The computer was not used to teach other subject for example Mathematics, Physics, Chemistry, English etc. The students of non IT course cannot access these computer labs. The e-learning resources of any kind were not available in such labs and there was no Internet connectivity mainly in rural school labs to access online resources (Qadir & Hameed, 2014; Govt of Punjab, 2008).

The project seems unsuccessful because the labs were underutilized especially in rural schools. A rural teacher reported that there is a shortage of IT teachers and IT staff and computers were mainly used for clerical work for example to produce official documents. The Principals/Headmaster’s concern is the security of labs in rural areas rather than providing opportunity to students to explore and utilize the labs for learning purposes (Govt of Punjab, 2008).

2.5.2 Adaptive English Language Teaching Tool (AELTT)

In the context of Pakistan, the pioneering e-learning initiative was taken to get benefit of ICT in improving education at school level through *"Adaptive English Language Teaching Tool"* (AELTT). AELTT was developed to teach English Grammar skills to grade 9^{th} students. The localized learning contents were designed using different media elements such as text, images and audio support. The system assess student's level of knowledge and make streaming accordingly in order to deliver most suitable learning contents to meet their prior knowledge. The empirical evaluation showed that AELTT was helpful in improving student's level of learning (Durrani, Ijaz, & Kiran, 2015).

2.5.3 E-Learn Punjab

Recently (2014) the Government of Punjab has launched an e-learning program called "*e-Learn Punjab",* that is a web based repository contains digitized books of Science and Mathematics for Grade 9^{th} and 10^{th} which are augmented with various Internet based resources including images, animations, 3D models and videos (http://elearn.punjab.gov.pk). The program aimed at the enhancement of learning and quality of education but in reality majority of the students and teacher cannot take benefit from this program because around 75% schools are located in rural areas where Internet facility is not available; secondly teachers of these schools are not exposed to the use of computer (Govt of Punjab, 2008).

2.5.4 Model of m-Learning in Pakistan

The use of SMS based learning was explored in two public schools of Pakistan to assess Grade 4 mathematical skills. SMS messages targeted basic arithmetic operations including addition, subtraction and multiplication. The students were provided with three options for each question. The answer options were designed in such a way that the wrong answers were based on the mistakes students usually make while doing mathematical calculations. The initiative found valuable and appreciated by the parents. The comparison of each student assessment on the SMS and onsite test showed no variation in responses (Waqar, 2014).

2.5.5 Interactive Learning Application

Interactive learning application also called *'Chotay Sciencedan'* digitized the Grade 5 science curriculum. The application assess pupil's prior knowledge on a science concept and presents lessons through storytelling, videos and animations. The flow of content is guided by three animated characters that children can relate to commonly occurring scientific phenomena in their daily lives. The application is being deployed in five local public schools. The student's taking much interest and giving attention to science learning (http://chotaysciencedan.com).

The education sector of Pakistan is far behind in taking ICT initiatives to reinforce the week education system. The significant evidence available suggests that ICT investment can be beneficial to deal with educational issues and to deliver quality education. So the government of Pakistan should approach ICT integration in a systemic way to unleash its potential and enhance teaching and learning process.

Table 2: Summary of ICT initiatives in selected developing countries

ICT Initiative	Objective/Issue	Impact/outcomes	Level
Singapore			
ICT Master Plan 1 *(CD-ROM based learning)*	Compete in knowledge economy	Standard technological infrastructure, improved student teacher ICT competencies, improved learning	Elementary & secondary
ICT Master Plan 2 *(Interactive web based learning)*	Anytime, anywhere learning	Improved infrastructure, Improved learning	Elementary & secondary
ICT Master Plan 3 *(innovative technology)*	Collaborative & self-directed learning	Improved ICT proficiency, Positive impact on CoL&SDL	Elementary & secondary
Malaysia			
Smart Schools	World class education system *(develop knowledge workforce)*	efficient student & teacher, better learning outcome, contributed economy	Elementary & secondary
India			
School Computerization project	To Improve educational state	Improve attendance rate, Reduce drop out	Secondary
Computer Aided Learning (CAL) program	Quality education	Improve attention, retention, understanding and academic score	Elementary
HiWEL Learning Stations	Access and quality education for deprived community, bridge digital divide	Reduce OOSC & Drop out, Improve academic performance	Elementary & secondary
Mobile Learning Centers	OOSC	Successful in mainstreaming children	Elementary
CALtoonZ	Drop outs and engage students	Reduce drop out, engage students	Elementary
KYAN	Access of quality education to marginalized community (SC/ST)	Improve attendance rate, interest and motivation towards learning	Kindergarten to grade X
Mobile learning centers	Access of education to urban deprived children	Reduce OOSC	Elementary
Pakistan			
Computer	Quality education, ICT	Underutilized	Secondary

Laboratories	literacy		
AELTT	Enhance learning	Improve learning outcomes	Secondary
e-Learn Punjab	Quality learning	Being evaluated	Secondary
Model of m-Learning	SMS based learning	Appreciated	Primary
Interactive Learning Application (Chotay Sciencedan)	Improving science learning	Being evaluated	Primary

2.6 Adaptation in e-Learning

Based on the review regarding ICT integration in education it can be argued that the education sector has not been fully benefited by the potential of ICT. The main issue found in ICT based interventions or e-learning systems is that they did not employ the learning needs, capacities and preferences of individual students. Whilst personalized learning systems have potential to fulfill the needs of knowledge based economy and knowledge society by delivering high quality education. In most of the reviewed systems, the learning content and user interface are not personalized in accordance to learning requirements of the students. The main focus of e-learning systems is to enrich learning environment using media elements to make it attractive and interested for learners and teachers.

The aspect of individual differences has vital role in producing quality learning experience. Therefore e-learning system should be *student centric* which means place student at the center while delivering learning contents and making important decisions (Grimley and Riding, 2009). To deliver personalized learning experience e-learning system should continuously assess the knowledge of student and timely offer the most suitable learning content or learning path. These systems should be highly adaptive or personalized. In order to make a system personalized there is need to have a complete knowledge about the student.

2.7 Recommendations

Following are some suggestions for the successful integration of ICT in education.

- Devise ICT plans and policies which are integral to the educational development and improvement.
- Allocate special funds for the integration of ICT in education.
- Establish ICT infrastructure in schools including new computer labs, overhauling of existing labs, network & internet connectivity, ICT facilities in classroom, access of digital learning resources and ICT support.
- Develop comprehensive ICT training programs for teachers to equip them with skills required to effectively use ICT tools in classroom.

- Develop ICT related curriculum at each level for each subject in order to equip students with specific ICT skills at different stages of schooling. Revise National curriculum with ICT curriculum.
- Encourage the appropriate use of ICT among teachers and students for teaching-learning purposes.
- Provide access of e-learning resources (offline/online) and encourage students to learn independently using these resources according to their own pace.
- Encourage teachers to develop e-learning content related to his/her area of expertise and share it with others to use in classroom.
- Encourage universities to initiate research and development projects to develop learning applications considering local educational and cultural aspects. Experiment these applications in real classroom setting to further tune up to impart quality education.
- Kick off research projects to determine the causes of OOSE, drop out, low enrollment, etc. and develop appropriate ICT interventions to cope up such issues.
- Develop central digital repository of e-learning resources accessible to teachers and students.
- Major focus should be on the research and development of adaptive e-learning environments to make every child successful.

2.8 Summary

ICT in education is being used for varied objectives in developing countries including quality education, access, equity, ICT literacy and to overcome educational issues such as enrollment, OOSE, drop out and lack of interest and motivation among students and teachers.

The Singapore and Malaysia have made immense use of ICT in education with major focus to transform learning simply from knowing information to applying in problem solving, developing thinking and ICT skills. They realized that such capabilities are requisite to survive effectively in 21st century life and workplace. Both countries have highly developed plans and policies to integrate ICT in education for the overall educational improvement. All schools in Singapore and Malaysia have been equipped with computers and related technologies, high level of internet access, high quality of offline and online e-learning resources were available to augment learning. The teacher's capacity to use ICT in classroom has been fully developed especially in Singapore. ICT integration positively impacts the learning outcomes and economic performance of both Malaysia and Singapore. These countries got maturity in many dimensions of ICT in education. Singapore reflects many characteristics of knowledge based economy such as the capability and capacity of its people to acquire, apply and create knowledge but there is a need of further innovative capabilities.

Singapore is further ahead on the ICT in education expedition than Malaysia especially in ICT enabled innovative pedagogies to support high level of engaged learning and research activities to evaluate ICT based educational practices to achieve further excellence in the use of ICT for teaching and learning. The Malaysian smart school concept is backed by high quality vision and is emulating in various countries for educational development. It still lacks in few dimensions including full professional development of teachers regarding ICT to foster the use of advance ICT tools and pedagogies, commitment and support of school principals in the use of ICT and more importantly research based evaluations to further improve existing ICT practices. India and Pakistan both are facing almost similar kind of educational problems such as low learning levels, issues of access, OOSC and high dropout ratio. India has taken some ICT initiatives to deal with such chronic educational problems. Although the ICT projects in education were implemented at small scale but all of these showed fruitful results. Keeping in view the success of these projects in handling issues of educational quality, access, drop out, retention, interest and motivation, the government of India has developed ICT policy on education and increasing funds especially for the integration of ICT in schools. The education system of Pakistan surround with serious educational problems but the country is not realizing the potential of ICT in revolutionizing the education. Overall the major shortcoming found in e-learning systems is that they do not provide personalized learning so future research should focus on adaptive e-learning.

CHAPTER 3

INDIVIDUAL DIFFERENCES IN E-LEARNING CONTEXT

Overview

Obviously learners are different from each and they learn best if learning environment cater their individual differences. So it is imperative to develop e-learning systems considering learner's individual differences for quality learning. First step towards this objective is to understand the characteristics of individuals which discern them from each other and support them in learning process. This chapter has reviewed some important theoretical models along with their respective assessment tools. The application of these models has seen in the context of e-learning particularly in AESs. The objective of this study is to present an in depth psychological review of major individual differences, their application in e-learning and impact on student's learning outcomes. It would be helpful for researchers to evaluate set of individual characteristics which could be more suitable source of adaptation for learning systems. The chapter also discusses the issues and gaps exist in previous research to carry out further studies.

3.1 Introduction to Individual Differences

Research in cognitive science confirmed that people are different from each other and every individual have varied differences (McLoughlin, 1999). Every student is a unique individual and there is a good deal of diversity among students in an average classroom. Learning can be improved by considering individual characteristics in learning process. For example, some students can understand concepts quickly whereas others may require to repeat the lesson many times to fully grasp it. Similarly some students learn more through visual depiction of learning material while others may learn most excellently using verbal representation of the same learning material (Lubart, 2005). It is commonly believed that individual differences have strong implications on learning and usage of computer applications (Lo, Chan, & Yeh, 2012). Therefore for quality learning experience learning content should be delivered considering learner's individual characteristics. In traditional learning environment, delivery of individualized instruction is not possible due to some practical problems such as large class size and lack of teaching staff (Lubart, 2005).

The role of Information Technology (IT) for education has changed quickly mainly owing to the manifestation of e-Learning approach. The e-learning approach has proportionally improved its value with the growth of sophisticated devices, computer networks, internet and World Wide Web (WWW). Integrating the potential methods of learning with ICT possess new challenges and opportunities in the domain of e-learning (Esichaikul, Lamnoi, & Bechter, 2011). E-Learning has an important role in imparting anywhere and anytime learning. Courseware has been designed using different media elements such as text, images, animations and audio/video to engage students and to foster their interest in their studies. The major issue in e-learning approach is that it neglects the learner centric aspects. Although multimedia courseware provides rich learning experience but it delivers same learning content to all students (Halim et al., 2005). Similarly, online learning systems also offered same learning material to every student which leads to learning difficulties. This approach is known as “one size fits all”, have some major shortcomings from educational point of view (Botsios & Georgiou, 2008).

The alternative to “one size fits all” approach is Adaptive Educational Systems (AESs) that is an advance concept to make e-learning systems more effective by adapting learning material in accordance to learner needs (Chrysafiadi & Virvou, 2013). HCI research affirmed that user’s performance variations can be credited to individual differences (Glavinic & Granic, 2008). In the same way, ability of e-learning systems to adapt individual characteristics of learner may enhance their learning outcomes (Granic & Nakic, 2010; Nakic & Granic, 2009). Hence, AESs premised on the belief that adapting learning material in accordance to learner’s individual characteristics could optimize the learning outcomes (Lubart, 2005).

To pursue this goal, AESs place each student in the center of learning environment through Student Model (SM) to adapt content in accordance to his/her needs. The SM developed using individual characteristics such as goals, knowledge and preferences etc., which is later updated on the basis of user interaction history to cater student learning needs which eventually leads to better learning results (Lubart, 2005).

When we talk about the student modeling/user modeling or adaptive systems the most fundamental question comes in the way is: What are the characteristics of the user we want to model? Or what aspects of the student should we model in a specific AES? The researcher has to answer these questions when a new SM is constructed (Chrysafiadi & Virvou, 2013).

To answer above questions there should be complete understanding of individual characteristics of students to know that how they learn best so that effective adaptive learning systems could be developed (Alomyan, 2004). This chapter presents a comprehensive review of individual differences, their application particularly in AESs along with their impact on student learning and suggestions for future research. The chapter explains various individual differences including gender differences, prior knowledge, personality models, cognitive styles, cognitive abilities, affective states, motivation and learning style models along with corresponding measurement tools.

3.2 Analysis of Individual Differences

The individual differences in terms of learning have been studied in cognitive science. Here, we presented individual differences which are implemented in various AESs.

3.2.1 Gender Differences

It has been confirmed by neurological studies that male and female process information differently due to brain their variations. For example, female brain have greater area related to language relatively than males and better verbal processing capacity in the right hemisphere as compare to males. It has been indicated that males and females have differences in right relative to left hemisphere function. So, they process information in various manners which imply that gender has different preferences in learning environment. The traditional learning environment has been suffered by gender bias and inequity. Hence, gender should be considered to modify learning content to suits the needs of male and female. An important factor in this regard is that there is no difference in ability on the basis of gender while there are differences regarding the use of abilities among men and women. Furthermore, it has been observed that a male member of a particular cognitive style respond to a task in quite different way than female of identical style. Riding research explains that fundamental difference regarding information processing is that male process information at surface level whereas females process at deeper level and take time to process information which improve recall in females than males. On the other hand, the males do better than females in short processing time but females exceed males when large amount of time for processing is available. Additionally, it is advocated that verbal memory for males is poorer than females and its influence is heightened when information processing load is increased (Grimley & Riding, 2009).

Gender differences are known as an important factor in students learning as they have relation to learning behavior, motivation and student learning outcomes so it could be considered in the design of AESs (Grimley & Riding, 2009; Fan, 2008). Some researchers are disagree that gender has any influence on learning and formulation of learning strategies (Kickmeier, Albert, & Roth, 2007). It is therefore imperative to explore gender differences in the context of adaptive e-learning to investigate impact on learning. Rare studies are conducted considering gender differences to present gender fair learning content through AES.

3.2.1.1 Application in e-Learning

Fan (2008) conducted study to investigate interaction between gender differences and hypermedia learning. Based on the examination of empirical findings the set of rules were proposed which guides the design for gender sensitive adaptive hypermedia learning systems in relation to adaptive navigation support and adaptive presentation. Kickmeier et al. (2007) proposed an approach to model gender differences in which adaptive e-learning system starts from assessing gender of learner and relate it to suitable learning style and learning strategy for the selection of suitable learning objects. This study recommended that design of learning objects and test items should also be gender sensitive.

3.2.2 Knowledge Levels

In Intelligent Tutoring Systems (ITSs) and Adaptive Educational Hypermedia Systems (AEHS) AESs, the most widely utilized characteristic of learner is the Knowledge. Knowledge means prior knowledge or current knowledge of a learner in the domain of interest. Prior knowledge is very important factor in terms of student learning. In simple words, it is considerably easier to learn something new if learner have prior knowledge in the area of domain. A plentiful research has been done on the subject of prior knowledge and its influence on learning. Research summarized that prior knowledge is one of the most powerful and consistent learning characteristics that is predictive of academic achievement (Brusilovsky & Millan, 2007; "Learning Theories", n.d.). Students who failed to relate new knowledge with prior knowledge must face difficulty in understanding, recalling, and accessing new knowledge later. It is stated that the most significant single factor influencing learning is what the learner already knows." According to schema theory, individuals build schemata based on knowledge they have attained in the past (Rias & Zaman, 2013).

A growing body of research examined the influence of prior knowledge in AEHS which suggested that different types of content structure and navigation tools in web based learning suited to different levels of prior knowledge. It demonstrates that prior knowledge can determine how well learners acquire information from hypermedia and can influence their learning patterns in a hypermedia system (Mampadi, 2012). Hence, it is important to evaluate and identify level of student's prior knowledge to assist them in learning process.

Measuroement

The learner's prior knowledge is commonly measured through questionnaires and tests that the learners have to complete before the start of learning session (Chrysafiadi and Virvou, 2015).

3.2.2.1 *Applications in e-Learning*

Various AESs have been developed considering prior knowledge to impart adaptive instruction. These systems includes SQL tutor, TNAGOW, WILEDS, MEDEA Info Map which estimates student's prior knowledge for each domain to teach students accordingly. ELM-ART and Inter Book are two classic systems developed to present learning content according to the level of student's prior knowledge (Brusilovsky, Schwarz, & Weber, 1996). AELTT is another adaptive system which determines prior knowledge before starting the learning session in order to adapt content correspondingly (Durrani et al., 2015). Overall, the knowledge based system lacks in evaluation studies only few studies have shown statistically significant results.

3.2.3 Personality Models

Artificial Intelligence (AI) aimed at modeling of human behavior specifically for e-learning systems, greatly demanded in computer sciences. Personality represents the internal and external attributes of individual character which affect the behavior of human in different states. Before applying human behavior in computer applications, the knowledge and understanding of personality models is necessary as it helps researchers in making decision about the selection of appropriate model for computer application. The researchers postulated different theories to represent personality such as Carl Jung presented eight psychological types including *(i) Extroversion/introversion:* (extrovert focus on external world whereas introvert emphasis on his/her own ideas. *(ii) Sensing/intuition:* Sensing learners like to perceive information through five senses whilst intuitive persons perceive through their imaginative power. *(iii) Thinking/feeling:* thinking means that an individual have a preference to process information on logical grounds and feeling means person likes to process information in accordance to his/her emotions and feelings. *(iv) Judgment/perception:* judging people like to organize information using step by step approach and come to closure promptly whereas perceiving people are more flexible, consider alternatives and open to further options (Fatahi, Moradi, & Kashani-Vahid, 2016; Graf, 2007). Another theory of personality is "16 personality factor model". The model based on 16 factors that believed to be existed in the human personality. These factors are Warmth (A), Reasoning (B), Emotional stability (C), Dominance (E), Liveliness (F), Consciousness (G), Social boldness (H), Sensitivity (I), Vigilance (L), Abstractedness (M), Privateness (N), Apprehension (O), Openness to change (Q1), Self-reliance (Q2), Perfectionism (Q3), Tension (Q4). Eysenck had also introduced personality theory, based on three dimensions including *extraversion/introversion* (extrovert represent active behavior while introvert represent solitary behavior) *neuroticism /stability* (neuroticism refer to extreme level of negative effects e.g. anxiety whilst emotionally stable people remain cool and composed) *psychoticism/socialization* (psychotic behavior refers to features of tough mindedness and anger whereas socialization is opposite of psychotic behavior) (Fatahi et al. 2016; Kshirsagar, 2002). Moreover, Robert and colleagues proposed Five Factor Model (FFM) of personality which consist of *extraversion* (preference for behavior in social condition) *conscientiousness* (persistent in achieving objectives) *neuroticism* (tend to experience negative thoughts) openness (imaginative & creative) *and agreeableness* (friendly and cooperative) (Fatahi et al., 2016).

Measurements

Myers-Briggs Type Indicator (MBTI) is a popular tool to measure above discussed psychological constructs mainly related to Jung's personality theory. The tool has been widely used for educational purposes (Graf, 2007). 16PF questionnaire was developed to measure 16 personality factor model (Fatahi et al. 2016). Eysenck Personality Questionnaire (EPQ) was developed to assess the personality dimension introduced by Eysenck (https://en.wikipedia.org/wiki/Eysenck_Personality_Questionnaire).

3.2.3.1 *Application in e-Learning*

Fathai et al. (2016) reported that during last decade MBTI and Five Factor Model (FFM) have been extensively utilized in the field of computer science. The survey highlighted research on the modeling of personality using FFM and MBTI in different kind of applications such as character based user interface of speech recognition and speech generation, affective user interfaces, chat systems, conversational and virtual humans, virtual characters, video games, human/genetic robot on mobile phones and e-learning.

Bachari, Abdelwahed & Adnani (2010) proposed framework called LearnFit to recommend suitable learning material to learners on the basis of their personality dimensions identified initially through MBTI and fine-tuned later using Bayesian model to further accommodate learning needs. The results of an evaluation study showed that subjects of experimental group achieve better score than participants of control groups.

Al-Dujaily, Kim & Ryu (2013) research empirically revealed that learner's personality traits have significant impact on learning performance in the context of e-learning. An ITS was developed based on the adaptive logic of ELM-ART to teach programming course considering introversion and extroversion personality dimensions. The evaluation results confirmed that adaptive e-learning system based on personality dimensions impact student's learning performance in comparison to non-adaptive system.

Another research study investigated relationship between personality and emotions in virtual learning environment. The evaluation results confirmed that proposed model formulates the relationships between personality and emotions (Fatahi, Moradi, & Zonoz, 2015).

3.2.4 Cognitive Styles

The term cognitive styles state individual's ways to think, perceive and process information. It represents psychological dimensions which talk about the preferred ways of individual's to acquire and process information for decision making and problem solving. Cognitive styles are generally a facet of personality and cognitive processes. Cognitive and learning styles are sometimes used interchangeably but they have difference as learning styles is basically a preferred strategy which may change over the time but cognitive styles are immutable features of personality (Grimley & Riding, 2009; Uruchurtu, 2009; Mitchell, Chen, & Macredie, 2005). The individual differences in cognitive styles leads to unique ways to process and organize information which eventually impact student's learning performance (Lo, Chan, & Yeh, 2012; Calcaterra, Antonietti, & Underwood, 2005, Durrani, 1997). The major cognitive styles are explained as follows.

Field Dependent (FD)/Field Independence (FI) cognitive style resulted by the work of Witkin and his colleagues. It is one of the most researched cognitive style in terms of student's learning. FD learners depend on the context to focus and understand information whereas FI learners have ability to understand components of a structure field separately from its background (Shi, 2011; Mitchell et al., 2005; Triantafillou, Pomportsis, & Georgiadou, 2002; Durrani, 1997). The research confirmed information processing differences related to FD/FI during web browsing. For example, FD individuals have propensity towards linear navigation and restricted interface whilst FI prefer nonlinear navigation and flexible interface. Additionally, FD individuals have a preference for breadth-first navigation path, whereas FI individuals prefer a depth-first path. Moreover, FD users like to have a map on interface to impose internal structure, FI users on the other hand like to have an index to locate specific information. FD individuals have exposed worse performance than FI individuals in the absence of map on the interface as they got confused and distracted (Mitchell et al., 2005).

Wholist-Analytic cognitive style was introduced in 1993 by Riding and Cheema (Uruchurtu, 2009). The *Wholist-Analytic* style refers to the propensity of users to arrange information in parts or as a whole. These dimensions indicate the structure of information for presentation to learner. For wholist, information organized in a way that learner can take a broader view of topic before getting into further details. In contrast, Analytic learners focused on well-structured linear approach to grasp one topic at a time. Research point out that in computer based instruction wholists prefer instruction delivery with organizational aid while analytics prefer less structured material as they like to impose their on structure (Brown, Brailsford, Fisher, Moore, & Ashman, 2006; Calcaterra, Antonietti, & Underwood, 2005).

Visualizer/Verbalizer is related to the individual's preference about the format of learning material. Visualizers prefer to study material available in the form of images, diagrams and graphs while verbal learner like to learn through reading textual information and listening audio material (Kolloffel, 2012; Grimley & Riding, 2009). Riding and Douglas, asserted that verbalizers be likely to do better than visualizers in learning environment based on textual or auditory learning material whilst visualizers perform better in pictorial representation of learning content (Uruchurtu, 2009).

Measurement

The Group Embedded Figures Test (GEFT) is the most widely used tool to assess field dependent and field independent. The test measures FD by inquiring learners to find and trace a simple figure embedded into a more complex figure (Durrani, 1997). Cognitive style assessment (CSA) test was developed to measure both Wholist/Analytice and Visualizer/Verbalizer dimensions. CSA is a computerized assessment test to measure an individual’s propensity to think visually or verbally and preference to process information analytically or holistically (Calcaterra et al., 2005). Richardson created visualizer/verbalizer questionnaire (VVQ) to judge individual’s preference for visual/verbal learning. Style of processing (SOP) is another paper and pencil based questionnaire developed to assess verbal or visual preference of learners (Triantafillou, Pomportsis, Demetriadis, & Georgiadou, 2004).

3.2.4.1 *Application in e-Learning*

Adaptive Educational System using Cognitive Styles (AES-CS) has been designed to teach multimedia technology course considering FD/FI. The system examined the effect of FD/FI dimensions on learning processing. AES-CS support students according to their cognitive style through implementing instructional strategies such as global approach, information from general to specific, program control, advance organizers, structured lessons, maximum instructions and feedback, graphic path indicators and social features for FD learners. The presentation of information from specific to general, learner control, post organizers, minimal instructions and feedback, flexible lesson structure and individualized learning environment for FI learners. The evaluation showed that participants of experimental group outperformed than participants of control group. The qualitative feedback showed that participants were satisfied with the adaptive learning system. The findings confirmed that adaptivity based on cognitive styles positively impact the students learning (Triantafillou et al., 2004; Triantafillou et al., 2002).

Adaptive Web Based Learning (WBL) program was developed using separate interfaces for FD and FI learners and normal interface having characteristics for both FD and FI. The WBL program was designed to assess learning performance and perception using cognitive styles. The FD/FI interfaces were developed on the basis of findings related to cognitive styles research. The interfaces were designed using Adaptive Hypermedia (AH) techniques including link ordering, link disabling and adaptive layout. The system sorts link on the basis of learner's cognitive style. For example, for FD interface the links were sorted on the basis of breadth-first path and for FI interface using depth-first path. To avoid disorientation for FD restricted navigation path provided by disabling links whereas FI provided rich links to navigate interface with flexibility. As both FD/FI processes information differently so layout provided with map for FD and with index for FI. The normal interface designed using rich links and multiple navigation tools such as map, index and menus to assist participants in the use of learning material (Mitchell et al., 2005).

Ong (2001) conducted study to observe relationship between visualizer/verbalizer and learning performance through computer based training program for statistics. The material of training program was designed using two formats, diagrams for visualizers and text for verbalizer. The experiment results showed that there is no effect of cognitive style or corresponding format on students learning.

Brown et al. (2009) developed a web based educational system (WHURLE) to investigate the impact of visual/verbal cognitive style based personalization on students' academic performance. The students were categorized into matched, mismatched or neutral *(mix of visual and verbal material)* groups. The results showed no difference regarding academic performance of matched and mismatched groups. The qualitative feedback indicates that students found learning environment enjoyable and useful.

LEARNINT (Learning Interfaces) present two completely different interfaces. The first one designed for Wholist/Imager or visualizer (W/I) and second one for analytical/verbalizer (A/V). The main feature was the presentation style of contents: For A/V index of content was placed to enable *Analytics* to perceive the whole structure of the material and use the sequence they think best, henceforth increasing their control over learning environment. On the other hand, for W/I interface the sequence of content was set system using linear approach keeping content in structure of smaller chunks to allow graphical presentation of learning material. The evaluation results showed that matching the design of interface to learner’s cognitive style enhance their learning efficiency (Uruchurtu, 2009).

PROBE another learning environment developed to judge the relation of visual/verbal cognitive style with learning performance. PROBE consists of two versions which were different in terms of mode of content presentation. In one version, the learning material was mainly diagram based and in second text based. The evaluation findings showed that there is no relation between cognitive styles and learning performance (Kolloffel, 2012).

3.2.5 Cognitive Abilities

Cognitive abilities are related to mental functionalities which are defined as an individual’s distinctive way of perceiving, thinking, remembering and problem solving. The human cognition or mental functionalities are fairly constant over time and independent of task that’s why sometimes also known as domain independent parameters (Durrani, & Durrani, 2010; Tarpin-Bernard & Habieb-Mammar, 2005).

Cognitive abilities take account of how sound an individual give attention, perceive, think, reason, solve problems, learn and understand the nature of problem complexities (Durrani, & Durrani, 2010). Cognitive abilities differ from one individual to another individual. The advancement in psychophysiological techniques including brain scanning enabled to recognize variances in the processing of human brain (Tarpin-Bernard & Habieb-Mammar, 2005). The information of such variances is valuable regarding any educational environment. The knowledge of such differences is valuable in every educational environment because teaching methodology that possibly works fine for some students might be counterproductive for some other on account of difference in brain processing (Durrani, & Durrani, 2010). Identifying and integrating cognitive abilities such as spatial ability, WMC and reasoning in AESs would help us to design better human computer interfaces to facilitate learning of students. The major human cognitive abilities are WMC, Spatial Reasoning, Verbal Reasoning, Numerical Reasoning, Attention, Visual Thinking and Language. WMC is a mechanism to temporarily store and process information. The

WM is characterized by small storage capacity to hold information for a shorter period of time. Certainly, there are differences among individuals in respect of WM and these differences affect number of different tasks including comprehension, problem solving and reasoning. The WM of an individual perform major role in the learning process as the empirical investigations related to school aged students had showed that WMC have strong relation to comprehension and academic achievement (Grimley & Riding, 2009). An individual with low WMC cannot hold much amount of information in WM so if he is presented with plenty of information at same time s/he will face difficulty in absorbing all concepts as well as plentiful information cognitively overload the memory of user. Conversely, low WMC individual is presented with small amount of information at a time and the information is presented in chunks that would help him/her in comprehending and memorizing the information. If content presented in AES according to the memory limitations of the students, s/he will understand things efficiently.

Spatial orientation is the ability to keep track objects or locations in space even after a rotation on movement to a new location. Spatial manipulation involves the ability to mentally rotate two or three dimensional figures rapidly and accurately. Learners with high spatial abilities do better by graphical or spatially oriented content than those have low spatial ability. *Verbal reasoning* is the ability to reason using words. The individuals with high verbal ability can easily comprehend textually explained concepts easily. Conversely people with low verbal ability may feel difficulty in comprehending lengthy text which consequently affects the speed of learning. So, if learner has low verbal ability then content should be presented with the help of graphical media rather than textual presentation. *Numerical reasoning* is the ability to reason mathematically. The individual with high numerical ability can easily understand mathematical concepts and hence can solve problems easily. The learner with high numerical ability quickly understands the content presented in mathematical form as compared to learner with low numerical reasoning. So mathematical presentation should be minimal for learner with low numerical reasoning and if it is necessary it should be with thorough details. *Attention* is the ability to focus and concentrate on the task is called attention. *Visual thinking* consists of visual, auditory and logical thinking, visual thinking is the ability to understand, manipulate and manage through visual experiences and mentally formed images whereas auditory thinking is ability to understand through auditory experiences. Logical thinking based on systematic and organized thinking includes reasoning abilities such as deductive, inductive, classification and seriation. *Language* collocate expression processes and understanding as per oral and written codes of communication (Durrani & Durrani, 2010; Tarpin-Bernard & Habieb-Mammar, 2005).

Measurement

Cognitive abilities tests are widely used to assess the cognitive abilities of humans includes Cognitive Abilities Tests (CAT), Woodcock-Johnson III NU Tests of

Cognitive Abilities (WJ III NU Test) and Differential Aptitude Test (DAT). CAT measures reasoning ability and it is extensively utilized in the schools of UK and USA. This test measures the three main areas related to reasoning namely verbal, non-verbal and numerical. It also measure elements of spatial ability (Durrani & Durrani, 2010). The Working Memory Test Battery for Children (WMTB) is used to measure memory capacity of 15 years old children (Tsianos et al., 2009).

3.2.5.1 Application in e-Learning

C++ Loop Tutor (CLT) was developed using knowledge and cognitive abilities of students. Learner's cognitive abilities were assessed through cognitive tests. According to the results of assessments students were allocated to suitable stereotype to present content accordingly. The evaluation results showed that students presented content as per their prior knowledge and cognitive abilities perform better than those who studied only on the basis of knowledge level or in conventional classroom (Durrani & Durrani, 2010).

Cognitive User Modeling for Adaptive Presentation of Hyper-Documents (CUMAPH) environment was developed to adapt hyper-document presentation by picking the elements that best fit the user cognitive profile. HAPPY neuron an interactive web site was used to evaluate cognitive abilities including memory, attention, visual and spatial abilities, executive function and language. The results of experimental study showed positive impact on students learning performance (Tarpin-Bernard & Habieb-Mammar, 2005).

The research study proposed an adaptive approach to present learning material considering learner's WMC. The results showed that the performance of learners with low WMC can be improved using personalization techniques and in this way they can reach to the performance level of medium/high working memory learners ((Tsianos, Germanakos, Lekkas, Mourlas, & Samaras, 2010; Tsianos et al., 2009).

3.2.6 Affective or Emotional States

Darwin defines emotions as an individual's feelings either produced by external conditions or caused by physical conditions such as hunger and pain. Emotions are important part of a mental process which affects the whole learning process. A learner's behavior and abilities are modified by emotional state during learning, problem solving and decision making (Tarpin-Bernard & Habieb-Mammar, 2005). For example, anxiety impact the WMC of learner, if he has high level of anxiety he will utilize low working memory and if he has low level of anxiety he will use high capacity of working memory during learning process (Grimley & Riding, 2009).

Researchers believed that generally emotions can affect our logic during the state of panic, fear, love as well as our decisions in ordinary situations. The emotions have two forms positive and negative - positive emotions place information related to proficiency, opportunities and something with positive results which may increase intrinsic motivation. On the other hand, negative emotions encode the information of failure, risk and something related with negative results (Grimley & Riding, 2009; Neji & Ammar, 2007).

The learner's positive emotional state improves his/her learning performance and motivation whereas negative emotional state declines the learning progress. The AESs should identify emotional state of learner and provide adaptive behavior corresponding to the emotional needs of each individual. The emotional, states which impact the learning process also known as affective states which includes: anger, anxiety, happiness, sadness, interest, fear, frustration, boredom, concentration, enthusiasm, confusion and tiredness. Among these emotions happiness and concentration have positive impact on learning and distraction, tiredness, boredom negatively impact the learning process (Neji & Ammar, 2007).

In literature of cognitive psychology and computer science, number of valuable theories related to emotions has been framed. To support the concept of affective computing such theories are used to model emotional. For example Russell's circumplex model of emotion states two essential dimensions (axes) of emotions including activation vs. deactivation and pleasantness vs. unpleasantness. Number of different emotions *(i.e. afraid, annoyed, angry, excited, happy, delighted, content, calm, relaxed, depressed, bored, tired etc.)* arranged around these axes. Ekman's theory proposes six emotional states including *surprise, happiness, fear, anger sadness and disgust.* Another important theory is Ortony cognitive theory of emotions known as *OCC* model. The *OCC model* propose 22 in total emotions including happiness, resentment, gloating, pity, hope, fear, satisfaction, disappointment, relief, joy and distress emotions etc. (Grimley & Riding, 2009; Neji & Ammar, 2007).

Measurement

To identify user's emotional state biometric sensors and psychometric questionnaires were used. The biometric sensor measures skin conductance response including heart rate and the volume of blood pulse. Among psychometric questionnaire the Beck Anxiety Inventory (BAI) is a well-known self-reporting anxiety inventory. The Depression Anxiety and Stress Scale (DASS) is also a self-report questionnaire to judge the negative emotional states. The Geriatric Anxiety Inventory (GAI) is also a valid tool to assess anxiety specifically in older adults (Grimley & Riding, 2009).

3.2.6.1 *Application in e-Learning*

EMASPEL an e-learning system utilized agents to detect emotions through analyzing facial features. The system identifies Ekman's six basic emotional states including surprise, happiness, fear, anger sadness and disgust. The experimental study was conducted to recognize emotions in the human's animated face. The results indicate that emotions can be envisaged with small number of facial features (Neji & Ammar, 2007).

Charoenpit (2015) has designed an e-learning system to consider emotional aspects of Russell's 'circumplex model'. The system recognizes emotions related to Russell's 'circumplex model' by eye tracking and provide feedback to avoid boredom. The experimental results showed that e-learning system has potential to help learners in continuing learning.

Conati and Zhou (2002) utilized the OCC cognitive theory of emotions to identify user emotions for an educational game namely prime climb. Both positive and negative emotions were modeled including joy, admiration, pride distress, reproach and shame. The model was used by an intelligent pedagogical agent which try to improve student learning by positive emotional engagement.

VIRGE is another ITS game, implemented OCC theory in order to provide important evidence about students' emotions during learning process (Katsionis & Virvou, 2004).

Mobile medical tutor (MMT) incorporated affective features using authoring tool. The authoring tool adapts the principles of OCC to model possible emotional parameters which a tutoring agent may use for learning objectives. The medical instructors can use authoring tool to generate their personal educational characters which will interact affectively with their students during learning (Alepis & Virvou, 2011).

3.2.7 Motivation

Motivation is another important factor for successful learning. Different theories and models of motivation are available. Weiner proposed two major types of theories including mechanistic and cognitive based theories. Mechanistic theories premised on the concept that humans are like machine and they got motivated through their needs while according to cognitive approach individuals motivation is related to their thoughts and beliefs.

Eccles and Wigfield categories motivational theories into four classes. First is self-efficacy theory which emphasizes on the competence for success. Second category includes self-determination theory, flow theory, interest theories, and goal theories which stresses on the causes of individuals involvement in different activities. This category entails intrinsic and extrinsic motivation, achievement values, interest and goals. The third category unites expectancy and value concepts *(attribution theory, modern expectancy-value theories, self-worth theory).* Fourth category explains links between motivational and cognitive process *(social cognitive theories of self-regulation and motivation, motivation and cognition theories, theories of motivation with volition)*. These theories of motivation are rarely applied in e-learning.

Keller's theory of motivation and ARCS (Attention, Relevance, Confidence and Satisfaction) model are used to incorporate motivation in e-learning (Ramaha & Ismail, 2012).

Measurement

In e-learning systems, motivational constructs were measured through questionnaires, direct interaction, eye tracking analysis, dialog based and log based analysis (Ramaha & Ismail, 2012).

3.2.7.1 *Application in e-Learning*

Ramaha and Ismail (2012) proposed an approach to assess learner's motivational state by taking into account different motivational factors including effort, confidence and engagement in real time during web based learning activity.

Flores et al. (2012) developed adaptable tutorial considering prior knowledge and motivational model. The motivation of students was measured using Keller's Instructional Material Motivational Survey (IMMS) which based on ARCS motivational model. The results showed the students both with low and high motivation equally benefitted from tutorial in terms of motivation gain. However, students with high motivation spent more time on learning study material than low motivation students.

ChanLin (2009) designed web based lesson guided by Keller's ARCS motivational model. Co-operative and task oriented learning activities were used to boost student's learning motivation. The students were found positive regarding the motivational design of web based instruction and tools used to improve their learning motivation.

3.2.8 Learning Styles

The students have different preferences, needs and approaches to learning which are called learning styles by psychologist. Learning style can be defined as "a specific way in which an individual learns". It is widely believed that learning style is predictor of quality learning experience. Researchers asserted that learner's performance and academic achievement can greatly increase by presenting learning content according to their learning styles (Hamada, 2012; Surjono, 2011, Klasnja-Milicevic, Vesin, Ivanovic & Budimac, 2011). The researchers are agreed on the importance of adaptation toward learning styles in e-learning (Graf, 2007, Stash, 2007; Deborah, Baskaran, & Kannan, 2014). It is therefore highly suggested that the contents of e-learning system should be designed to accommodate learners with different kind of learning styles (Deborah et al., 2014; Markovic & Jovanovic, 2012). There are many learning style models but few of them have been classified as major models owing to their theoretical importance and widespread usage. Graf in her PhD dissertation described some learning style models which are theoretically important and could be used in future systems (Graf, 2007). These models are discussed as follows.

3.2.8.1 Felder-Silverman Learning Style Model (FSLSM)

FSLSM define learners into four dimensions including *active/reflective, sensing/intuitive, verbal/visual* and *sequential/global*. *Active* learners learn best by applying and experimenting learning material. In contrast *reflective* learners like to think and reflect on learning material. *Active* learners prefer group discussion whilst *reflective* learners like to learn alone. Learners with *sensing* learning style like to learn content at concrete level, they are lean towards details while *intuitive* learners like to learn material at abstract level including theories, common principles and basic meanings rather than grasping knowledge at concrete level. The visual/verbal learning styles discern learners on the basis of preferred mode of receiving information that help them to remember best. For example, *visual* learners remember best information presented in the form of pictures and diagrams whereas *verbal* learners get more out of verbal information either written or spoken. The *sequential* learners prefer to learn in linear order while *global learners* tend to learn in large leaps.

Measurement

To measure FSLSM, Felder and Soloman developed Index of Learning Styles (ILS) which consists of 44 questions, 11 for each dimension. Every learner has personal preference regarding each learning style. These preferences are describe using values between +11 to -11 for each dimension with steps +/-2.

3.2.8.2 Dunn and Dunn Learning Style Model

The model consist of five variables where each variable entails multiple features such as *environment* variable involves sound, temperature light and seating arrangements. The *sociological* variable consists of preferences related to learning alone, with peer or in group. The *emotional* variable includes factors such as motivation, conformity/responsibility, persistence and structure. The physical variable involves factors about perception/modality preferences (visual, auditory, tactile and kinesthetic), food and drink consumption, time of day and mobility.

Measurement

To measure Dunn and Dunn learning style model two tests have been developed separately for children and adults. Learning Style Inventory (LSI) was developed to measure children preferences and Building Excellence Inventory (BEI) was developed to measure adult’s low or high preference for each factor.

3.2.8.3 Kolb’s Learning Style Model

Kolb’s underline four predominant types of learners including converger, diverger, assimilator and accommodator. *Convergers* are best in eliciting facts, analyzing and synthesizing them to solve a particular problem. There strong point is practical application of ideas. *Divergers* are excellent in observing concrete situation with different dimensions and establish relationships to meaningful form. They have ability to generate ideas and tend towards creativity. *Assimilators* are best in inductive reasoning and have ability to assimilate dissimilar information and represent it coherently, their strength lie in developing theoretical model. *Accommodators’* strong point is that they perform things actively, carry out plans and experiments as well as like to get involve in new experiences.

Measurement

To identify Kolb's learning style dimensions the Learning Style Inventory (LSI) was developed and revised many times. The current version of LSI consists of 12 sentences asked learners to determine their preferred way of learning.

3.2.8.4 Honey and Mumford's Learning Style Model

Honey and Mumford learning dimensions are *Activist*, *Theorist*, *Pragmatist* and *Reflector*. *Activists* take full interest in new experiences. They are passionate about new things and perform best by doing something actively. *Theorists* surpass in adapting and incorporating observations into theories. They require models and concepts to involve in the learning process. *Pragmatists* prefer to involve in real world applications of the learned material. The like to experiment on theories and ideas to see if they work in practice. *Reflector* people look into the experiences of other people from many different viewpoints to reach a conclusion. They learn through observing and analyzing others experiences.

Measurement

To measure Honey and Mumford's learning styles; Learning Style Questionnaire (LSQ) was developed and revised multiple times. Currently two versions of LSQ are available, one with 80 items and second with 40 items.

3.2.8.5 Grasha-Riechmann Learning Style Model

Grasha and Riechman recognized three bipolar constructs to understand learner's behavior. These constructs are *Participant/avoidant:* Learners with participant style enjoy the learning environment and get fully involved in classroom activities whilst students with avoidant style do not take interest in learning and do not enjoy the classroom environment. *Collaborative/competitive:* Collaborative learners view classroom, a place of learning and enjoy learning through interacting with others, they are supportive to others. In contrast, competitive learner views their fellow students as competitors. They enjoy competition and motivated merely to perform better than others. *Dependent/independent:* Dependent learners view teacher as the source of information and depends merely on information given by teacher whereas independent learners defined as confident and inquisitive learner. They like to think and explore subject on their own rather than relying merely on delivered instruction.

Measurement

Grasha and Riechmann developed self-report 5-point Likert scale inventory known as Student Learning Styles Scale (SLSS) to measure their six dimensions. The inventory consists of 90 items 15 for each dimension.

3.2.8.6 Pask's Serilaist/Holist/Verstailist Model

Pask identified three different types of learners including *serialist*, *holistic* and *verstailist*. They vary from each other in organizing, selecting and representing information. *Serialist* use serial learning strategy, they like to learn step by step in a linear order and emphasize on clearly defined chunks of information. Conversely, holists use holistic learning strategy; they prefer to develop broader understanding of topic. At the same time, they focus on multiple aspects of the subject. Verstailist learners apply both serialist and holist learning strategies to achieve deep understanding of learning material.

Measurement

Pask developed tools including Spy Ring History Test and Clobbits test to measure serialist, holist and versatile learning styles.

3.2.8.7 Entwistle's Deep, Surface and Strategic Learning Approach

This is based on the work of Pask, Marton and Biggs, identified three approaches of learning including *deep*, *surface* and *strategic*. The learners with deep learning approach intrinsically motivated and intended to know the meanings of concepts. They actively engage with course and accept information through logical and critical argument. Conversely, the students with surface learning approach motivated extrinsically and intended to complete minimum requirement of course. They focus on memorizing only those bits of knowledge which are likely to be assessed. They feel difficulty in grasping new concepts, feel pressure of study and fear of failure. The students with strategic learning approach apply both deep and surface approaches for best performance in exam.

Measurement

To measure these approaches several tests have been developed including Approaches to Studying Inventory (ASI), Course Perception Questionnaire (CPQ), Revised Approaches to Studying Inventory (RASI), the Approaches and Study Skills Inventory for Students (ASSIST) and Approaches to Learning and Studying Inventory (ALSI).

3.2.8.8 Learning Styles Relation to Culture

Hofstede defined culture as the "collective mental model which discriminates the members of one kind of people from other" (Kamentz, 2005). It is commonly believed that culture has influence on learning. A research study answered question: *Does individuals living in different cultures are different in term of their learning styles or learning approaches?* The results showed that culture has significant effect on learning style of students. The learning styles are influenced by family setup and norms at school (Kamentz, 2005; Wursten & Jacobs, 2013). An empirical analysis indicated that learning styles are culture bound cognitive schemes. The people from diverse cultural background such as French, German and Quebecois may vary in the way they think and act. It was revealed that German students have considerably diverse learning style preference relative to French and French-Canadian students (Wursten & Jacobs, 2013). Various studies have been conducted using Kolb's learning style inventory (KLSI) which found important difference in the learning style preferences amongst the students from various countries. For example, Chinese students in Taiwan and Hong Kong were inclined towards abstract and reflective learning style whereas their fellow students from Australia have concrete and active learning style (Levinsohn, 2009). Another study comparatively analyzed the learning approaches taken by Chinese and students of New Zealand. Results showed that Chinese student process learning material step by step with complete details and learn the factual information by heart while New Zealand students favor deep processing [108]. The research studies provided significant empirical evidence to point out that culture have strong influence on student's learning styles (Levinsohn, 2009; Barmeyer, 2004; Cagiltay & Bichelmeyer, 2000; McLoughlin, 1999).

We have closely observed the learning culture in public schools of Pakistan in order to associate students with specific learning style. The main practice used in such schools is rote learning. Owing to the dearth of teachers classrooms are generally crowded and teachers are overloaded. The major method used by teachers is memorization. Students usually take a passive role, accepting all information presented them by teacher. The major learning source available to them is merely poor quality textbooks. The teachers convey information related to subject using oral communication in the form of spoken words. All students are presented with same content. In Pakistani schools, the teaching methodology and overall learning scenarios favors surface approach. The prevailing surface approach effects even to those students intend to deeply process the learning material. It is therefore suggested to consider deep vs. surface approach in learning application(s) to promote deep processing of learning material and support learners with surface approach and gradually move them towards deep learning.

3.2.8.9 Application in e-Learning

The pioneer work regarding learning styles was CS 383 in which *visual/verbal* and *global* dimensions of FSLSM were exploited to cope up problems of inefficient and ineffective learning through hypermedia courseware (Carver, Howard & Lane, 1999). The causal feedback collected by various researchers about the learning experience using CS 383 described it uniformly positive. Arthur (2000) modeled *auditory/visual* and *tactile* learning style to adapt instruction in order to improve learning outcomes. The learners of Arthur reflected satisfactory learning experience. INSPIRE modeled knowledge along with *Honey & Mumford learning style model* to present individualized web content. The evaluation results showed overall satisfactory learning experience. This system, however, lacked in presenting varied contents as it only provided different sequences of the same knowledge module (Papanikolaou, Grigoriadou, Kornilakis, & Magoulas, 2003). Bajraktarevic, Hall, & Fullick (2003) (ILASH) considered learning strategies to prove that adaptive features in educational hypermedia can improve the learning outcomes and comprehension. In another study authors designed user interfaces considering *global* and *sequential* dimensions of FSLSM. The empirical evaluation showed that students presented with learning material matching their learning style obtained significantly better results than students who were provided mismatched learning material (Bajraktarevic et al., 2003). Graf (2007) research addressed the issue of non-adaptivity in Learning Management Systems (LMS) through modeling *active/reflective, sensing/intuitive* and *sequential/global* dimensions of FSLSM The evaluation showed that matched group found learning easier and satisfactory while no difference was found among matched, mismatched and standard group in terms of academic score. Brown, Brailsford, Fisher, & Moore (2009) conducted research with e-learning platform namely *Digital Environment Utilizing Styles (DUES)* to assess the impact of *sequential/global* dimensions of FSLSM on the academic performance of students. Indifferent results found in terms of academic performance among three groups. LS-PLAN incorporated student's *prior knowledge* and all dimensions of *FSLSM* to present adaptive learning material. The results showed 24.54% increase in the knowledge of students (Limongelli, Sciarrone, Temperini, & Vaste, 2009). iWeaver modeled perceptual and information processing dimensions of *Dun & Dun learning style* to adaptively present interactive multimedia learning material to improve learning. The results showed no significant impact on learning outcomes (Wolf, 2007). The Web based Educational System with Learning Style Adaptation (WELSA) integrated Unified Learning Style Model (ULSM) into student model. The ULSM is based on different constructs extracted from different learning style models. The evaluation showed that adaptive approach improve efficiency of learning process but no significant improvement found in terms of learning outcomes (Popescu, Badica, & Moraret, 2010; Popescu, 2009). Mampadi, Chen, Ghinea, & Chen (2011) developed Adaptive Hypermedia Learning Systems (AHLS) using two different interfaces one adapt to serialist learner and another to holist. AHLS subject's academic performance was compared with participants of non-adaptive system - Ordinary Hypermedia Learning System (OHLS). Results showed significant differences in learning outcomes and performance of AHLS and OHLS participants. Additionally, AHLS participants have more positive perception regarding navigation structure and other features provided in system. Oscar an Intelligent Tutoring System (ITS) intends to imitate human tutor through implicit modeling of FSLSM during tutoring. It responds to learner's questions as per their learning styles. The empirical evaluation showed that learner found tutor helpful and achieved learning improvement by 13% (Latham, Crockett, McLean, & Edmonds, 2012). Protus (Programming Tutoring System) recommends learning content in accordance to learning style of learners. The evaluation results showed that experimental group completed course in less time than control group (Klasnja-Milicevic et al., 2011). UZWEBMAT is an adaptive and intelligent individualized e-learning environment present learning content considering visual, auditory and kinesthetic (VAK) learning styles. The results of evaluation study showed positive impact on student's learning and suggested to use UZWEBMAT to strengthen classroom education (Ozyurt, Ozyurt, Baki, & Guven, 2013).

Another adaptive learning system was developed considering all dimensions of Felder Silverman's learning style (FSLSM) along with FD/FI cognitive styles. The system intends to deliver personalized learning contents and learner's preferred interface setting for easy processing. The empirical study was conducted to evaluate the impact of proposed approach on learning computer science course. The participants were divided into control and experimental groups. The experimental group learned course using adaptive learning system and control group studied in conventional learning environment. The results showed that experimental group students performed better in terms of learning achievements than students of control group (Yang, Hwang, & Yang, 2013).

It is concluded from above analysis that there are many characteristics of individuals which differentiate them from each other but most of the research studies conducted so far focused on the single source of personalization. For example initial research related to AESs has emphasized on the modeling of domain knowledge in order to deliver adaptive learning experience. Later research has mainly focused on the integration of different learning/cognitive style dimensions in student model. Rests of the individual characteristics have scant utilization in e-learning context. There shortcomings of existing research are identified which are as follows.

3.3 Limitations

Following shortcomings have been found in previous research (Truong, 2016; Haynes, Underwood, Pokorny, & Spinrad, 2014; Yang et al., 2013; Abraham, Balasubramanian, & Saravanaguru, 2013; Akbulut & Cardak, 2012; Mulwa, Lawless, Sharp, Arnedillo-Sanchez, & Wade, 2010; Essalmi, Ayed, Jemni, & Graf, 2010; Brown et al., 2009; Brusilovsky & Millan, 2007; Wolf, 2007).

- The influence of learning/cognitive style based adaptation on learning outcomes is still unclear, mixed results are reported.
- The overall success of AESs towards academic achievement is still low.
- The literature highlighted various important learning styles models but only few of them recurrently modeled for adaptive learning experience. The most preferred learning style model was FSLSM which has been utilized in almost 50% of research studies, 17.1% utilized cognitive styles, 9% Kolb's learning style model, 7.1% VARK model, 6% Honey & Mumford learning style and other models such as Dun & Dun. The learning styles related to study approaches and strategies such as Deep vs. Surface approach has been completely neglected in researches conducted so far.

- It is indicated that only learning style based instruction has limited effectiveness because they characterize only a single aspect of student characteristics.
- Similarly, among cognitive styles FD/FI were mainly taken into account while rest of the dimensions has been given less focus.
- In existing literature majority of the research studies have not indicated the reason to choose particular learning style model. There are small number of papers which have some motivation and intuition regarding the selection of particular learning style model for adaptive learning.
- Most of the previously discussed AESs are based on single source for personalization. The combination of different personalization parameters including prior knowledge, WMC, learning/cognitive styles and affective states to impart adaptive learning is an open research problem.
- There is a deficiency of empirical evaluations among AESs research studies, only few studies have presented statistically significant results.
- Most of the systems had recycled existing learning material instead of designing pedagogical contents considering local and cultural aspects.

3.4 Recommendations

Obviously learners could vary from each other in many ways. For example, learners with same learning preference may vary from each other in terms of cognitive capacities, emotions, prior knowledge, background and/or experience etc. Therefore considering a single variable to provide adaptivity is not enough to fully influence the learning process that is why combination of different effective variables is imperative to enhance learning. The large numbers of individual characteristics identified in literature are potentially relevant to adaptation in e-learning. The use of multiple effective personalization parameters in AESs have not been given much focused in existing research so that research in this area is incomplete and requires further investigation by employing combination of different parameters to impart learning. The combination of different characteristics of learners that should be considered when delivering personalized learning is an open research problem (Truong, 2016; Graf, 2012; Brusilovsky & Millan, 2007). It is affirmed by different researchers that considering multiple dimensions of learner significantly improve the learning achievement (Belk, Germanakos, Papatheocharous, Andreou, & Samaras, 2014; Yang et al., 2013; Inan, Flores, Grant, 2010). A content analysis of recent research studies *(47 peer reviewed journal articles, 13 preceding papers & 06 dissertations)* on LS based AESs reported that findings in terms of student learning outcomes were controversial and unclear so learning style should be considered with the combination of other significant variables such as Prior knowledge, WMC and competence. Hence, future studies should focus on the identification of effective variables which affect student learning at large extent. There are so many learner characteristics that could be used to adapt instruction. It is therefore crucial to determine the most important characteristics and focus future adaptability efforts on such variables (Akbulut &

Cardak, 2012; Surjono, 2011). Moreover, there is a need of experimental studies to judge the effectivity of AESs based on different learner characteristics (Abraham et al., 2013).

3.5 Effective Personalization Parameters

Following learning characteristics are identified as effective personalization parameters for proposed approach.

3.5.1 Deep vs. Surface Learning Styles

To accomplish research objectives, Entwistle's Deep vs. Surface learning style is selected mainly owing to two reasons. One is that such learning approaches have not considered in previous studies, second and most important is that it is highly related to the learning culture of the country where study is carried out.

This learning style has three main dimensions *(Deep, Surface and Strategic)* and two sub dimensions *(Holist and Serialist)* which are cognitive style dimensions but according to Entwistle's model such dimensions are associated to deep learning style. The strategic approach is out of the scope of this study as the system mainly intends to support surface learner to make them successful in their study and provide enrich learning environment to deep learners in order to tape their full potential (Entwistle, 2003).

ASSIST is used to measure student's learning styles (Tait, 1996) and categories them as Deep or Surface learner. Deep learners are further categorized into serialist or holist. The validity and reliability of tool is confirmed by different research studies conducted in different countries including America, Europe and Egypt as well as exercised in the environment of Pakistan (Gadelrab, 2011; Speth, Namuth, & Lee, 2007; Byrne, Flood, & Willis, 2004). The below Figure 1, visually highlight the two most important dimensions of the model.

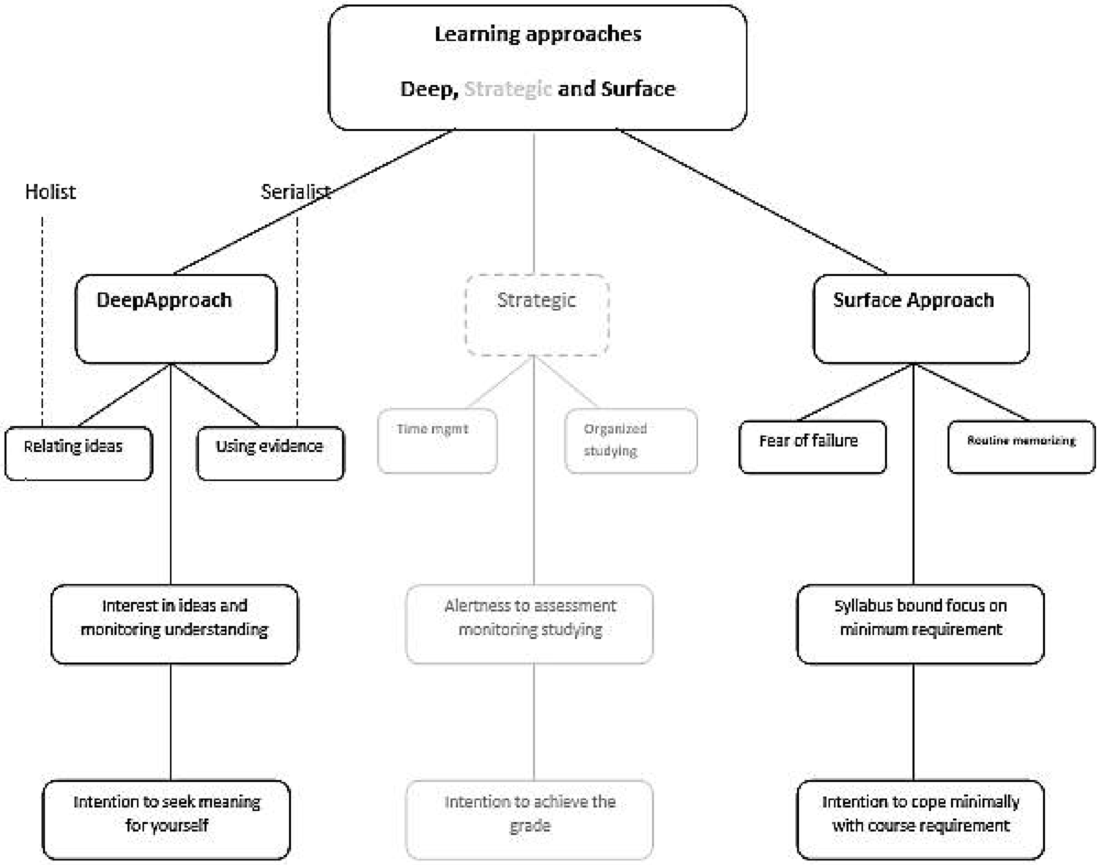

Figure1: Visual representation of Deep, Surface learning approach (Source: Entwistle, 2003)

Students who take a deep approach are intrinsically motivated having intention of understanding the whole picture, relate ideas to one another; make use of evidence which leads to understanding and long-term retention of concepts. The students with surface approach have not intended to understand the subject rather memorization of concepts as isolated and unlinked facts. They are extrinsically motivated; they just wanted to pass the course.

3.5.2 WMC

WMC keeps active a limited amount of information for a very short period of time. It affects students' learning ways to execute complex cognitive tasks such as reading comprehension and problem solving (Lin, 2007). Research on working memory has shown that the learning efficiency, retention of learned concepts, recall, skill acquisition and learning abilities are all affected by its WMC (Graf, Liu, Chen, & Yang, 2009). Providing content that overloads the cognitive capacity of the learner might greatly discourage them and after a while hamper the learning process. WMC could be key factor in adaptive e-learning to improve learning and retention (Graf & Kinshuk, 2014; Belk et al., 2014; Tsianos et al., 2009, 2010). Keeping in view previous research suggestions (i.e. incorporating LS with WMC) and importance of WMC in terms of improving learning and retention, it is also selected as personalization parameter for proposed approach.

3.5.3 Prior Knowledge

Prior knowledge is also considered as adaptive parameter for proposed approach. Mampadi confirmed that adaptive learning systems which adjust students' prior knowledge improve learners' performance and positively impact their perception. It is therefore recommended to consider combination of prior knowledge and learning/cognitive styles to deliver personalized learning experience (Mampadi, 2012; Mampadi, Chen, & Ghinea, 2009).

The proposed approach considers above mentioned three parameters to deliver adaptive learning experience in an expectation that these parameters would help to improve learning, retention and satisfaction of each learner.

3.13.4 Corresponding Instruments/Measures

- *Prior Knowledge (PK):* A self-designed tool will be used to diagnose student level of knowledge in English preposition to classify them into Low and High PK categories.
- *Working Memory Capacity (WMC):* WMC of each student will be measured via WMTB-C a standardized test for ages between 5- 15 years. The students will be categorized into Low WMC and High WMC groups.
- *Learning Style (LS):* Learning style will be identified using Entwistle's assessment tool called ASSISST to categorize students into Deep or Surface approach. The deep approach will further classify considering its sub-dimensions namely serialist and holist.

3.14 Summary

Various psychological models discussed in literature which differentiate individuals from each other as well as influence their academic performance positively as well as negatively. Although many models of individual characteristics exist but in AESs learning style models have been utilized, rest of the individual characteristics are still underexplored. Undoubtedly, learning style is a predictor of quality but it is not single contributor to quality learning. There are also other predictors of quality learning such as prior knowledge and cognitive abilities etc.

The research reported that LS based AESs have low impact on learning outcomes. It is therefore imperative to conduct further research studies using combination of some other effective parameters including WMC and prior knowledge etc., with learning styles in AESs to see their impact on learning (Graf, 2012).

There are many different learning style models exist which have relevance to technology enhanced learning. Among them, FSLSM found the most prevalent learning style model applied in AESs. A category of learning styles namely learning approaches specifically Entwistle's deep/surface approach has been completely ignored in previous research. Hence, it is recommended to apply learning approaches in AES to see their impact on student's learning.

A recent research has suggested to explore combination of individual characteristics in AESs for better adaptation. Such combination of individual characteristics possibly support and add value to each other. Author asserted that learning style based adaptive systems are still at the early stage, therefore further research studies and development are required using other individual characteristics. The evaluation especially statistical evaluation is highly recommended (Truong, 2016).

It is also suggested that before choosing learning style explore its relation to learning culture because learning style have a strong link to culture. Nonetheless, whichever learning style picked up by researcher, thorough identification of its strength and limitations must be explored.

AESs considering any single individual characteristic could not fully impact the learning process because through single factor learner cannot be realized thoroughly. So it is suggested that researchers should explore the link exist among individual difference or at least consider complementary variables while developing AESs. For example, if simply learning style is utilized for adaptation of learning content but learner's knowledge, background, emotions or WMC is not considered then there are less chances of exceeding learner's performance. With mere learning style based adaptation learner may found content relatively satisfactory but most probably in absence of prior knowledge he/she face difficulty in understanding the concepts because knowledge gap is there. In AESs, utilizing combination of cognitive and non-cognitive parameters specifically complementary, to adapt learning content is an open research issue (Graf & Kinshuk, 2014; Graf, 2012). This open research problem is being addressed in proposed approach.

CHAPTER 4

AES APPROACHES, METHODS AND TECHNIQUES

This chapter discusses the major components of AESs including Domain Model (DM), Student Model (SM) and Adaptive Model (AM) along with approaches used to build student or learner model including explicit, implicit and adaptation technologies used in different adaptive systems. Additionally, some example AESs are explained in terms of their working.

4.1 AES Components

An effective AES needs a strong commitment to DM, SM and AM which are described below in detail.

AESs generally rely on the domain knowledge, student/learner information and instructional strategies to provide adaptation including adaptive content, hints, guidance and feedback to learners. The domain model, learner information and instructional strategies are arranged into separate software modules. The knowledge, AES intends to convey to learners is kept in DM. The information related to students including knowledge level in specific domain, their learning styles and abilities etc. are maintained in SM. The AM consists of the information *(pedagogical method or strategies)* that can be used to deliver appropriate learning content to students. The interaction of these models with each other enable an adaptive system to determine the state of learner in order to tailor instruction as per his/her learning needs without the involvement of human tutor (Alshammari, Anane, & Hendley, 2014; Al-Azawei, & Badii, 2014; Carapina, 2013). The three models are described as follows.

4.1.1 Domain Model (DM)

The DM represents set of knowledge elements which structured the knowledge of a particular domain. The knowledge elements are termed differently in different systems for example concepts, knowledge items, topics, learning outcomes and learning objects etc. [182]. The knowledge of domain can be categorized into declarative and procedural knowledge. DM can be represented using different schemes including frame based, network based, logic based and ontology based. A frame based representation contains frames that have different characteristics which describe knowledge elements. A network based schemes depicts network of nodes and edges to denote concepts and their relationships to each other for example prerequisite relation (expressing the fact that a certain concept should learn before another concept) or semantic relation (i.e. “is-a”, “part of”) between concepts. A logic based representation normally deals with knowledge which can be stated as rules (Truong, 2016 Alshammari et al., 2014; Al-Azawei, & Badii, 2014; Carapina, 2013).

4.1.2 Student Model (SM)

Generally, in adaptive systems the term "user model" is used which characterize the internal representation of user's characteristics. The user model is applied to gain individualized response form the system. The user model has applicability in multiple domains including search engines, e-commerce, recommender systems, help systems and e-learning systems. The concept of user model is termed as learner model or student model is the context of educational domain. Hence, throughout in the thesis we will use the tem student model.

SM is a major component of AES which contains sketch of student's level of knowledge, any misconceptions, learning style and behavior. It maintain the complete information regarding each student for example what s/he knows and what s/he does not knows, what s/he misconceived and to what extent s/he has grip over a certain topic or concept as well as how s/he prefer to learn etc. On the basis of such information, AESs makes decision to teach each student in accordance to his/her learning needs (Alshammari et al., 2014; Al-Azawei, & Badii, 2014; Carapina, 2013).

4.1.2.1 Types of Data

The SM mainly contains two types of data including domain dependent and domain independent.

Domain Dependent Data (DDD):

The DDD refers to information which is related to domain knowledge such as it define students prior knowledge in the domain, their level of understanding of domain knowledge, misconceptions they have in the domain and error that they made during learning session, evaluations/assessments and so forth (Truong, 2016; Durrani, 1997).

Domain Independent Data (DID):

The DID represents information related to behavior and cognitive capacities of learners, independent from any domain. The DID is a composition of two elements including psychological model and the generic model of the student profile. The psychological model represents learning/cognitive styles, cognitive and affective characteristics of the learners. The data related to user interests, background and experience are maintained in generic profile of student. The research literature stressed on the need to consider both domain dependent and domain independent characteristics of the learner in order to carry out efficient adaptation (Truong, 2016; Durrani, 1997).

4.1.2.2 Approaches to Student Modeling

In order to incorporate learner's individual characteristics in SM different approaches have been introduced to imitate the real learning preferences of student. First step to construct SM is the collection of data. If AESs can accurately represent leaner characteristics, certainly a robust learner model could be built. Then the equilibrium between learning content and varied learning needs can be recognized in order to present the most apposite learning material to each learner. The two major approaches including *explicit* and *implicit* are used to identify learner characteristics. Each approach has some pros and cons. For example, the benefit of explicit approach is that it produces authentic information regarding learners. Similarly, implicit approach showed natural attitude of learner. Both approaches have some shortcomings for example in explicit approach, the student answers to questionnaire are likely to be biased and using implicit approach it is difficult to collect, measure and interpret learner behavior. The selection of approach depends on the context of study. Usually, researchers choose approach they feel suitable to specific situation (Martins, Faria, De Carvalho, & Carrapatoso, 2008; Graf, 2007). Both approaches are described below in detail.

Explicit Approach

The explicit approach refers the way to directly gather information from students through explicit user feedback or self-reporting questionnaire. Explicit approach is also known as user guided modeling, explicit user feedback and collaborative approach. Regardless of explicit approach shortcomings, almost half of the studies used it to collect individual learning characteristics. Through explicit approach data can be collected and interpreted with ease that's why it has share in large number of studies. The major drawback of this approach is that results could be biased or inaccurate as the response to questions depends on the judgment of respondents. Hence, if its shortcomings are addressed the accurate results could be taken (Abraham et al., 2013; Martins et al., 2008; Graf, 2007).

Implicit Approach

The implicit approach refers the way to automatically detect user characteristics through learner's interaction with learning environment. The methods to automatically deduce learner features are developed mainly for learning styles and affective states. There are many other individual characteristics such as cognitive abilities which are difficult to deduce by learner interaction. Hence, for the identification of these variables researchers rely on psychometrics instruments. The implicit approach is also known as automatic student modeling, dynamic student modeling or implicit user feedback. In automatic student modeling, the behavior and learner actions are observed in order to detect his/her learning style. Dynamic student modeling means that learner models are updated through automatically collected information. Implicit approach can provide precise results as it reflects the natural attitude of learners to accurately characterize their actual preferences. The difficulty of calculating and analyzing learner's behavior is the major drawback of implicit approach (Al-Azawei & Badii, 2014; Abraham et al., 2013; Martins et al., 2008; Graf, 2007)

The implicit approach further categorized into data driven and literature based approaches. The clear difference between these approaches is the availability of supported data.

Data-Driven Approach

The approach is constrained by the availability of sample data that's utilized as an input for training purposes. The major benefit of this approach is the precise classification from actual data. Different methods including Bayesian network, Decisions Tree, Hidden Markov Model (HMM) and Feed Forward Neural Network (FFNN) were used in different research studies to implicitly identify student learning needs (Al-Azawei & Badii, 2014; Abraham et al., 2013).

Literature Based Approach

In this approach, first of all the link between behavioral patterns and learning styles has to be established. Afterward, the behavior and action of learners are observed to use as clues regarding their preferences by applying simple rule method to handle the deficiency of data driven approach. Graf, in her dissertation defined that the strong point of literature-based approach is its ability to detect learning style without requiring training data. The data driven approach is dependent on the availability of data set whilst literature based approach directly rely on learning style model (Al-Azawei & Badii, 2014; Abraham et al., 2013; Graf, 2007).

Further, the working of implicit approach taken from (Abraham et al., 2013) is explained by below figures.

Step 1

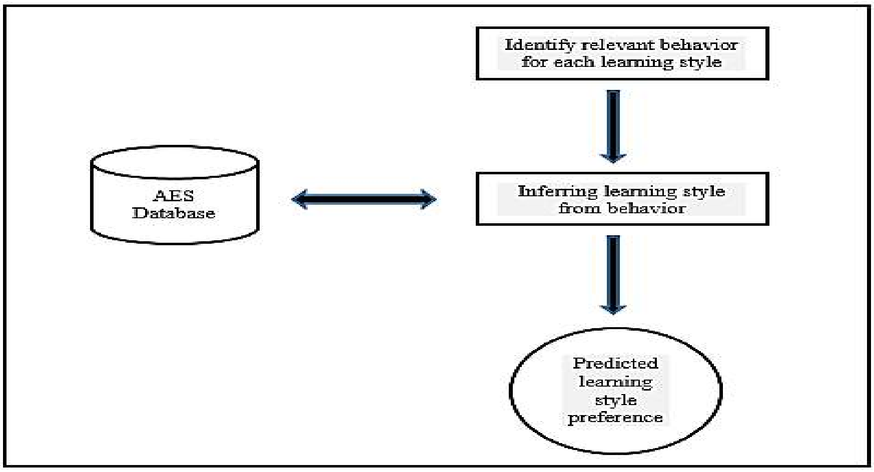

Figure2: Automatic detection of learning style (Source - Abraham et al., 2013)

Step 2

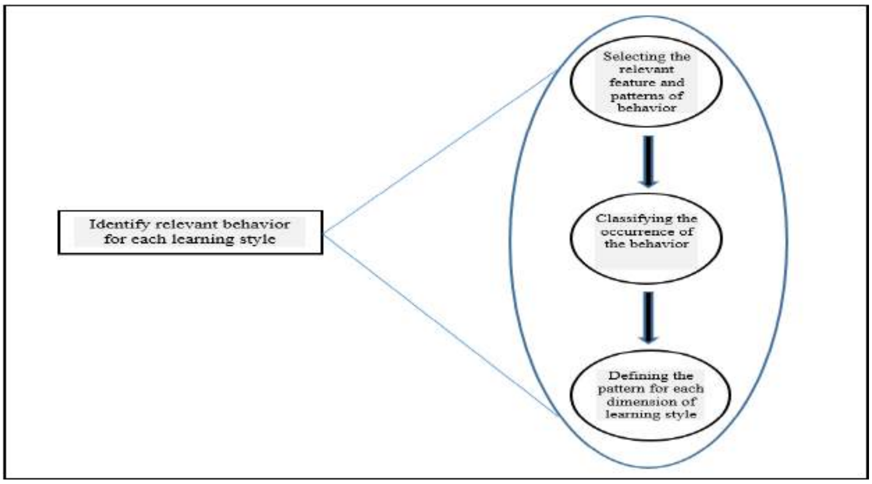

Figure 3: Identification of behavior corresponding to each learning style (Source - Abraham et al., 2013)

Step 3

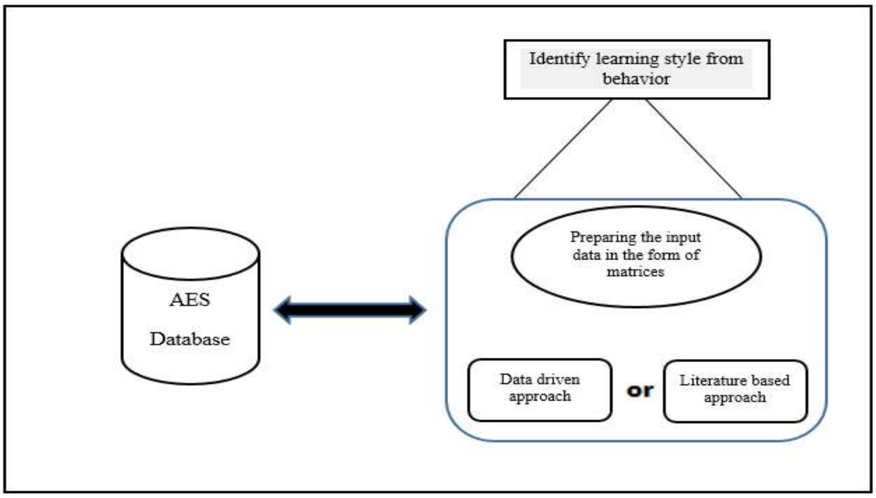

Figure 4: Detecting learning style from corresponding behavior (Source - Abraham et al., 2013)

The process to automatically detect leaning styles is two staged: *(i)* identification of pertinent behavior relevant to each learning style *(ii)* inference of learning styles from recorded behavior as shown in figure 2.

The second step is about pinpointing the pertinent behavior for each learning style which comprises on the following phases shown in figure 3. *(i)* Choosing the pertinent features and behavioral patterns, classifying the occurrence of the behavior. *(ii)* Outlining the pattern for every dimension of the learning style. Third step is about the inference of learning style from the corresponding behavior, a main differential point between data driven and literature based approach. The commonality in both approaches is the initial step that is relevant to the preparation of input data based on the extracted information that's further framed in the form of matrices with respect to

each learning style. Afterward, the computational methodology such as data driven or literature based can be applied as shown in figure 4.
The selection of student modeling approach depends on the conditions and environment in which study is being conducted. Implicit approach reflect actual behavior of learners and represent their definite learning preferences but the approach represent high complexity and computational cost in comparison to collaborative approach. Secondly, identifying learning style specifically using literature based approach requires student's interaction with learning environment for a longer period of time in order to detect their behavioral pattern corresponding to each learning dimension as shown in above figures (Abraham et al., 2013). And, if multiple learner characteristics are required to identify then modeling process become more challenging and complicated. As features related to each variable possibly be separate and diverse kind of behavioral pattern would require to determine each student unique set of learning characteristics.

Similarly, data driven approach would also be more complex and time consuming if multiple sources of personalization are involved. Data driven approaches imitate the self-reporting questionnaire. The process as shown above first requires sample data, if not available a separate study is needed for data collection. Afterward, to initialize learner model, the learners have to fill out questionnaire before entry into e-learning system, to which they feel extra work on their part. In case of multi-sourced personalized system, multiple questionnaires have to be filled by each learner to initialize their learner models. Hence, the applicability of implicit approach is not suitable for educational environment which have different constraints including availability of learners and access of computer lab for limited amount of time, unavailability/limited internet access, and access to real educational setting for a shorter period of time. In such condition, the explicit approach can work better. The explicit methods are considered more accurate and reliable (Truong, 2016; Al-Azawei & Badii, 2014) but it also encountered some issues such as lack of learner's motivation to fill out questionnaire and learners may easily deceive such as skip questions or give wrong answers. Some issues may rise due to instrument's internal consistency, test re-test reliability and the formulation of questions in such a manner which non-intentionally influence respondents. So, these issues must be addressed when explicit method is used for student modeling. Some suggestions to deal with such issues includes clarify the participants about the objectives of the study and explain them regarding the consequences of skipping questions and intentionally giving wrong answers and take support od authorities to successfully complete the job. Further, motivate students by keeping short time to answer questionnaire, keeping possibly low number of questions in instruments and if there are multiple questionnaires deploy them in different time periods.

4.1.3 Adaptive Model (AM)

As shown in below figure, this model presents link between SM and DM to match the learning material with the individual characteristics of learners stored in his/her model.

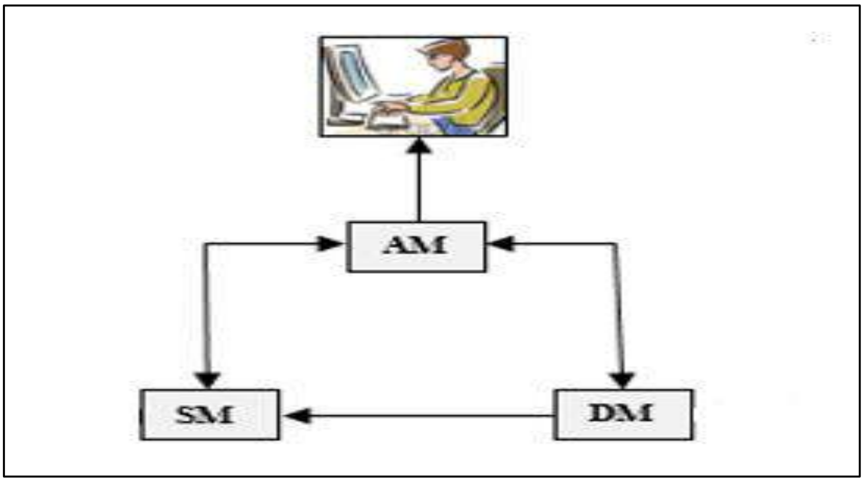

Figure5: Main components of AES and their interaction

It enables AES that how to teach by encoding instructional methodologies used via the user interface of adaptive learning. Based on students' knowledge level, strengths and weaknesses, abilities and learning styles etc., the AM select the most suitable learning content. For example, if a student categorized as novice in a specific domain the AM might be give step by step demonstration of learning material. Through AM, AESs provides feedback, explanations and coaching to students during solving specific problem. Additionally, AM may also present learning material to address student's proficiency gap. When a learner gain expertise in the domain it may decide to provide progressively more difficult questions and problems (Al-Azawei & Badii, 2014; Čarapina, 2013).

4.1.3.1 Adaptive Technologies

The major adaptive technologies used in ITS and AEHS are depicted in below figure 6.

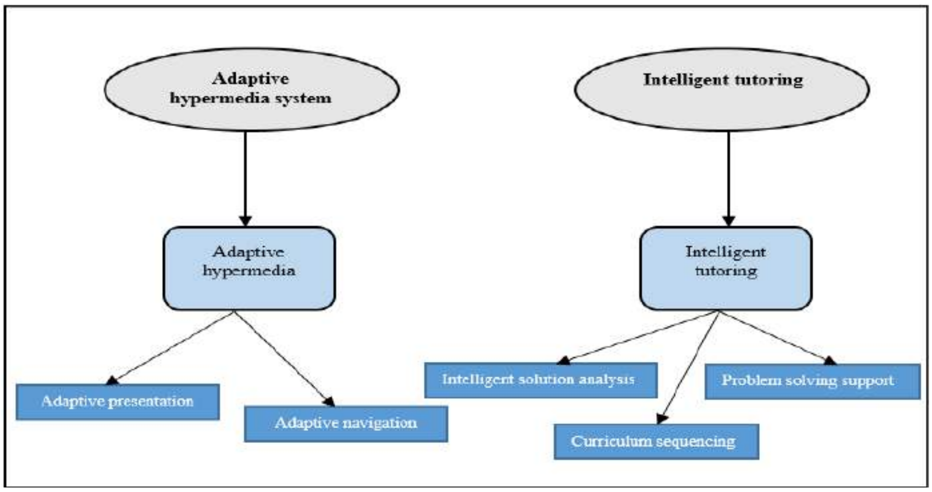

Figure 6: Adaptive techniques (Source: Brusilovsky & Peylo, 2003)

The major intelligent tutoring technologies includes: *curriculum sequencing, intelligent solution analysis* and *problem solving support*. These technologies have been extensively explored in ITSs. The aim of *curriculum sequencing* is to provide most appropriate sequence of learning material *(e.g. explanation, example, problem, question etc.)* to each individual. It provide learners an optimal path through learning repository in accordance to his/her needs. It was first implemented in pioneer adaptive and intelligent web based education systems (AIWBES) namely ELEM-ART. Later, implemented in other AIWBES including CALAT and KBS-HYPERBOOK. In ELM-ART, it recommends suitable links and adaptive next button while in KBS-Hyperbook suggests suitable learning path (Brusilovsky & Peylo, 2003).

Intelligent solution analyses help students in solving educational problems. It provides solutions for both simple (i.e. question) and complex problems (i.e. programming problem). This technique prompt and highlight missing, incomplete or incorrect piece of knowledge become cause of error. It gives extensive feedback on errors and update SM accordingly. It is implemented in many web based adaptive systems including ELM-ART, WITS, SQL-Tutor and German tutor (Brusilovsky & Peylo, 2003).

The *interactive problem solving support* provides intelligent help to learners on each step of problem solving. Intelligent help provided in the form of hints and execution of next step of learner problem. It was mainly implemented in standalone ITSs due to some implementation issues. The pertinent functionality to apply this technique requires client-server implementation for example AlgeBrain but such kind of systems are difficult to build (Brusilovsky & Peylo, 2003). The technique is implemented in ActiveMath and ELM-ART to provide example based problem solving support.

Other two technologies are adaptive presentation and adaptive navigation support, mainly explored in AEHS (Martins et al., 2008; Brusilovsky & Peylo, 2003, Brusilovsky, 1997).

Adaptive Presentation Technology: It adapts the learning content of hypermedia system in accordance to student learning characteristics stored in his/her SM. The adaptive presentation techniques are as follows.

Conditional text: It is simple but effective content adaptation technique. It divides learning material into components to present it adaptively. Each component is associated with knowledge level of student defined in his/her SM. Hence, system imparts only that chunk of knowledge to learners where condition is true. Conditional text filters have been used in many systems such as ITEM/IP, Lisp Critic, MediaDoc, AVANTI and I-DOC (Martins et al., 2008; Brusilovsky, 1997).

Stretchtext: This technique used to expand or collapse different parts of the learning content according to the level of student knowledge such as demanded page with all stretch-text options that are irrelevant to learner being collapsed and all options related to learner being un-collapsed. The benefit of this technique is that it allows the learner to refine adaptation support. The learner has the option to expand or collapse stretch text to meet their learning objectives. Some adaptive systems trace that which stretch text student contracted or expanded and update SM accordingly. The concept is utilized in MetaDoc and KN-AHS (Martins et al., 2008; Brusilovsky, 1997).

Frame based approach: This approach utilize frames to provide information regarding a concept. Each frame consists of different slots and each slot of a frame contains different explanations of the concept. The decision regarding the presentation of a specific slot and order of presentation is made through special rules. It is the most powerful technique. It is utilized in Hypadapter and EPIAIM. The hypadapter used rules to calculate priority of presentation for each slot of the frame. The slots with highest priority were presented and further with descending order. The PUSH project also implemented frame based technique along with stretch-text technique (Brusilovsky & Peylo, 2003; Brusilovsky, 1997).

Adaptive multimedia presentation: This technique helps to change the presentation of multimedia items on the basis of SM. The techniques are similar to stretch-text except multimedia learning material is adaptively sorted and presented rather than text (Brusilovsky & Peylo, 2003; Brusilovsky, 1997).

Adaptive Navigation Support Technology: The goal of adaptive navigation support is to support students in navigating hyperspace through modifying the appearance of visible links. For example, AEHS can adaptively sort, annotate or hide the links of the page for easy navigation. It is similar to curriculum sequencing, the difference between both techniques is that adaptive navigation is less directive and more cooperative than curriculum sequencing. As it direct students but leaving the choice of further learning over them. The adaptive navigation support techniques are as follows (Brusilovsky & Peylo, 2003; Brusilovsky, 1997).

Direct guidance: It is the most constricting form of adaptive navigation support. Students are presented with a sole adaptive link either they use it or not. It has been implemented in different systems including ISIS tutor, Web Watcher, HyperTutor and CS383. The main advantage of direct guidance is that it is simple to use. The shortcoming of this technique is that it is an all or nothing approach. It is up to learner either s/he use the adaptive link or not (Brusilovsky & Peylo, 2003; Brusilovsky, 1997).

Adaptive Sorting: It sorts links of a page in accordance to SM, the most suitable links for each individual presented first. The user keep the choice to override the adaptive model and choose the information seemed appropriate. The technique is not useful where the sequence of links is already determined. It has been used in different systems including ARNIE, ELM-ART, Hyperflex, WebWatcher and CS 383 (Brusilovsky & Peylo, 2003; Brusilovsky, 1997).

Hiding: The most common adaptive navigation technique is *hiding*. It hides the links which are not relevant to learner and shows only pertinent links. It is a rule based technique which is implemented in AEHS such as Hyper Tutor and SYPROS. Both systems use specific set of pedagogical rules to choose that which concepts should be discernible at the moment and which should not (Brusilovsky & Peylo, 2003; Brusilovsky, 1997).

Annotation: The technique present textual or verbal cues to learners in order to suggest the links to visit and their direction. In accordance to SM, multiple educational states of each node such as ready to learn, not ready to learn, in work and learned are presented. Each educational state is annotated differently by distinct color and character. The technique is implemented in ISIS tutor ELM-ART and ITEM/PG (Brusilovsky & Peylo, 2003; Brusilovsky, 1997).

4.2 Types of Student Models

The commonly used types of SM are as follows (Millan, Loboda, & Perez-de-la-Cruz, 2010; Brusilovsky & Millan, 2007).

4.2.1 Overlay Model

In overlay approach, the knowledge of learner is considered subset of domain knowledge. The overlay model estimate student's knowledge in each item of domain and store it to make decisions regarding adaptive presentation. The estimate of knowledge items is stored in the form of Boolean value *(yes/no)* to indicate that a particular knowledge item is learnt or not. The knowledge estimates can also be stored in qualitative *(poor-average-good)* or quantitative form *(probability).* This model works well when major objective of tutoring system is to deliver knowledge to the student. The drawback of this model is that it does not consider erroneous beliefs of learners.

4.2.2 Differential Model

In this approach, the domain knowledge is decomposed into necessary and unnecessary components. This model makes believe similar to overlay model, but defined on the sub-components of the domain knowledge.

4.2.3 Perturbation Model

In this approach the knowledge of learner is categorized into correct and incorrect. It is normally built upon the knowledge of domain along with usual mistakes students can make. The SM is an overlay of an augmented set of knowledge elements including both correct and incorrect knowledge statements. Incorrect knowledge is further categorized into misconceptions and bugs. The pool of mistakes involved in perturbation model is normally called bug library. Although perturbation model provide better explanation of students' behavior but it is much difficult and costly to develop and maintain.

4.2.4 Constraint Based Model

In this model, the domain knowledge is represented through a set of constraints on the state of problem. The constraints help to recognize the correct solution. The violation of employed constraints indicates erroneous solution. The SM is considered as an overlay on set of constraints.

4.3 Example AESs

During past few years, numerous AESs have been developed using learner modeling techniques. This section presents some existing AESs in order to know their working, individual characteristics employed in learner model to provide adaptation effect, how these are identified? What were the adaptive targets? And how AESs were evaluated?.

4.3.1 CS-383

CS-383 is pioneer adaptive learning system which adapts course material on the basis Felder Silverman Learning Style Model (FSLSM) learning dimensions. The learner's profile was determined by initial survey using Index of Learning Style (ILS) questionnaire. The learning resources were divided into categories including audio/video files, digital movies, instructor slideshow, lesson objective and quizzes. The learning resources were given rating from 0 to 100 regarding their relevance to each FSLSM learning style dimension. When a learner interact with system, a common gateway interface (CGI) load profile of that student and create a distinctive classification of each learning resource through combining learner's profile with the rating of learning resources. Further, CGI dynamically create HTML page which consist of ordered list of most to least apposite learning resources for each learner in accordance to their learning preference. The formal evaluation of system was not conducted; only causal feedback was collected by researchers which consistently defined it positive in terms of learning (Carver et al., 1999).

4.3.2 INSPIRE

An Intelligent System for Personalized Instruction in Remote Environment (INSPIRE) was developed using knowledge level and Honey & Mumford learning style dimensions including Activist, Pragmatist, Reflector and Theorist for the provision of appropriate learning content. The techniques used include curriculum sequencing, adaptive navigation and adaptive presentation. The student learning styles were determined through corresponding questionnaire and/or defined by learner him/herself. The system was both adaptive and adaptable so that learners were allowed to control system adaptation. The learner model was open for learners to make changes. The learner model of the system describes the learning style of learner and their knowledge level on different concepts. The domain structure consists of independent elements such as concepts and educational modules. The educational material was related to three level of performance such as remember, use and find. The knowledge level of learner on particular concept was represented using these keywords including “sufficient”, “insufficient”, “rather sufficient” and “almost sufficient”. These keyword were assigned to concepts on the basis of performance in assessment material. The content generation module of the system generates further contents on the basis of learner performance. For example, if knowledge level of learner evaluated as *insufficient* then learner learns material of *remember* level and if his/her knowledge evaluated as *rather sufficient* then he/she learn material of *use* level. Further, the presentation module presents learning material to learners corresponding to their stored learning style (Papanikolaou et al., 2003).

NSPIRE was evaluated using 23 undergraduate students. The experiment was lasted for two & half hours. The results showed that overall participants were satisfied. They found learning material easy to study and understand. Further, it was easy to locate specific information as compare to handouts of the module. The evaluation study had some shortcomings for example it was executed without control group and only 50% learners submitted learning style questionnaire, rest of the participants either self-assessed or ignored the feature. The shortcoming noted regarding the design of INSPIRE is that it did not provide different versions of learning material to different learners. It provides same learning resource to each learner using different order and appearance for each learning style (Papanikolaou et al., 2003).

4.3.3 e-Teacher

e-Teacher is an intelligent tutor which recommend teaching/learning tasks to students as per their profile. The student profile consists of FSLSM dimensions. The learning dimensions were automatically detected by observing students learning behavior and their interaction with learning system. Bayesian modeling method was used to infer student's learning style considering their learning behavior for example type of preferred learning material, number of exercises completed and involvement in chats and forums. Additionally, e-Teacher consider some other parameters related to performance of learners for example total number of exercises completed successfully, performance in exam questions and overall progress as compare to others. The tool collects such information to provide personalized help to students for the improvement of their learning performance. e-Teacher was evaluated using 42 pupils studying an artificial intelligence course. (Schiaffino, Garcia & Amandi, 2008).

4.3.4 LearnFit

LearnFit adapt teaching strategies in accordance to learning preferences of students, identified using Myers-Briggs Type Indicator (MBTI) questionnaire. To enter into system students give inputs using psychological instrument to represent their learning preferences. The student responses were computed, categorized into four dominant preferences *(i.e. sensing, intuition, thinking or feeling)* and stored into SM. Four versions of learning material are available in LearnFit to provide adaptive learning experience. The AM select teaching strategy in accordance to psychological dimension of learner. The learner preferences could be adjusted during learning process through probabilistic decision model. The adaptive system was evaluated using 48 participants which were equally divided into control and experimental groups. The difference between both groups was that the control group learnt in traditional learning environment whereas experimental group learnt through LearnFit. The results indicate that matching learning material to the learning preferences of the students improve their learning performance and delivered them an enjoyable learning experience (Essaid El Bachari & El Adnani, 2011).

4.3.5 WELSA

WELSA is a web based adaptive educational system which integrates multiple learning dimensions into SM to provide adaptive learning experience. The WELSA is distinct from previous learning style based AES as it integrate various learning preferences related to different learning style models. It premised on believe that there are large number of learning style models but there is no generic model which consider distinct aspects of learning style models and eliminate overlapping feature of such models. Hence, this study proposed a Unified Learning Style Model (ULSM) which incorporates learning preferences associated to perception modality, manners of processing and organizing learning material as well as motivational and social aspects. The major components of system are authoring tool, analysis tool and course player. Authoring tool allow teacher to create course according to the format of WELSA. A data analysis tool is responsible for interpreting and analyzing the behavioral pattern of students to create/update SM of each student and generate corresponding aggregated information which is utilized by adaptation component. The course player component enriched with specific capabilities including student tracking ability *(monitor student actions performed during the interaction with the system)* and adaptation functionality which trigger adaptation rules to recommend learning page in accordance to aggregated value regarding learner preference provided by analysis tool.

The system continuously monitor and analyze student actions to identify student learning preferences so that individualized course material could offered to each student accordingly. The system was evaluated using 64 undergraduate students which were equally divided into two groups, one group learnt the topic of Artificial Intelligence course using adaptive version whereas second group learnt same topic through non-adaptive version of the system. The results showed that students learnt through adaptive version outperform in terms of learning efficiency than students interacted with non-adaptive learning system but no significance difference found in terms of learning gain. The students interacted with adaptive version found satisfied and they have enjoyed learning (Popescu, 2009; Popescu, 2010; Popescu et al., 2010).

4.3.6 DEPTHS

Design Patterns Teaching Help Systems (DEPTHS), a web based ITS to teach software design patterns. The system made intelligent selection of learning material according to student's background knowledge and performance in learning domain. The tool traces each activity performed by learner and store information in SM. Additionally, student performance related data also stored in SM. This information further utilized to determine background knowledge of students and categorize them in beginner, intermediate and expert. The concept variant technique was used to keep alternative content of the same concept to serve students with different levels of knowledge. DEPTHS provide navigational support such as direct guidance and link removal. Through direct guidance the students view only single option to carry on the browsing activity that is a next button to move on subsequent page. The target of next button dynamically determined by the system. System used link removal technique in order to remove links to advance topics for beginners. The advanced learners have given option to select concepts from content menu. The evaluation of tutor was performed using control and experimental group. Each group consists of 14 computer science students of undergraduate studies. The evaluation results indicated that DEPTHS had positive impact on learner's motivation and learning performance (Jeremic, Jovanovic & Gasevic, 2012).

4.3.7 TSAL

Two Sourced Adaptive Learning (TSAL) provide adaptive learning experience using student's learning behavior and learning style. The learning style was determined using questionnaire and learning behavior through student's learning performance and interaction with system. The system consists of different modules including course editing module, tutoring system, system management module and user profile database etc. Each module is responsible to perform different functionality. For example, course editing module allows teachers to access and update course material. Tutoring system offer adaptive learning on the basis of student's learning style, learning ability and efficiency. The user profile database contains characteristics of each modules and system management module provides access to administrator for the management of user accounts and other system maintenance tasks. The system contain six versions of learning material in order to provide personalized learning experience to students with different learning styles and learning progress. An evaluation study was conducted using 91 students of high school. The participants were divided into experimental and control groups. A pre-test was conducted to ensure that all students have equal knowledge of subject. The subjects of experimental group learnt the concept(s) of Mathematics with TSAL whereas students of control group learnt lesson using non-adaptive version. The results showed that adaptive functionality is useful in improving student's learning performance (Tseng, Chu, Hwang, & Tsai, 2008).

4.3.8 CLT

C++ Loop Tutor (CLT) is an individualized learning environment developed to teach programming concepts to computer science students of undergraduate studies. The study was conducted to address issues related to existing ITS which deliver adaptive learning experience merely on the basis of domain knowledge. CLT was designed to impart instruction on the basis of student's cognitive abilities including spatial, numerical/quantitative and verbal reasoning abilities. The cognitive abilities were assessed through corresponding tests. The system define student's stereotype on the basis of their cognitive abilities. The content were developed in accordance to cognitive abilities such as verbal content consists of textual description, spatial content consist of figures and flow charts and numerical content using examples and problems. The major components of CLT were instructor module, student module, expert module and user interface module. Each module was responsible to deliver specific functionality for example instructor module instruct student with the help of student and expert module, whereas student module contain student information and expert module contain repository of lessons, quizzes and problems etc. The evaluation results showed that students taught through CLT outperformed than those who learnt in traditional classroom environment (Durrani & Durrani, 2010).

4.3.9 AELTT

Adaptive English Language Teaching Tool (AELTT) is a computer aided language learning tool which delivers English Grammar skills to the students of grade IX. The learning content has been designed considering local and cultural aspects. The Bayesian model was used to classify students into below average, average and above average categories. The system delivers content according to the learning needs of students. An evaluation study was conducted using students of local public school. The results showed that adaptive system has potential in increasing the learning performance of students (Durrani et al., 2015).

4.3.10 iWeaver

iWeaver incorporated Dunn and Dunn learning style model in order to provide adaptive learning experience while teaching concepts of java programming language. The system based on two concepts including media experience and Dunn and Dunn learning style model. The learning styles were identifies using explicit approach. The system supports each learning style dimension with different type of media experience. For example, verbal learners were presented learning material in textual format whereas visual learner with visual format *(i.e. pictures and animations)*. Similarly, auditory learners were supported through audio material and tactile kinaesthetic learners with interactive learning content. Moreover, learning tools reinforced global learners with mind maps and reflective & verbal learners with context aware note taking tool. The impulsive learners supported with an option to try out learnt knowledge and kinaesthetic learners had option to see supplementary examples. Adaptive link ordering and adaptive link hiding were used for different presentation modes. The evaluation results showed that adaptive system do not improve students learning performance (Wolf, 2007).

4.4 Summary

The major components of adaptive systems are DM, SM and AM. Each component performs certain responsibility such as DM kept repository of concepts related to domain of knowledge. The SM contains student's information and AM interact with both DM and SM to keep recent information regarding learners in order to deliver them appropriate learning content. The major approaches used for student or learner modeling includes explicit and implicit. The existing AESs mainly exploited domain knowledge and learning style models to deliver personalized learning. In AESs research, major focus remained on the modeling of learning styles using different approaches including collaborative, data driven and literature based approaches. The learner model has given less attention to incorporate multiple adaptive variables to impart personalized learning. WELSA is a pioneer system which incorporated multiple dimensions of different learning style models but characteristics other than learning styles have not been considered. Few other studies such as CLT were conducted which modeled parameters *(i.e. cognitive abilities)* other than domain knowledge and learning styles. The approach with combination of different parameters have not yet taken in existing AESs so that proposed research aimed at delivery of learning content through combination of different parameters. In existing systems predominant adaptive target was learning content. It is noted that mostly LS based AESs presented in literature adapt contents by changing their order for different learners rather than designing different versions so that different learning content could be recommended to learner with different learning characteristics. It is also noted that the systems utilized adaptive versions of contents present better learning outcomes. Secondly, most of the evaluation studies were conducted using undergraduate students, capable enough to manage learning even with mismatched condition. It is therefore required to conduct further studies with subjects of variable age.

CHAPTER 5

DEVELOPING ADAPTIVE CONTENTS USING COGNITIVE AND NON-COGNITIVE PARAMETERS

Overview

The AESs in an e-learning environment deliver learning material based on learner's characteristics as defined in a typical SM. Overall such systems have been found to have low impact on learning. There could be multiple reasons behind this poor response. One, majority of the systems being developed provides adaptivity based on single parameter like learning styles. Two, most of these systems utilize recycled learning material instead of designing localized learning contents according to individual characteristics. Among many individual differences research literature has emphasized to consider some effective variables in AESs including Prior Knowledge (PK), Learning Style (LS), cognitive traits and affective states. This chapter presents an effort where adaptive contents have been designed considering different combinations of cognitive and non-cognitive parameters such as PK, WMC and LS for the domain of our interest.

5.1 Introduction

Individuals differ from each other on the basis of prior knowledge, learning style/goals, interest, cognitive traits and affective states which effect their performance though they may have been provided the same learning content (Premlatha & Geetha, 2015). For example, in traditional learning environment it is not possible for a teacher to identify learning needs of each student and then deliver lesson to cater those needs of each individual. The instruction imparted is primarily teacher centric. Consequently, the learners who are gifted or those who coincidentally matched to the teaching style may learn the contents. Others especially learners with low level of knowledge and capacities may feel serious difficulties in learning. Similarly, in the context of online learning, the Learning Management Systems (LMS) are commonly used which deliver exactly the same learning content to every learner without considering individual differences which eventually become the cause of difficulty in learning, cognitive overload, frustration as well as drop out from online courses (Graf et al., 2012). This approach is known as “one size fit all” which does not cater individual learning needs. The alternative to “one size fit all” approach is adaptive e-learning which consider individual learning characteristics before imparting them any instruction. Adaptive e-learning is stated as an exclusive, combined educational model that is tailored to individual learning needs. It typically emphasis on learner’s preferences and current state of the learner to provide suitable learning contents (Premlatha & Geetha, 2015). The research literature represented numerous AESs developed using e-contents. However, most of the developed systems utilized recycled learning material to teach courses except few studies conducted using custom designed e-contents such as iWeaver (Wolf, 2007) & AELTT (Durrani et al., 2015). Since the last decade, the developing countries have emphasized on ICT integration in education for quality learning experience at school level. The courseware was the major component of such endeavor which designed using diverse media elements without considering individual learning needs (Halim, 2005). The learning material available on learning portals in the form of digital objects called learning objects (LOs) is used in e-learning environments for learning purposes. Although, these learning objects are designed in a new and interesting way but individual learning requirements have been neglected (Premlatha & Geetha, 2015).

Learning contents are an important part of any e-learning system so it is highly suggested that content should be designed considering individual needs of learners. Considering the issue of adaptive learning contents this chapter presents the design of adaptive contents tailored to various combinations of adaptive parameter including PK, WMC and LS to teach preposition part of English Grammar at grade IX and X.

5.2 Background

5.2.1 Computer Supported English Tools

The available computer based tools to teach English Grammar have some limitations in terms of learning contents. For example, Grammar 2 (Satz, 1995) teaches English grammar but it supports partial coverage of grammar contents. The contents are designed using single media (i.e. text) with limited number of examples (single example against a concept) and without explanation of concepts. Moreover, the informative feedback is also missing. Hamesh McGee (1994) presents grammar lessons using animated games and activities. The concepts have been presented with practice and evaluation material. The best feature of this tool is that it highlights the concepts using various colors, which helps to grasp important aspects of the presented material. Further, it provides informative feedback in the form of voice to explain the concept behind each question. Tell Me More is another English tool which presents contents using audio and video activities. The contents have been designed for adaptation at three levels of difficulty namely beginners, intermediate and advance learners. The students can operate system using any mode suitable to them. The quality of contents is non-standard, even though a large number of animations, audio/videos are available in system. The major drawback is that user get lost in the system and even does not know what s/he is learning as there is no focus on important aspects of the lesson. The informative feedback is not available (Auralog, 2007). Adaptive English Language Teaching Tool (AELTT), is an innovative intervention developed to teach English Grammar. The localized learning contents were designed with the support of media elements such as text, images and audio. The system assesses student’s level of knowledge and makes streaming accordingly in order to deliver most suitable learning contents according to their level of knowledge (Durrani et al., 2015). The Computer Assisted Language Learning (CALL) program is developed by MOE Malaysia to enhance learning of English preposition (Ngu & Rethinasamy, 2006). The contents of CALL consist of instruction phase, exercise phase and final quiz to teach preposition of time and place. The instruction phase of CALL includes video pictures to illustrate the preposition along with the support of narrations. The best feature of CALL is that it illustrates the use of preposition using an appropriate context. For example, to teach 'at' preposition of time, the image of clock is used that is associated with the time (specific time) of their school bus which implies a great way to illustrate the concept. CALL lacks in offering informative feedback as it shows only right or wrong answer.

This chapter talks about the design of adaptive contents for 'preposition' concept of English grammar. The concept of preposition is complex relative to other parts of grammar. It has been observed that students frequently misuse preposition during use of English. (Dr. M. Islam, personal communication, Apr 04, 2015).

Prepositions are extremely difficult to master mainly due to their polysemous nature, as the prepositions have a range of meanings depending on the context. Further, the use of preposition differs significantly from one language to another, frequently causing negative syntactic transfer (Delija & Koruti, 2013; Lorincz & Gordon, 2012). Owing to these complications teachers often do not explain the concept of prepositions (Lorincz & Gordon, 2012). Different effective strategies are devised to teach concepts like prepositions. The research study based on prototype theory claims that teaching prepositions in an explanatory semantically-based manner leads to deep learning, improved learner confidence and longer retention. The theory claims that prepositions have multiple meanings but one meaning is believed to be central, or prototypical. For example, the preposition '*on'* has several meanings, but the prototypical definition is "connection of an object with a line of surface". So to deal with the polysemous nature of prepositions analyze the prototypical meanings of different preposition words and use them to teach prepositions. The research related to cognitive linguistic approach revealed by empirical investigation that the use of images and pictures to represent different prepositional concepts can have amazing effect on the performance of learners (Sotiloye, Bodunde, & Olayemi, 2015).

5.2.2 Individual Characteristics

The cognitive and non-cognitive parameters shown below are selected on the basis of research literature recommendations to utilize combination of PK, WMC and LSs to improve learning outcomes (Akbulut & Cardak, 2012; Graf et al., 2012). The table below depicts each parameter along with their corresponding characteristic value.

Table 3: Adaptive variables & their values

Adaptive Variables	Properties/Values
Working Memory Capacity (WMC)	Low capacity, High capacity
Prior Knowledge (PK)	Low level , High level
Learning/Cognitive Styles	Deep *(Serialist, Holist),* Superficial

WMC

The human mind perceives information through sensory memory from outside world, process it in working memory (WM) and eventually stores into long term memory (LTM). The information stored in LTM can be retrieved which is perceived as remembering and facilitate WM processing. The WMC is indispensable to comprehend the learning material as the process of understanding or comprehension is accomplished in WM. The WM has limited capacity and brief duration. Its storage capacity fall in the range of 7 plus or minus 2 and duration to hold information item is less than one minute without a rehearsal. The limited capacity and time duration become cause of forgetting and information loss (Dedık, 2015; Bielikova & Nagy, 2006; Agh, & Bielikova, 2004).

Owing to the limited capacity of WM, the information items are either moved to LTM or they get lost. The loss of information can be stopped through periodic repetition. For learning purposes, elaborative rehearsal is advisable rather than maintenance rehearsal. The elaborative rehearsal takes in deep semantic processing of information to be remembered which is more effective (Bielikova & Nagy, 2006; Agh, & Bielikova, 2004).

Ebbinghaus research discovered that for memorization distributed practice is much better than massed practice in a single session. Author further noted that continuing practice after learning enhances retention (Bielikova & Nagy, 2006; Agh, & Bielikova, 2004). The WM is a predictor of learning performance. However, WMC varies from person to person and these variances can affect their learning performance. The individual differences in WMC effects the learner’s ability to maintain information into WM as well as recall from LTM. Particularly, the learners having low WMC are poor in actively maintaining and recalling information than learner who possess high WMC (Unsworth & Engle, 2007).

Deep vs Surface LS

Learning styles indicates the way individuals perceive and process information. This has been known as being a significant factor for the presentation of learning materials. Learning style (LS) is a predictor of quality education so it is suggested that designers of e-learning systems should pay attention to learning styles and design learning contents respectively (Markovic & Jovanovic, 2012).

The literature reported many models of learning styles. Among them, many LSs have been utilized in existing AESs but Deep vs Surface approach has been completely ignored (Graf, 2007). However, this LS is picked up to explore it in e-learning approach.

The model is based on the research of Pask (1976), Marton (1976), Biggs (1979) and Entwistle (2001). They identify deep vs. surface learning style keeping in view the ways students used to approach learning. They point out that students either remember only those facts they believed they would be tested on them later or try to grasp the meanings, underlying principles, learning implications in order to fully comprehend the concept (Graf, 2007, Rhem, 1999). The learners who focus on rote memorization are known as surface learners whereas the learners who look for the meanings of the learning material to build understating of subject matter are identified as deep learners. Moreover, deep learners are intrinsically motivated aiming to understand ideas for themselves. They tend to read, relate new ideas to previous knowledge and interact enthusiastically with the learning contents and study beyond the requirements to develop understanding of the topic. Conversely, the surface learners are extrinsically motivated and intends only to meet the course requirements, accept knowledge uncritically, feel under pressure and worry about their work due to fear of failure in exam. The deep learners are further categorized into serialist and holist cognitive styles which present the general ways they used to build understanding. Serialists feel easy with detailed, well defined and a clear logical structure of sequentially ordered chunks. In contrast, Holist learners want to see broad picture of learning material. They are desirous to learn efficiently but do not prefer reading material along with full of illustrations and examples. They can quickly develop model of the material to be learned using analogies, metaphors, and links to particular experience, and later fill and adjust that model as they get more detailed information of the subject matter (Entwistle, 2003).

PK

Ausubel (1968) noted, “The most significant factor influencing learning is what the learner already knows”. The learners can vary in terms of their prior knowledge in a particular subject. The learning takes place when new knowledge relates with prior knowledge. In case of knowledge gap, students face difficulty in comprehending the learning material. It is therefore imperative to evaluate and identify the level of student’s prior knowledge before imparting instruction (Rias & Zaman, 2013).

Based on the different values of above discussed cognitive and non-cognitive parameters twelve combinations has been formed. Other combinations were also possible, for example, considering medium value for PK and WMC along with values of LS but scope of this study is limited only to these twelve combinations (Table 4), as it is not possible to deal with all combinations at once. So rest of the combinations would be considered in future research.

The contents have been designed for each combination (Table 4) to cater the learning needs of learner with any combination of characteristics.

Table 4: Combination of Cognitive & non-Cognitive Parameters

Combination(C)	PK	WMC	LS
C-1	Low	Low	Deep-Serialist
C-2	Low	Low	Deep-Holist
C-3	Low	Low	Surface
C-4	Low	High	Deep-Serialist
C-5	Low	High	Deep-Holist
C-6	Low	High	Surface
C-7	High	Low	Deep-Serialist
C-8	High	Low	Deep-Holist
C-9	High	Low	Surface
C-10	High	High	Deep-Serialist
C-11	High	High	Deep-Holist
C-12	High	High	Surface

5.3 Introduction to Content Development

The content development is the most important part of an effective e-learning system. Good contents contribute to the enhancement of learning whereas bad contents can damage the whole learning experience and eventually it can result in failure of system. Therefore, while developing e-contents bear in mind that unattractive presentation, boring style of writing, unexplained terms and concepts can demotivate the students. To improve the effectiveness of learning material it is imperative to know about the target audience and their learning needs. Secondly, real life scenarios should be used to impart knowledge. The content developed for e-learning systems are categorized into five types including *fact*, *concept*, *process*, *procedure* and *strategic principles*. Fact represents specific and unique information such as terminologies. Concept represents detailed information related to topic of any subject with the help of different examples. Process represents the order of activities to achieve specific objective for example how to create a web page. Procedure represents information to perform step by step actions (Dirksen, 2015).

5.3.1 Content Development Cycle

The content development cycle shown in below figure 7 is useful for the development of learning content. The process avoids demotivation factors and facilitates to incorporate suggestions for improvements (Clark, & Mayer, 2016).

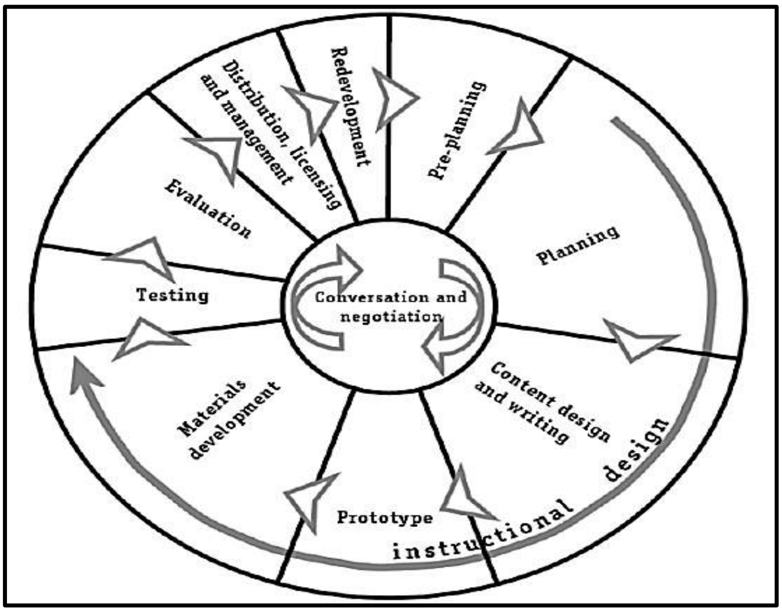

Figure 7: Content development cycle (Source Clark, & Mayer, 2016)

The cyclic depiction focus on iterative process for the design of learning content/activities. The different phases of iterative process followed for content development are briefly discussed here.

Pre-planning: This phase is related to the establishment of content development team, arrange equipment and locate financial resources. In the context of this research, a loosely coupled team was established for the development and evaluation of contents. The domain was selected and learning resources were arranged.

Planning: During this phase, we have made an effort to identify and assess existing learning resources to find out if existing learning resources fulfill the objective of this research. It is found that existing resources did not achieve the unique requirement of research in terms of learning content. The technical considerations, constraints and possibilities related to content development are also identified in this phase.

Content Design: The adaptive contents are designed such as instructional material is written with variations keeping in mind different triplet learning needs of learners. Different images and/or illustration are also arranged to cater different learning needs of learners. Feedback is also designed to support learners during learning process. The assessment material was designed to evaluate students learning progress during learning process.

Materials Development: The learning material designed in previous phase is packaged into different versions so that it could be recommended through adaptive system to learners in accordance to their unique learning needs.

Evaluation and Testing: After developing different versions, content were tested by development team and afterward reviewed by independent evaluators having expertise in the domain. The evaluators suggested changes to further improve the learning material.

Evaluation, Feedback and Redevelopment: In this phase, content were evaluated by representatives of student groups to ensure that the design of content is corresponding to the learning needs of learners as well as the language used is easily understandable by them? The student representative sample belongs to the same environment where later experiment was conducted. The representative’s assured that content are easy to read and understand. They appreciated its design. The surface group representatives express that some illustrations are bit complex which were simplified later. After validation, content were incorporated in to adaptive e-learning system to teach concept in real environment.

5.3.2 Content Development Guidelines/Principles

Following are some useful guidelines and principles for the development of e-learning content. (Dirksen, 2015; Pitler, Hubbell, & Kuhn, 2012; Allen, 2011; Jamornmann, 2004).

1. The content should consist of words and graphics rather than only words. The words could both in the form of printed and spoken text as well as graphics in static and dynamic form. The content present both words and graphics can engage learners in active learning. The material with right blend of text and graphics is more helping for novice learners. The research has showed that expert learners learn equally well through both condition such as with simple text or using both text and graphics.
2. The content should carefully incorporate only those graphics which could support learning. All kind of graphics are not appropriate to be included in content. For example, the decorative graphics cannot help in learning; it is just to decorate the page. It is also believed by many people that animation is better than static illustrations but research do not support this thought. In some cases, static illustration perform better while in some other animations are well. With static illustrations, learners have to link and animate the image by themselves that is why it is better in most cases as well as actively engage learners in cognitive processes which results in better learning.
3. According to contiguity principle, textual information should be presented along with appropriate graphics rather than placing each at two different points. In case text is much lengthy and difficult to display along with the relevant graphic than designer should use mouse over technique. The mouse over technique also known as roll over technique that is used to show text when cursor of mouse is over a specific graphic.
4. The audio streams should synchronize with relevant graphics. The audio explanation should be played when the graphic is displayed. Some people think it’s a nice idea but it can enhance learner’s cognitive load because he/she has to keep the relevant information in working memory to match it with relevant graphics.

5. According to modality principle, when it is feasible audio should be used in learning content rather than on screen text. Audio narration should be used along with graphics which are relevant to textual information. It works better because incoming information is being divided into two different cognitive channels. The suggestion is limited only to the situations where words and graphics are concurrently used and does not apply when text is presented without any simultaneous visuals. Conversely, there are certain situations where on-screen text is better to support learner's memory.
6. According to redundancy principle, avoid redundant text along with both graphics and audio narrations because it can cognitively overload the learner as s/he has to focus on three type of information.
7. Further redundancy principle, stress to consider text and audio narrations only in specific situations. The text would be added with audio narrations only when it is not overloading learner's information processing system. For example, when there is no visual material and pace of presentation is slow which means learner has ample time to understand the learning material.
8. According to coherence principle, avoid cluttering of learning material such as extraneous audio in the form background music, extraneous graphics as well as extraneous textual material which could cognitively overload the memory and harm the learning process.
9. The design of content should transit learners from worked example *(detailed self-explanatory representation)* towards problem through fading process *(only few steps are provided rest is omitted so learners could think to comprehend full picture by themselves).* Novice learners should presented content with the help of worked examples, when material is stored in memory then fading process should initiated to lead towards problem assignment. The concept of worked example is very much helping in developing new cognitive skills. Nevertheless, always presenting worked examples is not a good approach.
10. Instructions should be written in such a way that learners could feel the presence of author. If author presence is shown through instruction, learners may feel personal guidance and engage in deeper processing.
11. Content should incorporate practice material that's distributed throughout the learning environment and provide explanatory corrective feedback. The feedback should in text to convey learner that given answer to question is right or wrong and present succinct explanation.

5.3.3 E-Evaluation/e-Assessment and e-Feedback

The activity to assess student's learning is known as evaluation or assessment. The assessment is of two types *formative* and *summative*. Formative evaluation measures student knowledge during learning process to reinforce learning. Summative assessment measures learning progress at the end of learning process. E-evaluation means automatic evaluation of learner's knowledge without involving human instructor. The best way to improve one's knowledge/skills is assess learning, present feedback and repeat whole learning process as often as possible.

In e-learning systems the importance of e-evaluation or e-assessment cannot be ignored as it is the only way by which students learning progress is measured. The e-learning system updates SM in accordance to evaluation and delivers learning content correspondingly (Pitler et al., 2012; Jamornmann, 2004).

Types of e-assessment

Following are the types of e-assessment.

- ***Objective type test:*** The possible types of objective test are as follows.
  - Multiple choice tests
  - True/False
  - Matching
- ***Subjective type test:*** The possible types of objective test are as follows.
  - Fill in word
  - Fill in phrase
  - Fill in sentence
  - Write a passage or essay

In objective type test, the learner responses are calculated and sent to students instantly whereas in subjective type test e-assessment is not capable enough to assess, therefore a human evaluator is required to perform evaluation (Pitler et al., 2012; Jamornmann, 2004).

E-feedback

E-feedback is defined as the information given to learners during formative assessment in order to improve their skills and avoid mistakes in future. Feedback mechanism is an important part of e-learning systems. As in e-learning systems there is no instructor's interaction so system should be able to give proper feedback to learners on wrong attempts. The decision of feedback made by computer according to learner's performance and learning characteristics stored in SM. The feedback mechanism helps students in many ways. It can inform them about the correctness of their responses and bridge student's knowledge gap by giving information that is not known to them. Hence, it patches student's knowledge and corrects their misconceptions. Feedback could be given in different formats including text, images, audio and animations (Pitler et al., 2012).

There are two main kinds of feedback which are as follows:
Immediate feedback: The feedback presented instantly to the errors of students is known as immediate feedback. It avoids student's unproductive struggling and related frustration. Immediate feedback is further divided into verification and elaborated feedback.

Delayed feedback: The feedback which do not intervene students instantly on errors called delayed feedback (Pitler et al., 2012).

5.4 Design of Adaptive e-Contents

The adaptive e-contents, assessment material and feedback are designed in accordance to student's learning characteristics along with keeping in view above guidelines and principles. The design of e-contests is as follows.

5.4.1: C-1: L-PK, L-WMC & Deep-Serialist

For, low PK contents are communicated with basic usage of preposition of time. For example, content started to communicate that 'at' is used to show "clock time or exact time" with the help of multiple example sentences. To cater learner's low WMC following strategies have been used (see Figure 8) *(a)* concepts have been chunked into smaller parts. *(b)* Text along with meaningful graphical illustrations have been used to present concepts so that it could be grasp easily. *(c)* Color variations have been used to underline important parts of the concepts so that at least main points (*e.g. 'at' used for "time of day and night")* could be remembered and easily recalled. *(d)* Idea of periodic and spaced repetition have been used to support memory. The graphical illustrations shown in figure 1 is two pronged. It avoids cognitive overload and at the same time showed detailed and well-structured view of concept "time of day and night". Because deep-serialist wants to get into meanings and eager to see link of newly learned material with previous learned material. For this, at the bottom of content a separate block of information explain meanings of knowledge items such as 'dawn' and 'dusk', indicate that why 'at' is used with midday, midnight and mealtimes and how they are related to previously learnt usage of 'at' (i.e. exact /clock time) . At the completion of each concept relevant links to Internet sources in the form of teaching videos, PDF notes and web-based instructions are given for deep-serialist learners for further exploration of concepts.

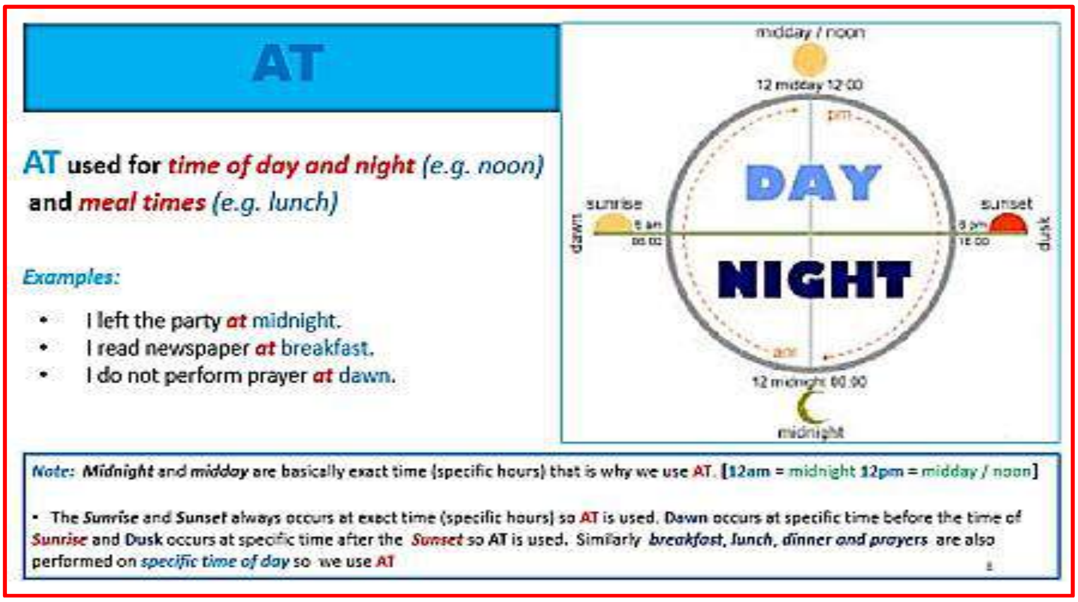

Figure 8: Sample screen C-1

5.4.2: C-2: L-PK, L-WMC & Deep-Holist

The **C-2** is different from **C-1** only in terms of learning style as the learning style is deep-holist instead of deep-serialist while rests of the variable values are uniform. Therefore starting point for teaching and strategies used for memory support are similar to C-1 but the style of content regarding presentation of learning material has changed in accordance to deep-holist dimension. To cater the learning demands of deep-holist's the content has been designed to present the broader picture of learning material, providing an overview of the topic preposition of time with brief details as shown in figure.9.

After presenting broader picture, further details related to the concepts of preposition of time have been designed with examples to avoid learning deficiency of holists as they do not focus on details. They view the overall picture of material and try to build understanding their own through analogies, metaphor and personal experiences which possibly be irrelevant or incorrect.

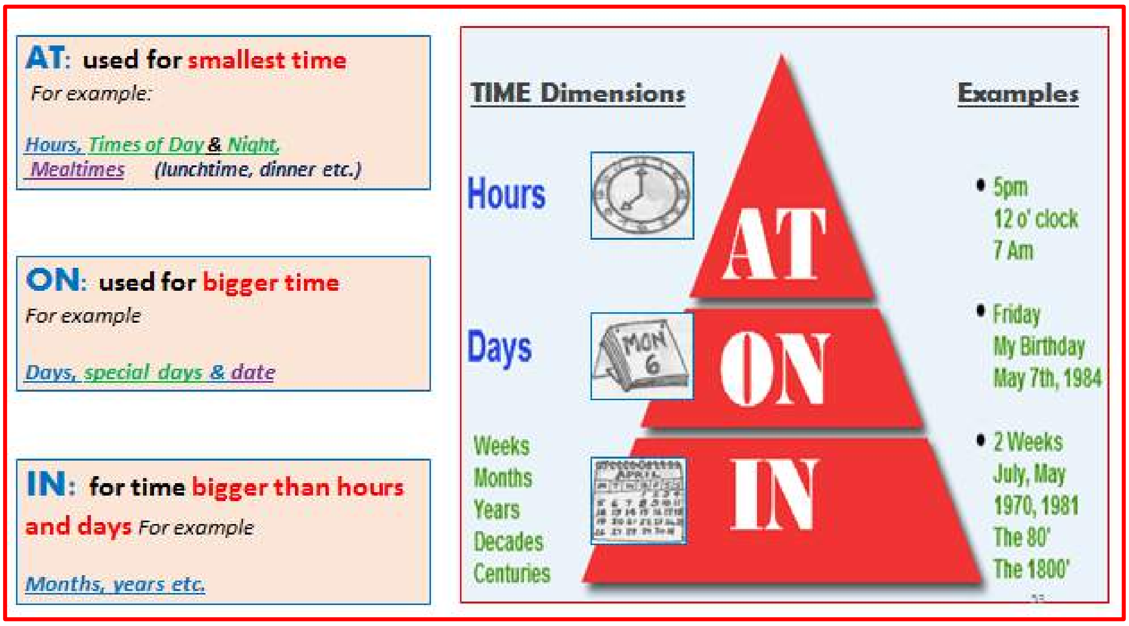

Figure 9: Sample screen C-2

5.4.3: C-3: L-PK, L-WMC & Surface

C-3 is also varied from **C-1** only in terms of learning style that is surface in **C-3**, so content changed in terms of presentation style whereas starting point to communicate concept and memory strategies are similar to **C-1.** For surface learners, the contents have been designed using simple instruction through basic details with relatively smaller chunks and more visual representations (see Figure 10), keeping in view that surface learners comparatively has low memory trace and overall weak knowledge base than deep counterparts. So concepts are defined at lowest level. For example, to teach that 'at' is used for "clock time", further explained that clock time means time in the form of hours and minutes. For surface learners, more examples have been designed such as example words along with the use of preposition will be presented first (Figure 10) then on subsequent page examples showed use of 'at' in English sentences. The content designed to show usage of preposition in multiple ways so that memorization could take place and later could be reproduced. It is pertinent to mention here that objective of our approach is not to promote surface learning. The objective is to present material according to the user's present habit/style to gradually encourage them towards meaningful learning. As shown in Figure 10, the meanings of word Dawn and Dusk are explained briefly in relation to sunrise and sunset.

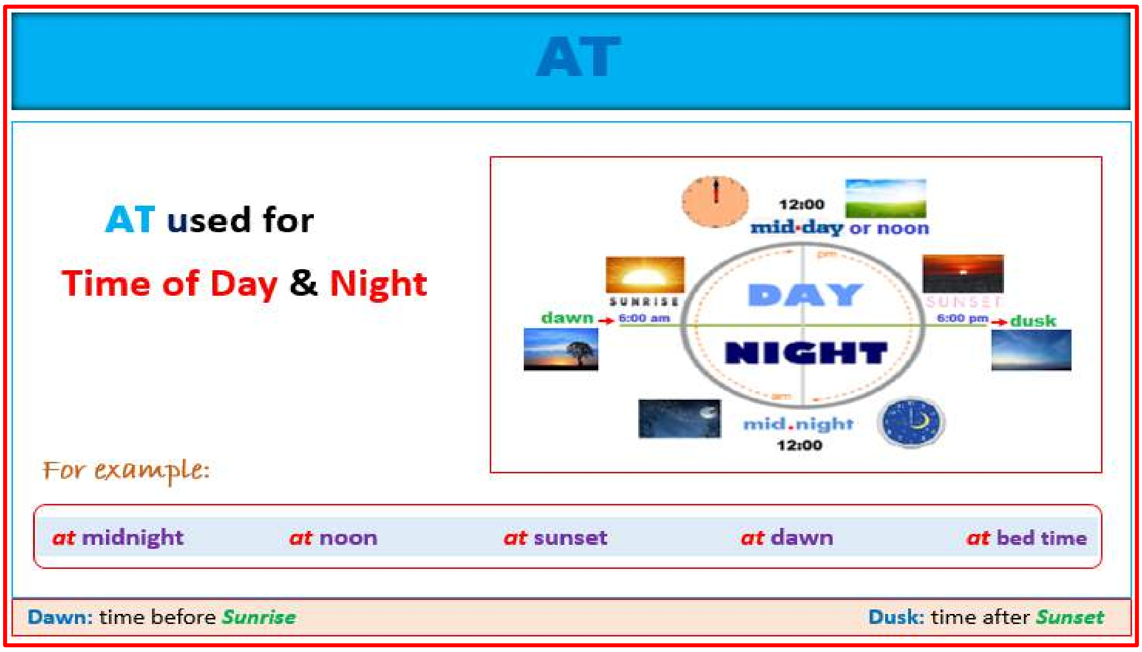

Figure 10: Sample screen C-3

5.4.4: C-4, C-5, C-6: L-PK, H-WMC {Deep-Serialist}, {Deep- Holist}, {Surface}

In C-4, C-5 and C-6 only the value of WM has changed rest of the parameter values are similar to C1, C2 and C-3. Therefore for above combinations content communicates basic knowledge of concepts using presentation style corresponding to the dimension of LS. Owing to high WMC of C-4 the content has been designed to present knowledge using larger chunks. For example, the content present concepts in parts to low WMC counterparts has been designed to present altogether same concept to high WMC learners (C-4). The graphical representations used for low WM learners have not been used for high WM learners. Generally to avoid cognitive overload suggested by Cognitive Load Theory (CLT) [19] high WM learner material has been designed to present details, examples and justifications using separate blocks of information as shown in figure 11. For C-5, where learner is deep-holist along with low PK and high WMC so that basic knowledge related to both preposition of time and preposition of place have been designed to present at once rather than separately as presented to low WM learners in previous cases. The relationship between prepositions words of both topics have been developed for deep-holist efficient learning. Finally, C-6 learners, with low PK and Surface LS but WMC is high so that the content has been designed to present the whole basic usage of ‘at’ of preposition of time into three separate parts as shown in figure 13. Each part presented in separate frame with the support of visual illustration and using basic details as surface learners in general have weak memory trace and knowledge base (Figure 13).

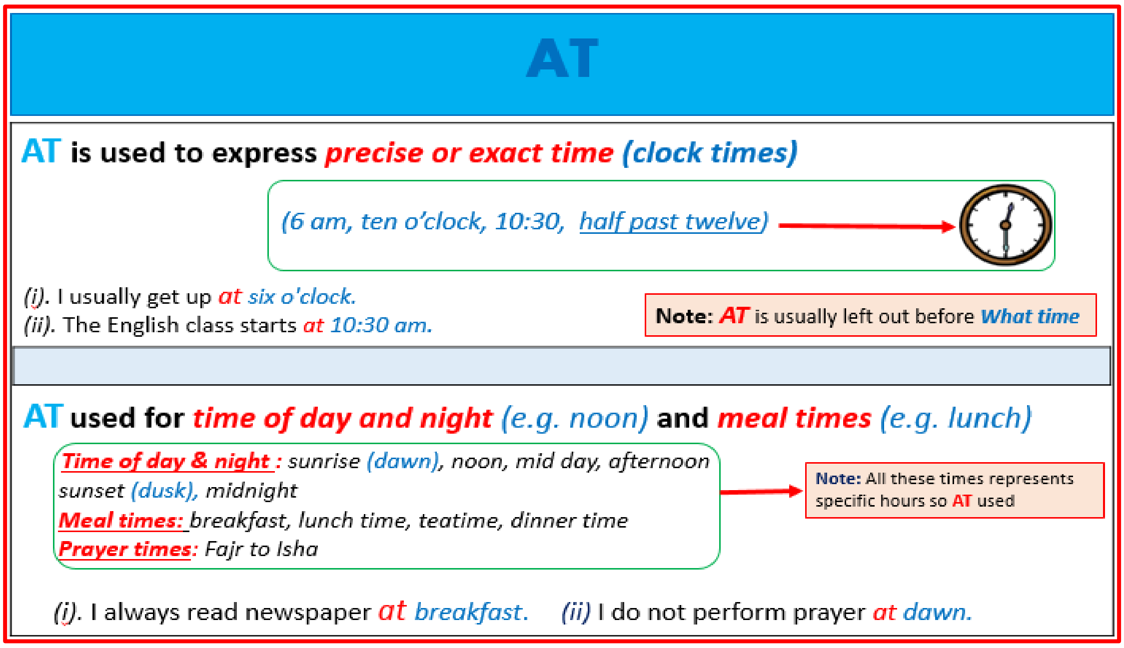

Figure11: Sample screen C-4

Preposition of Time & Place

	IN	ON	AT
Time	General Time (month, year etc) in 2001, in July In winter, in past	Specific time (Days & Date) on Monday, on 31st march on my birthday	Exact time (clock time) at 8 ‘o’ clock, at 3 pm at sunset, at breakfast
Place	General locations (City, Country, Continents etc) in Islamabad in London, in Paris, in Asia	Surface (e.g.) on table, on wall, on ceiling, on island	Exact location/Point /location in space (e.g.) at house# 3 street 7 at the door, at bus stop at reception

Figure 12: Sample screen C-5

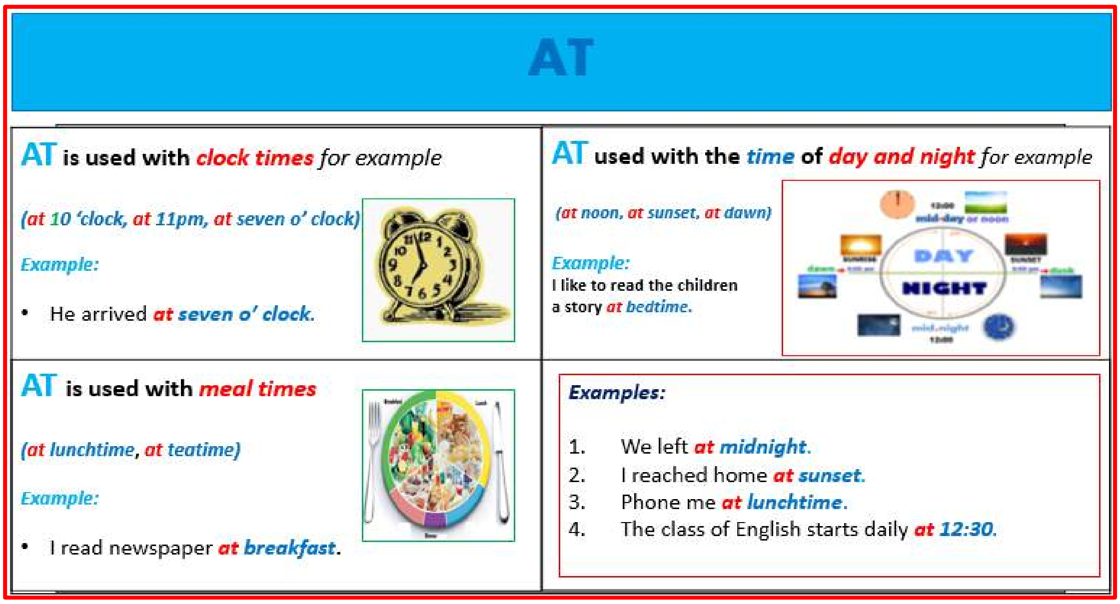

Figure 13: Sample screen C-6

5.4.5: C-7, C-8, C-9: H_PK, L_WMC {Deep_Serialist} {Deep_Holist} {Surface}

In above mentioned combinations the value of variable PK changed from low to high rest of parameter values are similar to C1, C2 and C3. So the content has been designed to present advance concepts related to preposition of time and preposition of place whereas the strategies to support memory and presentation style are similar to C1, C2 and C3. As shown in Figure 14, the content related to C-7 has been designed with detailed material and logical explanation using color variations. For C-8 (Figure 15) content has been designed to present broader view related to the advance usage of 'at' of preposition of time through color variations and meaningful presentation to help memory. For C-9 (Figure 16) the content has been designed to present advance usage of preposition 'at' using simple instruction in smaller chunks with visual illustration so that learning can take place for learners with surface LS and low WMC.

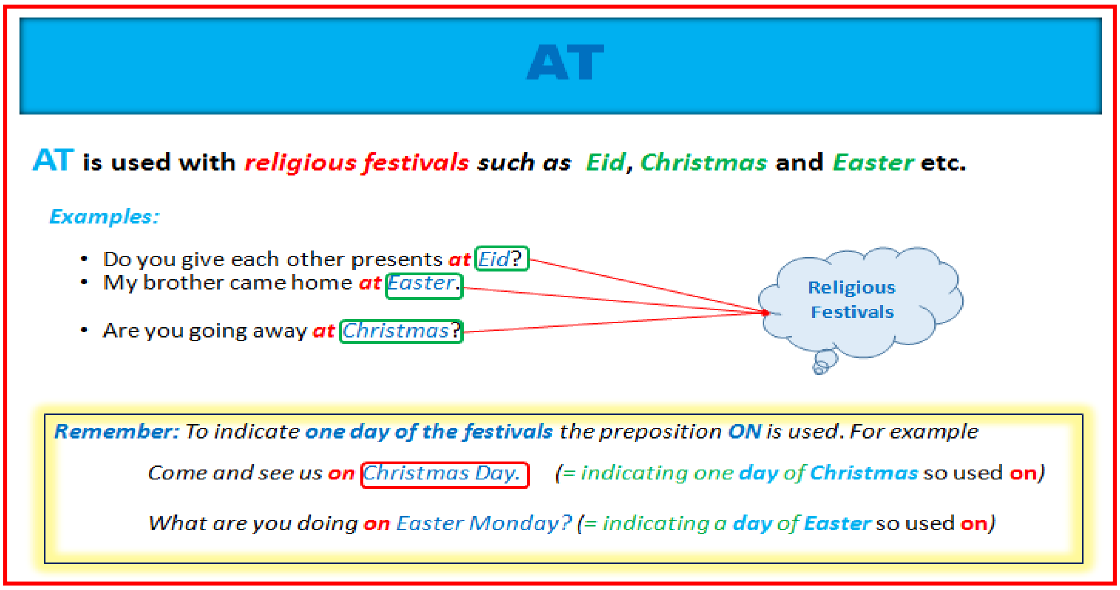

Figure 14: Sample screen C-7

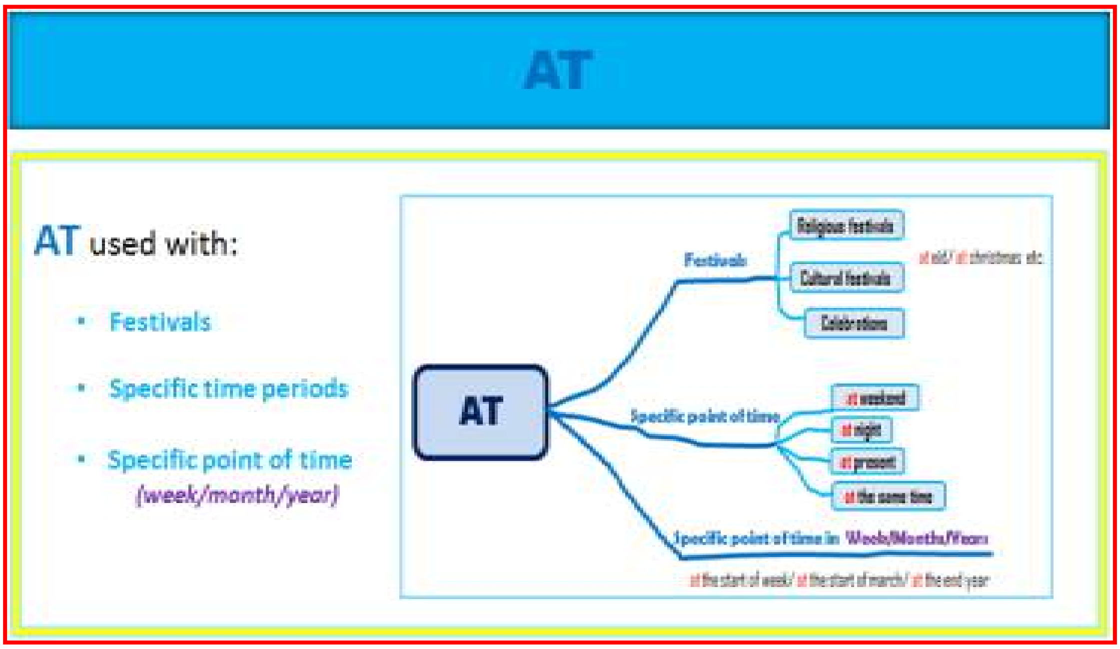

Figure 15: Sample screen C-8

Figure 16: Sample Screen C-9

5.4.6: C-10, C11, C12: sH_PK, H_WMC {Deep_Serialist} {Deep_Holist} Surface

In these combinations, the value of both variables namely PK and WMC has changed from low to high while value of LS is similar to previous categories.

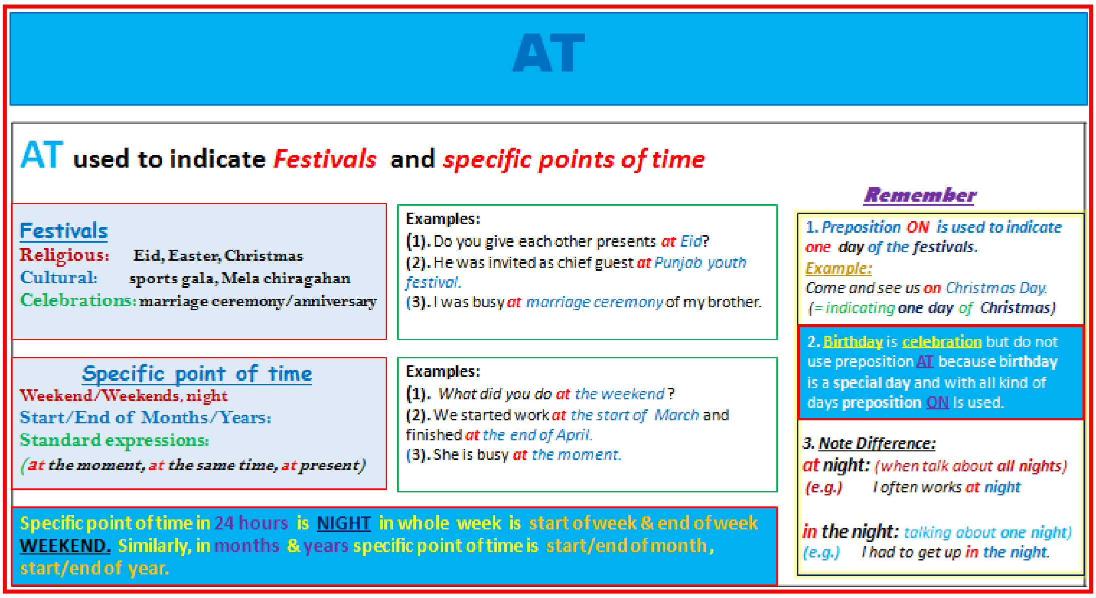

Figure 17: Sample screen C-10

So that for above combinations content has been designed to present advance concepts with few examples, using larger chunks with minimal support of visual illustrations. In general, the content has been designed to present concepts using separate frames of information to avoid unnecessary burden on memory. Overall the presentation style is corresponding to each dimension of learning style (see Figure 17, Figure 18, Figure 19).

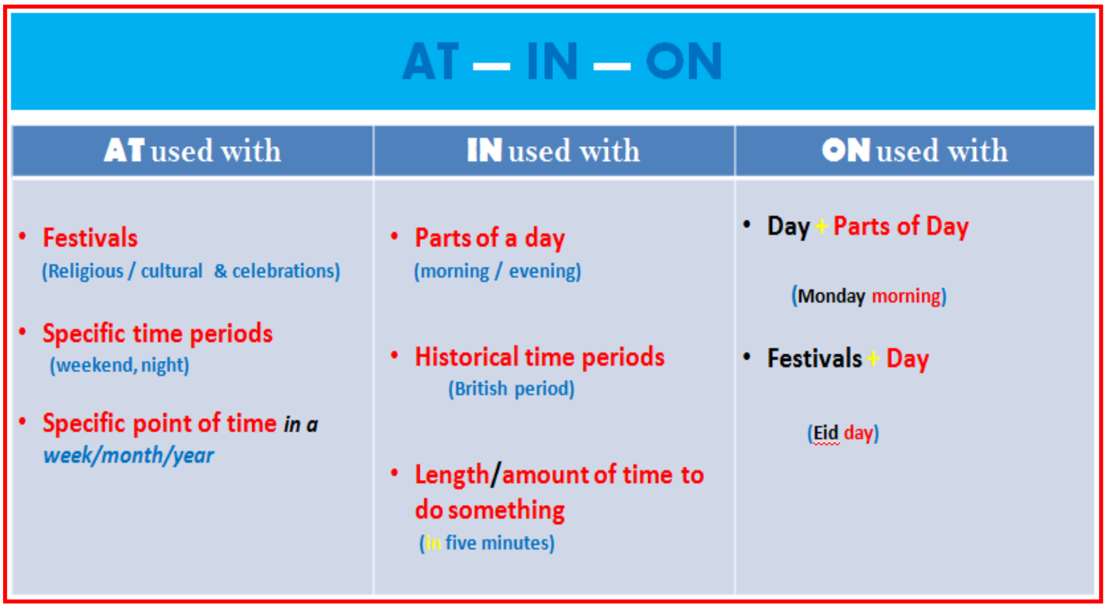

Figure 18: Sample screen C-11

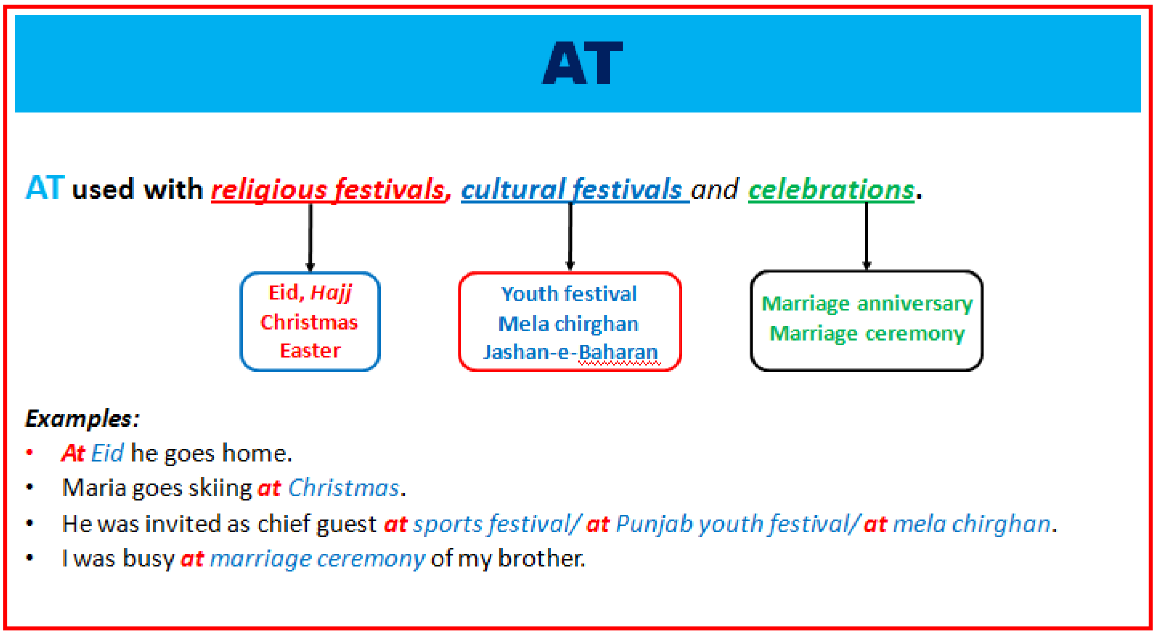

Figure 19: Sample screen C-12

5.4.7 Design of Evaluation Material

The evaluation material is designed using formative and summative assessment techniques. The formative assessment material *(practice material)* has been designed to monitor students learning. The summative material *(exercises)* has been designed to evaluate students learning at the end of each topic. For learners, with low WMC, the assessment material have designed corresponding to each concept at two different levels, (i) to judge the recall ability of learner in learned concept; and (ii) questions to fill in the right words. At the completion of concepts (at, in, on) related to a topic (preposition of time/place) the assessment material designed at three different levels. First, to check the recall ability of learners in each learned concept; second, test using fill in phrases with right choice of preposition using given choices; third, test using fill in sentences with right choice of preposition from given choices. For learners, with high WMC assessment material has been designed to present it at the completion of each topic. The material has designed to test recall ability and to fill in words to complete sentences. Summative material exercises have been designed using fill in sentences. It also has variation on the basis of individual's memory capacity. For low memory learners, initial exercises have designed using images representing the context of textual questions while later exercises have designed using only textual questions. For high memory learners' only textual exercises have been designed.

5.4.8 Design of Feedback

Two type of feedback messages have been designed including immediate feedback and hints. Immediate feedback will be given instantly to students based on the diagnosis of their errors. Immediate feedback has further two types - verification and elaborative, both used to design feedback. For surface learners, elaborative feedback messages have been designed, not in the form of concrete answer but in the form of guidance *(concepts explained)* for each question using text. This will be used to avoid students' frustration and encourage them towards learning activity. The verification messages have been designed to show that answer is wrong or right and give credit of right choice to student. Hints have been designed for deep learners, which appear at the completion of practice material to motivate them to think and re-try to solve the question on his/her own instead of giving direct answer.

5.5 Summary

The content development is an important part of e-learning system. We believe that adaptive strategies along with e-contents developed considering specific learning needs of learners would enhance the effectiveness of e-learning systems in terms of improving learning outcomes. Although, personalization improve the learning process but if system deliver recycled learning material then the full potential of an adaptive e-learning system could not be realized. In this research, an effort has been made to develop localized adaptive learning content to deliver through adaptive e-learning system to the diverse kind of learners.

CHAPTER 6

DESIGNING ADAPTIVE E-LEARNING SYSTEM

Overview

This chapter has two parts, first it presents review of user modeling and its related techniques used to construct student models. Among these, we have picked up an appropriate technique to construct SM of an adaptive learning system. Second part of chapter presents architecture of system along with internal details of each component and algorithms used to adaptively select learning contents and for adaptive presentation of content in accordance to learner's performance. Finally, the tools and language used to develop prototype are discussed.

6.1 User/Student Modeling

History of User Modeling

The pioneer work regarding user modeling research is presented by ELANE RICH in which she discussed stereotyping technique that's considered as a base for user modeling (Kobsa, 1993). The description of this technique is as follows:

6.1.1 Stereotyping

Stereotype is a technique to create user models. Grundy is a system which created user model through stereotyping technique. Stereotype comprises on three steps

- Identification of user groups
- Identification of key characteristics
- Hierarchal representation of stereotype

Identification of User Groups

The users are separated into different groups according to their characteristics relevant to application. Users with identical characteristics are clustered into one group. For example, groups of students can be novice, beginner, advance and expert users as shown in below figure 20.

Identification of Key Characteristics

The characteristics of user are determined by developer in order to analyze the type of user. The system recognizes the presence or absence of these characteristics in a particular user. In AESs, the key characteristics of learner's could be learning styles and domain knowledge etc.

Hierarchal Representation of Stereotype

The users with similar application relevant characteristics are merged into one group. If the characteristics of one stereotype are overlapping in any other stereotype such stereotype can be represented hieratically in which parent stereotype encompasses the features of the child stereotype. For example, one stereotype can be male and female and then children stereotype can be represented according to their level of expertise such as novice and expert. The SM based AESs might use stereotype techniques in order to categorize identical learner to one group. Stereotyping is very powerful in providing significant information based only a few observations but it does not provide precise model of learner. Stereotypes are mostly constructed manually but once constructed they can quickly model and serve new learners (Chrysafiadi & Virvou, 2015; Kobsa, 1993).

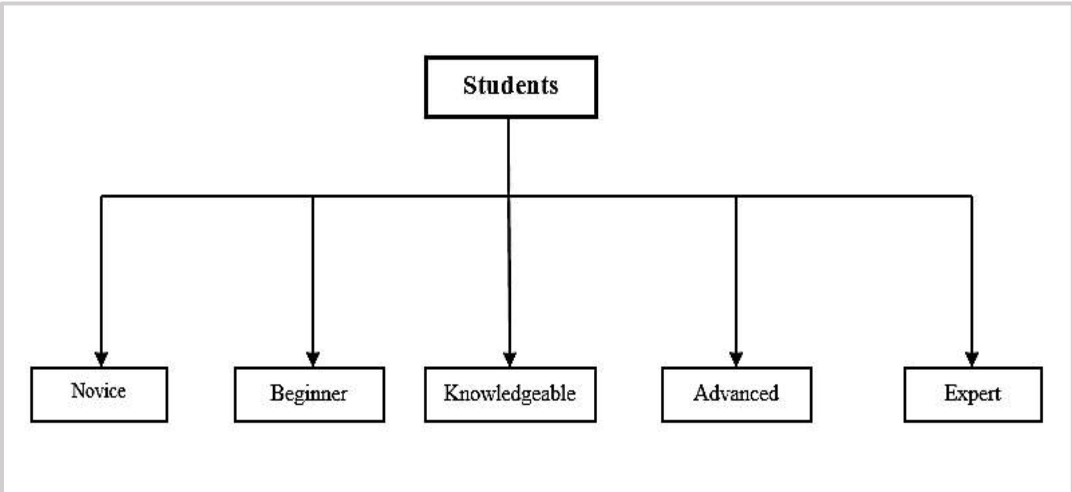

Figure 20: Stereotype of student's knowledge levels (Source: Chrysafiadi & Virvou, 2015)

6.1.2 User Plans

After stereotype, another technique called "user plan" was introduced. Plan basically is an order of user actions to achieve certain goal. The system developed using user plan called plan recognition systems which observe the user input actions in an attempt to identify all possible user plans. User plan has two further techniques known as plan libraries and plan construction which are used for the recognition of user plans. These techniques are described as follows (Kobsa, 1993) [216].

Plan Library

This technique directs to store all possible user plans in a plan library. The user actions are matched to these pre-stored plans. Those plans are chosen whose initial information matched to observed user actions. Using this technique, it is difficult to handle the possibility of plan variations. So, all possible deviations from a plan should store as separate plan. In AESs, all learning material can be stored in a database with all possible combination of lesson. For example, AES dealing with active/reflective learning dimension. All possible lessons for such dimension should be available in plan library (Kobsa, 1993).

Plan Construction

This technique maintain library which consists of all possible user actions along with their effects and preconditions. The order of user actions is determined by the order of all possible user actions which meet the requirements and effects of past actions and meet the preconditions of succeeding actions. For example, in AESs learning material is stored in hierarchal form to indicate the flow of lessons such as prerequisite of concepts should store in database.

In earlier work, the task of user modeling was accomplished by software application. There was no clear difference between modules serving user modeling and performing rest of the tasks. The user modeling component in software is expansive and hard for developer as they have to develop it from scratch each time when the system is developed. To handle such problem, user modeling shells and servers have been developed to separate user modeling from application system. The four main user modeling shells were GUMS, UM, UMT, BGP-MS (Kobsa, 2001).

Since last many years, the focus of user modeling is on modeling of learning styles. The specific learning styles of students are assessed and used as input for user modeling engine to present matched learning material to the students (Kobsa, 2001; Kobsa, 1993).

6.2 Machine Learning Techniques

Machine learning techniques are used to incorporate intelligence in educational systems. Following techniques are used in AESs.

6.2.1 Fuzzy Logic

Zadeh (1965) introduced fuzzy logic to deal with uncertainty. The technique deals with reasoning that is imprecise rather than precise. In other words, we can say that fuzzy logic is capable to reason and make sensible reasoning in situation when information is uncertain, incomplete and imprecise. The elementary component of fuzzy logic theory is fuzzy set which defines a feature, factor, state such as “expert” is a fuzzy set which defines the level of student knowledge, ‘old’ is a fuzzy set that defines the age of persons and ‘IQ’ is a fuzzy set that defines the IQ level of students. Similarly, ‘far’ is a fuzzy set that defines the distance of two objects. The concept is elaborated by below figure 21 and 22 (Chrysafiadi, & Virvou, 2015).

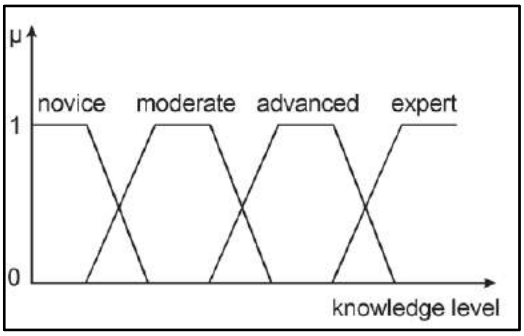

Figure 21: Fuzzy sets of age (source: Chrysafiadi, & Virvou, 2015)

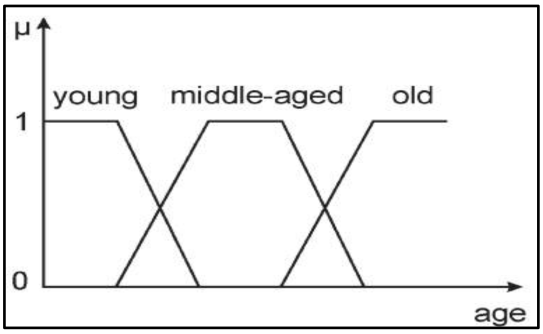

Figure 22: Fuzzy set of knowledge (source: Chrysafiadi, & Virvou, 2015)

The variables of fuzzy logic have truth values fall in the range of 0 to 1. The value defines the amount in which specific variable be relevant to fuzzy set. Fox example, if s is a fuzzy logic variable which defines the level of student knowledge and its value is 0.8 for the fuzzy set ‘surface’, indicating that 80% students are surface learners. Such value is called membership value that is denoted by μ.

The items of fuzzy logic can have relation to two contiguous fuzzy sets at the same time but with varied membership degrees. For example, if student learning style value is 0.7 *(the membership degree for the fuzzy set ‘active’ is 0.7)* and 0.3% for reflective dimension (*the membership degree for the fuzzy set ‘reflective’ is 0.3)* then the certain learner is considered to be 0.3% reflective learner.

To fully handle uncertainty, fuzzy logic theory extended to advance type which considers different dimensions in order to completely cater the imprecision.

Owing to the benefit of handling uncertainty, imprecision and incomplete information make fuzzy logic one of the most useful technique for many human centric fields including decision making, approximation, clustering, control health care and educational systems. The educational systems include *grading systems*, student’s evaluation and AESs.

The objective of AESs is to deliver learning material in accordance to student’s learning needs. The fuzzy logic has been extensively utilized to represent SM in order to provide personalized learning experience (Chrysafiadi, & Virvou, 2015).

Advantages of Fuzzy Logic

Following are the advantages of fuzzy logic.

- Able to approximate human like diagnosis of student knowledge.
- Successfully handle reasoning with incomplete information.
- Represent student knowledge in similar way as human instructors do.

Disadvantages of Fuzzy Logic

Following are the disadvantages of fuzzy logic.

- Hard to develop model from fuzzy system

- Require fine tuning and simulation before operational

6.2.2 Student Modeling with Fuzzy Logic

The community related to learning technology has recognized the promising aspects of fuzzy logic. In educational systems, for each concept the fuzzy value is computed as the numerical degree of the system's belief regarding student's level of understanding of the corresponding concept. Following systems have been designed using fuzzy logic.

DEPTHS

DEPTHS trace each action of students and store observed actions in SM. The system uses this data to make instructional planning to presents student future recommendations. The system uses collection of fuzzy membership functions and rules to reason about the student's knowledge. The rules used in the reasoning process has form for example IF test difficulty is 'easy' AND duration is 'long' AND success is 'good' THEN knowledge is 'enough'. *Easy* is one of the possible value of input variable 'test difficulty' defined by membership function of the respective fuzzy set. Similarly, *long value* represent the time spent is greater than learner should spend. *Good* represent the possible input variable value *'success'*, degree of the correct answer fall in the range of 1 to 100 and *'enough'* is one of the values that can be used to depict the belief of system regarding learner's degree of mastery of concept. The logic to diagnose student's knowledge related to a concept is determined through fuzzy rules. The diagnostic engine hold set of pedagogical rules and domain knowledge to determine assessment results to infer learner's level of knowledge on the basis of such results (Jeremic et al., 2012).

Adaptive Learning System (ALS) Based on Fuzzy Set Theory

The system facilitates adaptive learning through fuzzy set theory. ALS premised on the believe that majority of the adaptive systems emphasize on the adoption of learner's behavior and interests to present personalized learning material and normally ignore to take into account the level of ability to match the content and difficulty of learning resources. The inappropriate resources may create problem of disorientation and learner's cognitive overload. The system assesses the student's knowledge and considers factors related to ability in order to provide appropriate learning material (Jia, Zhong, Zheng, & Liu, 2010).

6.3 Bayesian Network

Bayesian Network (BN) also known as probabilistic or belief networks which are used to give reason to uncertain information. BNs are used to develop knowledge based applications in such domains which require the reasoning of uncertainty. The network represented using Directed Acyclic Graph (DAG) which trains the causal relationships between nodes which represent random variables. The nodes have causal relationships in the form of parent *(causes)* and child *(effects)*. The child node can also be parent node as shown in below figure.

The nodes which have more than one parent nodes require conditional probability distribution that is provided through Conditional Probability Table (CPT). The CPT defines the probability of child node given probability of its parent node. In this way, BN depicts the information using influence diagram that is a logical way to make the problem domain simple and understandable.

The probability of a root node is called prior distribution. Using prior probability and conditional probability distribution the posterior probability for all the nodes in a network can be calculated which define the belief value regarding these nodes. BN have been used for static systems which have preliminary values for the nodes and probability table that do not change over time. It is also used for dynamic systems which rearrange learning strategies as per learner needs. Such systems initialize by the probability of the root node and conditional probabilities (Iqbal et al., 2015; Permanasari, Hidayah, & Nugraha, 2014; Barber, 2012; Millan et al., 2010).

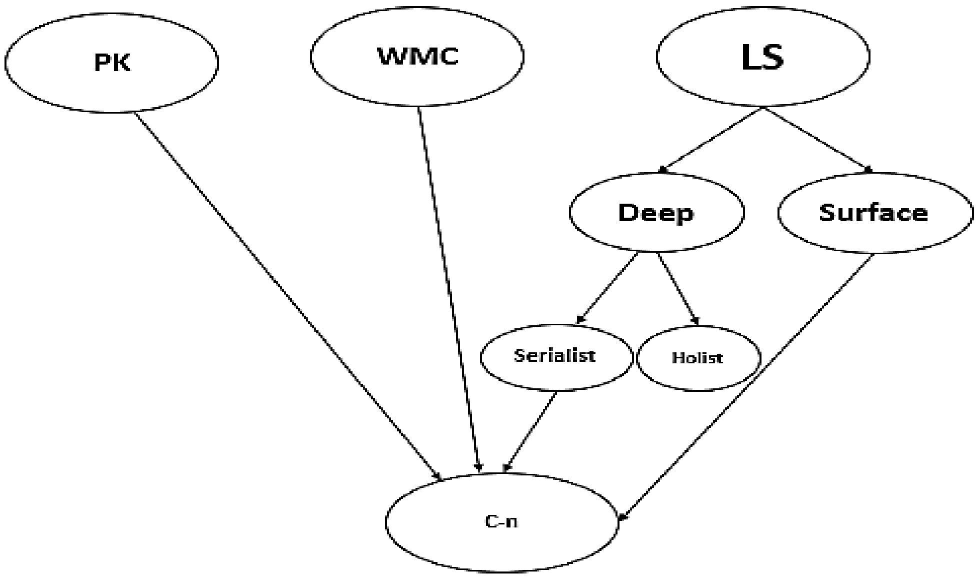

Figure23: A simple Bayesian network

Advantages of Bayesian Network

Following are the advantages of Bayesian network.

- BNs are capable to deal with incomplete data set as it can logically handle the dependencies among variables.
- BN assist to learn causal relationships which are helpful for the understandability of the problem domain. The knowledge of causal relationships allows to make predictions.

Disadvantage of Bayesian Network

Following are the disadvantages of Bayesian network.

- It is difficult in terms of computations to add or delete a branch of the BN because in these cases the probabilities must be recalculated completely. As with the increase of parent nods the calculation of the network probabilities is increased which makes it NP-hard problem that can be expensive.
- The usefulness of BN based on the reliability of prior knowledge. The subjective approach for the prior knowledge may distort the whole network.

6.3.1 Student Modeling with Bayesian Network

The SM is a component of AESs which characterizes the current state of student knowledge and the process which manipulates this is known as diagnosis process. BN nodes represented knowledge in the form of concepts, topics and subjects etc. For example, a student needs to know *n* concepts in order to answer certain questions. To realize this scenario using BN there is a need to define variable Q using *true* and *false* values which define that either student is able or not to answer the question. Similarly, concepts are defined using variable *Ci* where i = 1, 2….., n, a variable *Ci* takes two values *true & false* which defines that either student knows the concept or not. Generally, the parameter required for this network are the set of probabilities of concept C_1, C_2,…..,C_n and conditional probability of Q given C_1, C_2,….., C_n i.e., $P(Q=q/C_1, C_2\ldots..,C_n)$. Such probabilities are used to find evidence and belief values (Iqbal et al., 2015; Permanasari et al., 2014; Millan et al., 2010).

ANDES Tutoring System

It is an ITS to teach the course of physics. The system refers to probabilistic model which make decision to respond help requests. The system utilized BN to model student help thorough dependency graph which contain the topic for help as nodes. The system decides how to respond when learner requests for help. The SM of system calculates probabilistic evaluation of three types of information such as student's general knowledge about physics, specific knowledge regarding current problem and the plans that the learner may follow to solve problems. On the basis of such information, the system gives feedback and hints which are tailored to student's knowledge and goal (Conati, Gertner, & Vanlehn, 2002).

KBS Hyperbook

The KBS Hyperbook is an open adaptive hypermedia system to teach "Introduction to Java Programming" course. The BN have been utilized to implement user model to update the estimation of learner's knowledge on the basis of observations regarding the learner's performance with Hyperbook. The nodes of DAG are random variables, each further have four discrete variables to define the amount of knowledge a student has on the topic of respective node (Henze & Nejdl, 1999).

6.4 Artificial Neural Network (ANN)

The concept of ANN is proposed by McCulloch and Pitts (1943) that is based on the processes of neurons of human brain. The neural networks are mainly used to classify patterns and for nonlinear adaptive filters. The neural networks are adaptive as it learns function from training data and after training function of parameters the system is used in real setting to fire rules for specific input pattern. The neural network is a mechanism which takes many inputs and produces one output as shown in below figure. The main application of neural network is in pattern recognition which can be implemented using a feed-forward neural network. In the course of training, the network is trained to relate outputs with input patterns. During network evaluation, in real environment, it diagnoses the input patterns to associate them with output pattern. It is therefore useful to estimate learning style dimension in e-learning scenario by identifying behavioral pattern (input pattern) to associate them with specific learning style dimension (Stergiou, n.d).

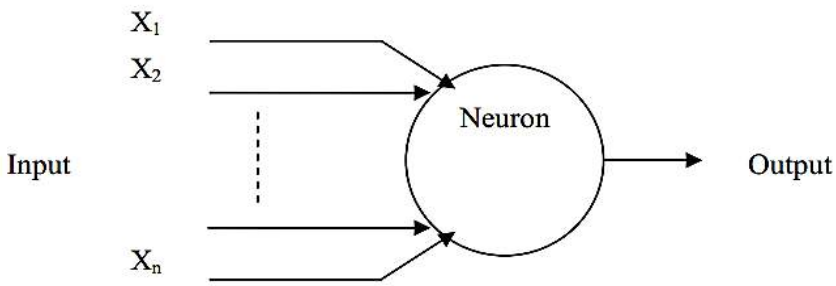

Figure 24: A simple neural network (source Stergiou)

For the training of network, there is a single input against single output. An error is handled by taking difference of predicted and targeted output of the neural network. The error is sent to system and network weights are updated on the basis of the error. The process remain continued until the improved function is not achieved (Stergiou, n.d).

Advantages of neural network

The advantages of neural network as follows:

- A neural network can be used for any specific domain after training data.
- Upon destroying one network of neural network its performance does not degrade.
- Neural network have capability to utilize for nonlinear classification.

Disadvantages of neural network

The disadvantages of neural network are as follows.

- A large dataset is required to train the neural network.
- Large training data requires high time to process.

- In case of noisy data overfitting arises.

6.4.1 Student Modeling with Neural Network

The paper proposed an approach using Artificial Neural Network (ANN) to identify student's learning styles. The researcher asserted that automatic approaches to detect learning style are at early stage and accuracy level is also low. So a novel approach called LSID-ANN was introduced for automatic student learning style modeling on the basis of FSLSM. The input of LSID-ANN is behavioral pattern and the output of the ANN relative to the learning style as recognized by ILS questionnaire (Bernard, Chang, Popescu, & Graf, 2015).

Another paper proposed neural network architecture in order to find association between actions taken by students while interacting with e-learning application and their most appropriate learning styles. To accomplish this objective, the inputs of the network were represented on the basis of student actions such as reading material, access to examples, answer changes, exercises, exam delivery time, exam revision, usage of chat, usage of forum and information access by students. On the basis of value of these actions, the student output was represented in the form of learning style dimensions such as active/reflective, sequential/global or intuitive/sensitive (Villaverde, Godoy & Amandi, 2006).

6.5 Production Rules / Rule Based

The production rules are also known as the condition action rules which have the following form

If <condition> then <conclusion> or if <condition> then <action>

For example, if customer closes the account then delete the customer from database. The statement or set of statements after the keyword **if** depicts some pattern that you may observe. Similarly, the statement or set of statements after the word **then** represents some conclusion that you can draw or some action that you should take. There are several production rule systems which are also known as rules engines or production systems. Production systems examine huge quantities of knowledge in order to solve problems. These systems consist of declarative and procedural knowledge. Declarative knowledge makes a database of facts and procedural knowledge consists of rule based systems. The rule based systems usually include one or more conditions; if these conditions are satisfied then some specific actions are performed (Thirumuruganathan & Huber, 2011; Popescu et al., 2010; Popescu, 2009).

Advantages of Rule Based

The advantages of rule based systems are as follows.

- The major advantage of production rules is that they make easy to express appropriate pieces of knowledge.

- Ability to use in a direct way, experiential knowledge attained from human experts.
- It consists of some predefined number of possible paths which reduce the complexities.
- Good performance is possible in limited domains.
- Provide good explanation facilities. The basic rule based framework supports problem specific explanations.

Disadvantages of Rule Based

The disadvantages of rule bases systems are as follows.

- The predefined number of possible paths restricts the system.
- As the rules are got from human expert so highly heuristic in nature.
- Restricted power of expression.

The paper (Kumar, 2005) describes the rules based adaptation mechanism to adaptively generate problems in programming tutor. The learning objectives related to each topic of subject are presented. The system assesses prior knowledge of learner using pre-test to judge the weak topics of student and then focus on those topics. The learner move to next topic on the basis of correct answer given to questions.

Another paper (Lu, Eugenio, & Ohlsson, 2007) also introduced rules to assess the cognitive skills of the student to deliver them domain specific knowledge accordingly. Further the tutor provides feedback on errors through production rules.

Concluding Remark

From the above mentioned machine learning techniques, it is learnt that adaptive rules are most suitable for the situation this research intends to address.

The subsequent part of chapter presents details of adaptive e-learning system designed to prove our hypothesis.

6.6 Architecture of the System

The architecture presents the major components of our system and their interaction with each other to achieve the desired functionality of individualized learning environment. The components include domain model, student model, adaptive model, evaluation module, feedback module and user interface module. The student model was built on the basis of student data collected through instruments *(details are discussed in next chapter).* According to the information against each student stored in his/her student model the system offer suitable learning content that is recommended by adaptive logic employed in the system. The identified learning content retrieved from the domain model. Further, system tracks student performance in terms of marks obtained on each practice task. Based on the performance parameter, the system adapts presentation of the learning content. At the end of each topic, the system takes an assessment test to judge the knowledge level of learner. On the basis of performance in test system makes further decisions. Following are the main components of the system showing interaction to each other.

- Domain model
- Student model
- Adaptive model
- Evaluation model
- Feedback model
- Unser interface model

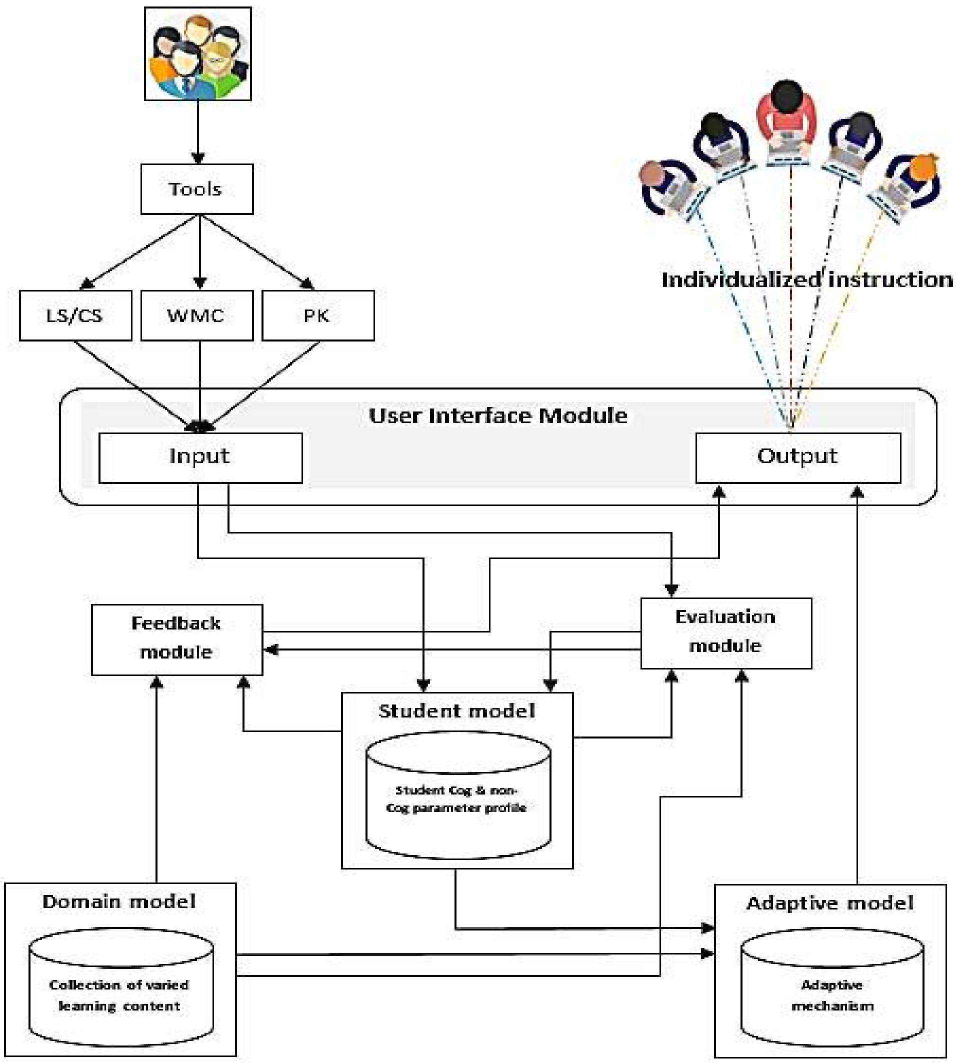

Figure 25: Architecture of adaptive e-learning system

The above figure depicts detailed architecture of the system. The evaluation module and feedback module could merge with adaptive model but here presented separately. The major objective of this model is to impart instruction considering student's learning characteristics and their progress during learning.

Each component of the system is explained subsequently with complete details.

6.6.1 Domain Model (DM)

The DM captures domain knowledge of the subject we are interested to teach. In this project, English Grammar specifically preposition topic has been picked up as domain knowledge as depicted by National English Curriculum for Grade IX and X. The below figure depicting the hierarchy of topics which were developed as part of this research and described in detail in chapter 5. The DM contained multiple versions of each concept of English preposition, considering different combinations of adaptive parameters, which are Prior Knowledge - PK (low, high), Working Memory Capacity - WMC (low, high) and Learning Style - LS (Deep *(serialist/holist)*, Surface).

For example, low PK, low WMC means learner has poor knowledge base and has poor memory retention abilities whereas high PK, high WMC means the learner has essential knowledge of subject as well as good memory processing and retention abilities. The learner with deep learning style like well-structured and well-connected concepts. The surface learners make use of rote learning. Furthermore, learning strategies related to deep learning style such as serialist specify that learners use details to develop understanding and feel at ease with clear logical structure whereas holist learner want to take overview of topic and is desirous to learn efficiently by relating concepts with each other. They do not prefer to read material and do not emphasis on an adequate amount of details. Therefore they could experience learning deficiency.

Hence, each version provides distinct presentation of the same concept corresponding to different combinations of learning characteristics. For example, learner with Low PK, Low WMC and Deep LS get learning content that's begin with basics of a concept using simple and smaller pieces of domain knowledge emphasizing on learner's ability to remember usage of grammar constructs. Moreover, in case of *serialist* sub-dimension of Deep-LS the contents are presented in sequentially ordered chunks with enough details using illustrations and examples while in case of *holist* the content are offered in the form of overview and summaries without much detail. If the value of PK changes from low to high then the content changes respectively from basic to advance knowledge of preposition. Similarly if WMC value found high then the learning content presented without the constraint of size. If LS is surface then content changes to simple form with less details and more self-explanatory examples. The DM maintains the repository of distinct contents corresponding to all combination of parameters considered in this study along with formative and summative assessment material, feedback material and correct answers.

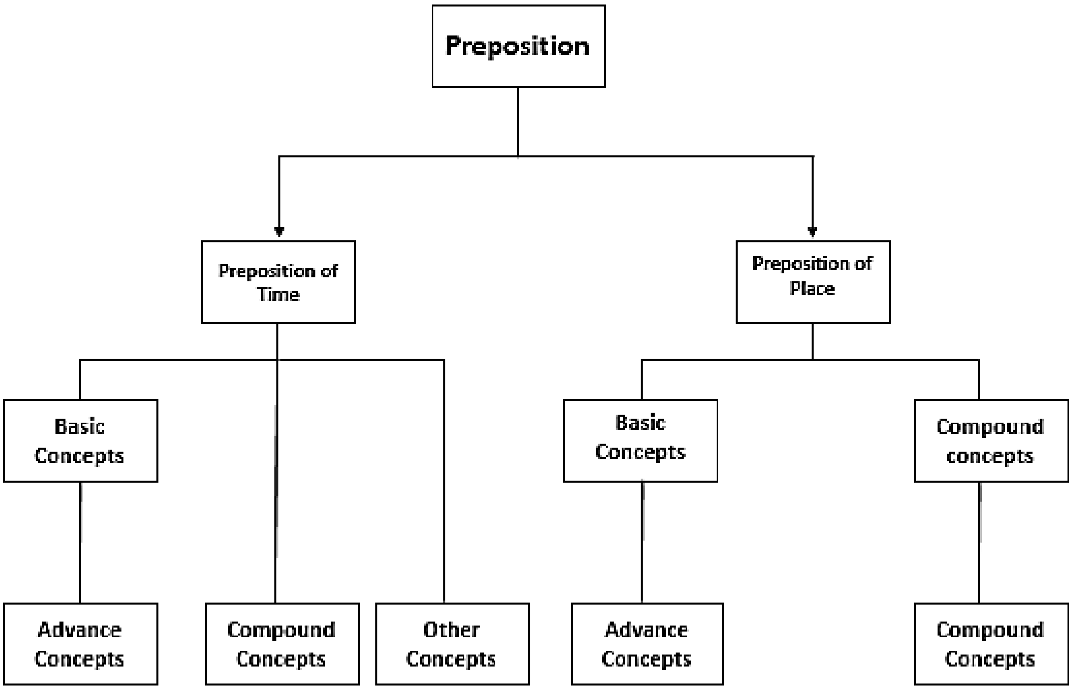

Figure 26: Hierarchal representation of domain

6.6.2 Student Model (SM)

The SM encompasses thorough information about the student in the form of student profile. The student profile depends on the values of learning characteristics or parameters researcher interested to model for the sake of adaptive learning. In this research, student information collected through standard tools *(details are discussed in chapter 7)* and incorporated directly into SM. The standard tools includes Approaches and study skills inventory for students (ASSIST) Working Memory Test Battery for children (WMTB-C) and self-designed test used to determine subject prior knowledge. The SM provides information to adaptive model, evaluation module and feedback module. The SM is updated by evaluation module according to the performance of student that is continuously evaluated by evaluation module. The below paragraph explain further details related to SM.

Based on the approach discussed in (Germanakos, & Belk, 2016) it is adopted that SM is the set of cognitive and non-cognitive individual characteristics. In particular, the SM consists of non-cognitive characteristics, for example, prior knowledge that is characterized by low and high values e.g. low-PK and high-PK and cognitive characteristics such as cognitive abilities which include WMC that's further characterized by low and high values e.g. low-WMC and high-WMC. Other cognitive characteristics are learning styles & related cognitive styles such as Deep vs. Surface learning style have further characterization such as deep-serialist and deep-holist. Below figure 6.6 graphically depicts this scenario.

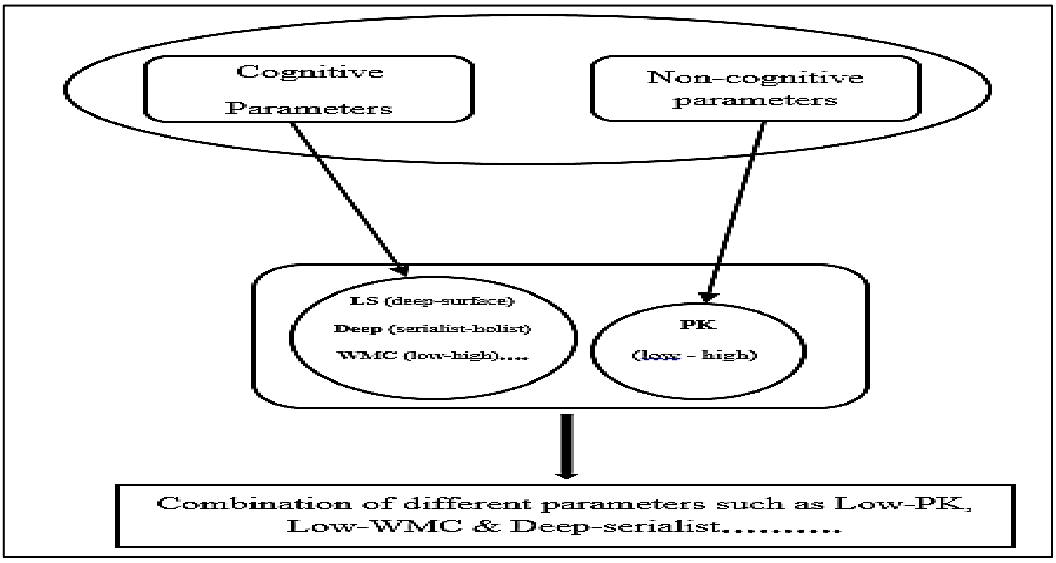

Figure 27: Representation of proposed student model

More individual's non-cognitive (e.g. experience, background) and cognitive characteristics (e.g. attention, affective states) could be incorporated into model but the scope of this study is limited only to the cognitive and non-cognitive parameters which are defined above.

The student interacting with the e-learning environment can exhibit any combination of non-cognitive and cognitive characteristics for example s/he may have low-PK, low-wmc and deep-serialist whereas another may have low-pk, high-wmc and deep-serialist. Similarly, others may have variation in any one of the above defined parameters or in any other dimensions which make him/her distinct from rest of the learners in terms of learning needs. Therefore, each learner is characterized in SM to present him/her learning content in accordance to their learning needs.

Therefore, the student model *sm* of a student *si (sm(si))* is composed of non-cognitive characteristics *(individual differences = ncc)* and cognitive characteristics which further consist of cognitive abilities *(individual differences = ca)* and learning styles/approaches *(individual differences = ls)* and consist of triplets of the form *(ID, sch, val)* where ID is for individual differences represents a combination of cognitive and non-cognitive individual characteristics for example non-cognitive characteristics, cognitive abilities and learning styles. *Sch* student characteristics represent student's cognitive and non-cognitive characteristics for example prior knowledge, working memory capacity and learning styles. The *val* stands for value which represent the value of each user characteristic for example prior knowledge have either *low* or *high* value, WMC have also either *low* or *high* value and learning style/approaches have either *deep* or *surface* value and deep learning approach further have either *serialist* or *holist* tendencies (value). For example a student *si* may have the following student model.

sm (si) = {(ncc, prior knowledge, low), (ca, working memory capacity, low), (ls, deep, serialist)}

The above student model representation shows that *si* has low prior knowledge in the category of non-cognitive characteristics *(ncc)*, his cognitive ability is working memory capacity which is low and his learning approach is deep with serialist tendency.

6.6.3 Adaptive Model (AM)

The AM is responsible to impart instruction to students in accordance to the student information stored in SM. The decision of selecting appropriate learning content from DM is made by AM so it is a central model which interacts with both DM and SM for decision making. It then generates output for User Interface (UI) module to present appropriate learning contents in accordance to the learning needs of diverse learners as shown in figure 25. It individualizes learning and degree of practice at each knowledge item to certify that the learners master the content. The internal details related to AM are as follows.

The adaptive model encompasses adaptive rules (AR), the collection of learning contents (CLC) and the adaptive engine (AE). AR is the group of all adaptive rules adopted from (Germanakos, & Belk, 2016). These rules are described in detail in further paragraph. CLC is the collection of learning contents each based on the form of triplets *(individual differences, student characteristics and values)* which means that the design of content is represented by three values of individual's learning characteristics. The adaptive engine is liable to recommend suitable learning content (LC) for a student *si* using the student model *sm* (*si*) and adaptive rules (AR). The process is shown in below figure.

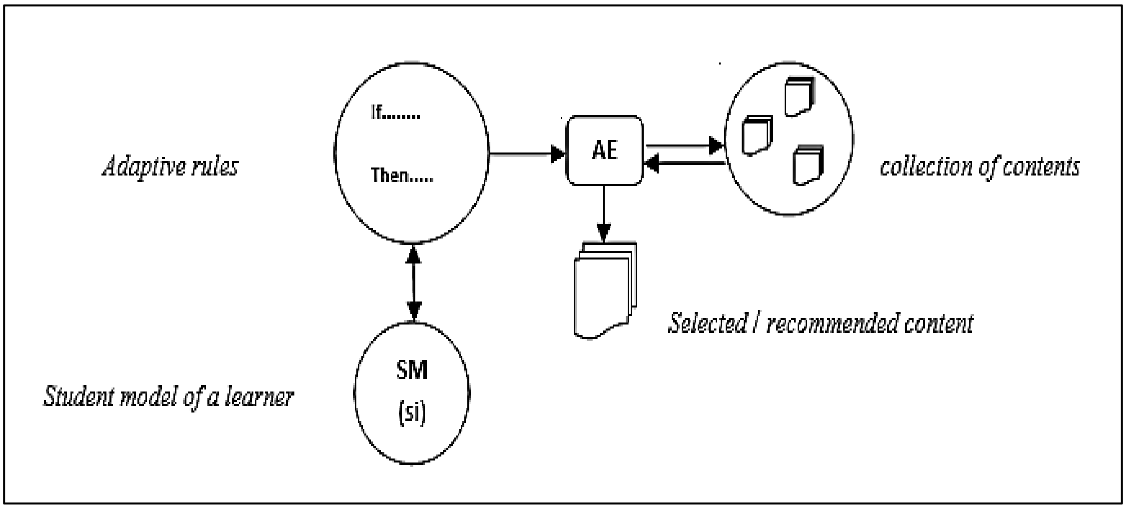

Figure 28: Representation of adaptive model

The adaptive engine may conceptually be envisioned in the form of below given function.

$$AE\ (sm\ (si),\ AR) = LC,\ LC \in CLC$$

The adaptive rules relate the student characteristics defined in his/her student model with particular learning content. The adaptive rules develop link between set of student learning characteristics including cognitive and non-cognitive with specific learning content in order to recommend suitable content for learning. An example of an adaptive rule is if student *si* has low PK, low WMC and deep serialist then learning content C-1 type should be recommended to learn concepts of preposition because the design of C-1 satisfies the needs of *si* related to PK, WMC and LS. If any value of user characteristics is changed the corresponding learning content should also be change respectively. Below examples of rules are defined which shows the change of content type with the change in value of student's learning characteristics.

Example Rule # 1: {(pk, low), (wmc, low), (ls, deep), (deep, serialist)}, (content_type, C-1)

Example Rule # 2: {(pk, low), (wmc, low), (ls, deep), (deep, holist)}, (content_type, C-2)

Example Rule # 3: {(pk, low), (wmc, low), (ls, surface)}, (content_type, C-3)

Example Rule # 4: {(pk, high), (wmc, low), (ls, deep), (deep, serialist)}, (content_type, C-7)

The Boolean expression is basically an expression which entails variables and each variable have either true or false value. Such variables are joined by Boolean operator for example **and** also called conjunction, **or** also called disjunction and **not** also known as negation. There is a theorem which states that a Boolean function can be written using merely two levels of logic and probable negation of variables. There are two distinctive forms, correspondingly known as disjunctive normal form and conjunctive normal form which are specifically useful. A clause have set of variables with operator **and,** called conjunctive form and collection of variables with operator **or** called disjunctive form (each optionally negated). If a Boolean expression is a conjunction of variables then it is believed to be in conjunctive normal form and if it is a disjunction of variables then it is supposed to be in disjunctive normal form.

The above rules are conjunctive such as if pk is low **and** wmc is low **and** ls is deep **and** deep is serialist then perform action to present specific type of content i.e. C-1. The AM stores an adaptive rule $ar_m \in AR$ in the form of a tuple (B, LC) where B is a Boolean expression and LC $\in$ CLC that is a learning content. The adaptive selection of apposite learning content is done by evaluating Boolean expression, the intelligent mechanism is illustrated by below algorithm i.e. adopted from (Germanakos, & Belk, 2016).

Algorithm: Adaptive selection of learning content

Input: student model *sm (si)* and a set of adaptive rules AR

Output: apposite selection of learning content LC, LC $\in$ CLC

Step 1: Process: ae (sm (si), AR)

Step 2: For every *ar* (B, LC) in AR // Test every adaptive rule *ar* in the set of adaptive rules *AR*
Step 3: If (Test == true) // suppose that the rule *ar* applies

Step 4: LC = LC ∈ CLC //select apposite learning content

Step 5: Return CLC // present selected learning content

Step 6: Else

Step 7: Test == false // suppose rule does not apply

Step 8: End if

Step 9: End for

Step 10: Return ∅ **//** nothing to present

Step 11: End procedure

For the adaptive selection of learning content on the basis of learner's learning needs, the student model of such particular student is given as input along with set of adaptive rules. On the basis of the given information the program selects an appropriate learning content *(output)* from the repository *(domain model)* of learning contents. The major procedure for adaptive selection of appropriate learning content is that adaptive engine offer learning content for a specific student using his/her student model and applying adaptive rules. To perform this exercise, system tests every adaptive rule in the set of adaptive rules. For example, if rule applied then appropriate learning content is selected from the collection of learning contents and presented to learner. Conversely, if test remains unsuccessful *(means no rule applied)* then program control exit from its conditional structure and present nothing to learner.

6.6.4 Adaptive Strategy

This section explains the learning algorithm *(shown in figure 29)* used to make it possible for the system that how to teach knowledge elements *(i.e. at, in, on)* of concepts *(i.e. time & place)* of selected learning content. The knowledge elements means the learning elements of selected concept for example preposition words *at, in* and *on* of preposition time and place.

The student starts learning through adaptively selected learning content. The system further adapts learning content on the basis of student performance, the performance value stored in the *sm* of *si*. The student performance is determined through practice material presented after teaching each element of concept. If student got greater than or equal to 70% marks in first practice task *(recall test)* then he is moved to second practice task *(a)*. If s/he got less than 70% marks but greater than or equal to 35% marks then system guess that learner have some sort of knowledge gap so present the review of the learned concept. After review, again give randomly selected recall test to assess learning performance *(b)*. This iterates until threshold value is achieved. If learner got less than 35% marks then system assess that he/she has not learnt the concept so offer learner to repeat the lesson *(c)*. Upon receiving second practice task *(i.e. is related to the application of learned concept)* system again assess if learner obtains greater than or equal to 70% marks then next knowledge item is presented and student model updated regarding learned item as *"learnt"*. If marks are less than 70% and greater than or equal to 35% then summarized information is presented which give examples regarding the usage of preposition. If learner obtained marks less than 35% then system offer repetition of whole lesson and re-attempt the practice material.

Upon successfully learning all the knowledge elements exercise is presented which consists of bit complex sentences. If still student has not achieved desired results *(i.e. greater than or equal to 70% marks)* then system guess that learner is unable to recall so offer repetition of lesson *(mark him non-proficient in learned topic and reset all learned knowledge items).*

If student got greater than or equal to 70% marks then his/her model updated as *"proficient"*, which means that student has gained basic knowledge related to preposition of time and preposition of place along with related items. Therefore SM updated from knowledge value form low to high and system recommends learner an advance version of topic.

6.6.5 Adaptive Process

The adaptive process consists of four steps which are as follows.

- The cognitive and non-cognitive characteristics of learner are primarily retrieved from the data store.
- To take adaptive decision specific adaptive rule is applied from the set of rules.
- Retrieve the apposite learning content.
- Client side adaptive mechanism/strategy applied on the retrieved content for adaptive presentation of learning content.

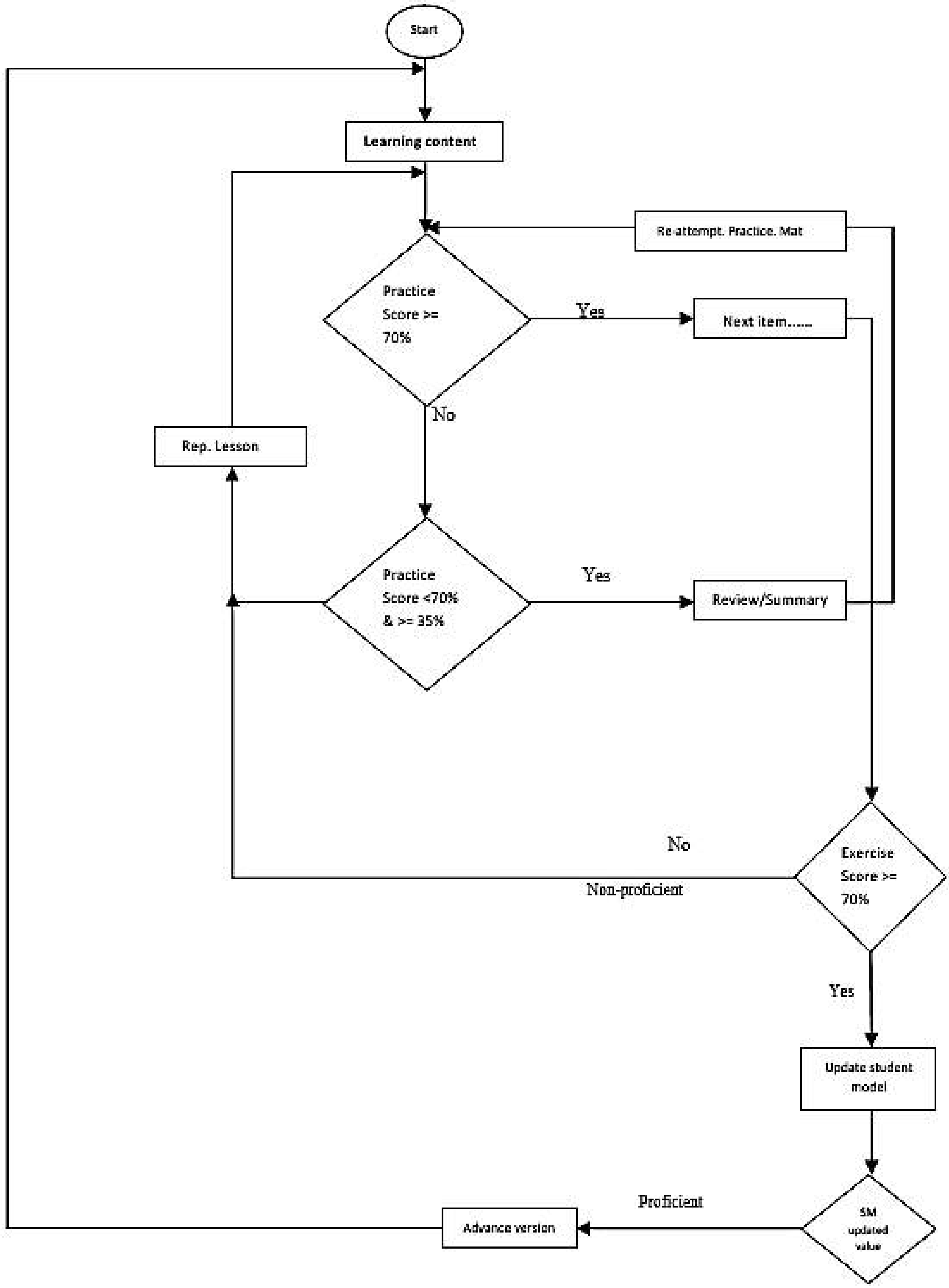

Figure 29: Representation of algorithm used for adaptive presentation

6.7 Evaluation Module

The evaluation module is responsible to calculate student performance. The module assesses student responses given to questions of different tasks of assessment material. Consequently, student profile of learner is updated in accordance to assessments made by evaluation module. For example, if a student successfully completed lesson the SM raise his/her knowledge level and move him/her towards an advance lesson. Conversely, if a student is continuously lagging behind, then SM mark him non-proficient and offer repetition of same lesson. This module gets correct answers regarding assessment material from DM and evaluates student's solution by comparing it with DM answers. Further, learning content is presented according to the performance shown in practice material. Following formula is used to determine the performance of students in assessment material.

$$\text{Performance in test} = P = (\text{total number of correct answers} / \text{total number of questions}) * 100$$

The decision regarding the presentation of learning material depends on the marks obtained in assessment material as shown in below table.

Table 5: Evaluation criteria

Range of marks got in tests	**Form of learning content**
$P \geq 70\%$	Next knowledge item
$35\% < P < 70\%$	Review / Summary *(depends on assessment task)*
$0 \leq P \leq 35\%$	Repeat lesson

6.8 Feedback Module

The feedback module is responsible to give feedback to learner in accordance to their learning needs. For example, if a surface learner making mistakes in giving answers to English sentences s/he got immediate feedback with detailed message which politely convey the reason behind mistake and ask to re-attempt the same question. The student may place right choice in subsequent attempt but evaluation module assess student performance on the basis of first attempt and further decision made accordingly. In case of correct response the mark appears to show that answer is true along with encouraging message to admire the effort made by learner. In case of deep learner, the delayed feedback is provided after attempting all questions. The system shows right and wrong answers with appropriate mark and present short feedback only related to wrong answers which enable deep learner to think out in this regard. The feedback module interacts with SM, DM and evaluation module and user interface module. It takes information related to student such as deep or surface learner from SM. It receives information regarding assessment material from evaluation module and it got correct answers from DM to identify desired feedback. Finally, it interacts with user interface module in order to show appropriate feedback to learners.

6.9 User Interface Module

The module allow user including student and administrator to interact with the system in order to give some inputs such as student information and login information etc., and to receive outputs generated from system in the form of learning content, feedback etc. Therefore, the user interface module consist of two sub-modules namely input and output modules which supports learner's interaction with the system.

6.10 Technologies Used for Prototype Development

The prototype is developed to verify and prove our hypothesis. The prototype designed on the basis of client server architecture. The language and tools used for prototype development are defined as follows.

- **PHP** ***(Hypertext Preprocessor):*** PHP is a server side scripting language mainly designed for web based development but it can also be used general purpose programing language. In this project a client-server based application is developed and PHP was used as a main language.
- **HTML** ***(HyperText Markup Language):*** HTML was used to format and display content.
- **Action Scripting** ***(object oriented scripting language):*** Action scripting is an object oriented programming language which is alike to JavaScript programming language. Action script was used in the development of prototype to include interactivity in learning material.
- **SQL** ***(Structured Query Language):*** SQL is most widely used language to interact with databases. In the development of prototype it was used to communicate with MySQL database.

Following development tools were also utilized in the design of prototype.

- **MySQL:** As the concurrent number of learners is very low, approximately from 10 to 120 maximum that is why we decided to utilize MySQL as a Data Base Management System (DBMS) rather than Oracle or SQL server.
- **Apache:** Apache is widely used web server software which is utilized to launch Adaptive e-learning prototype.
- Macromedia Flash 8
- Macromedia Dreamweaver
- Adobe Photoshop

6.11 Screen Shots of Prototype System

Some screenshots of adaptive learning system are shown in subsequent figures.

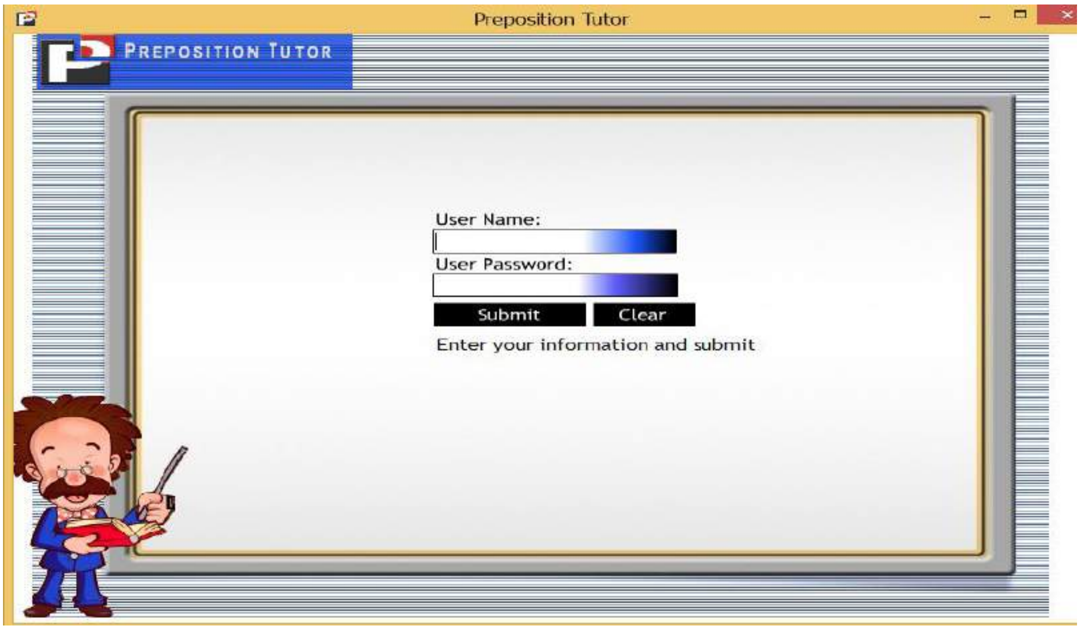

Figure 30: Login Screen

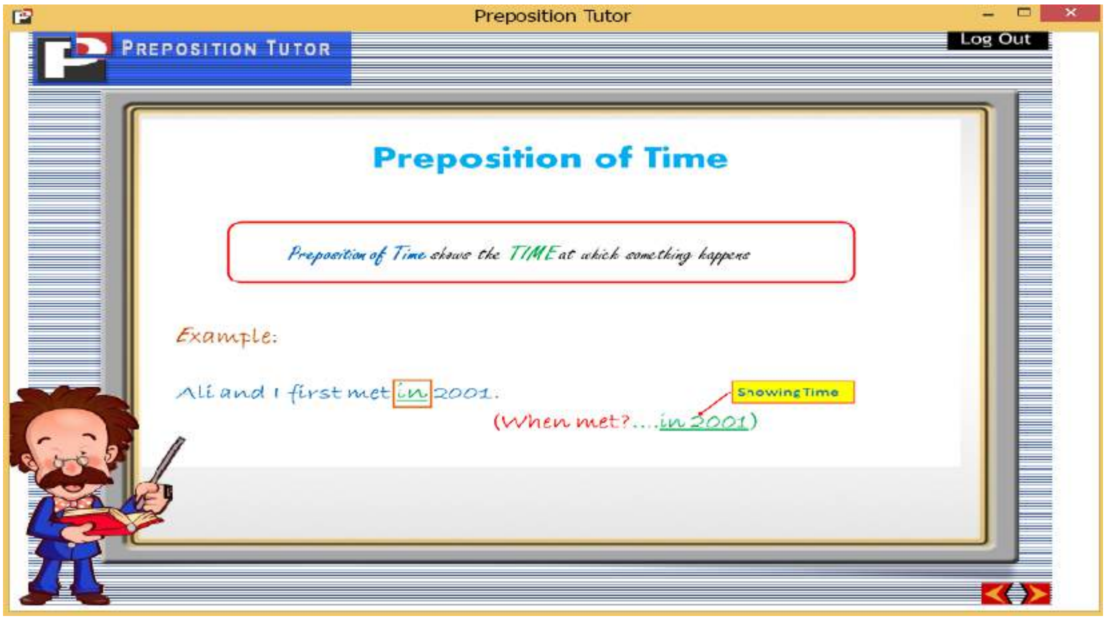

Figure 31: Preposition definition screen

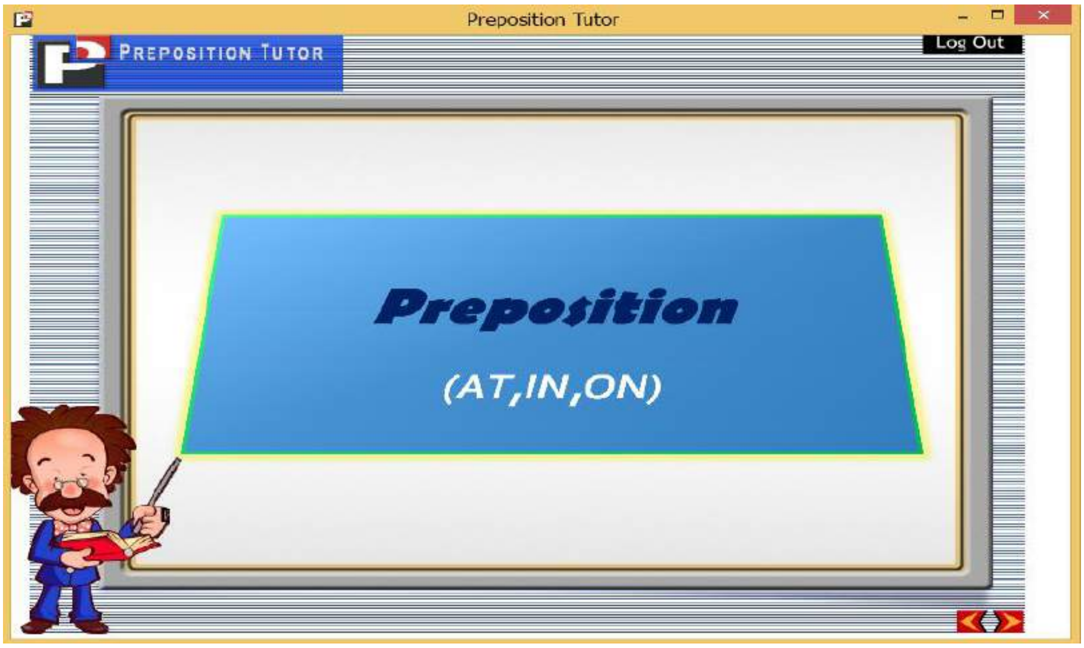

Figure 32: Topic screen

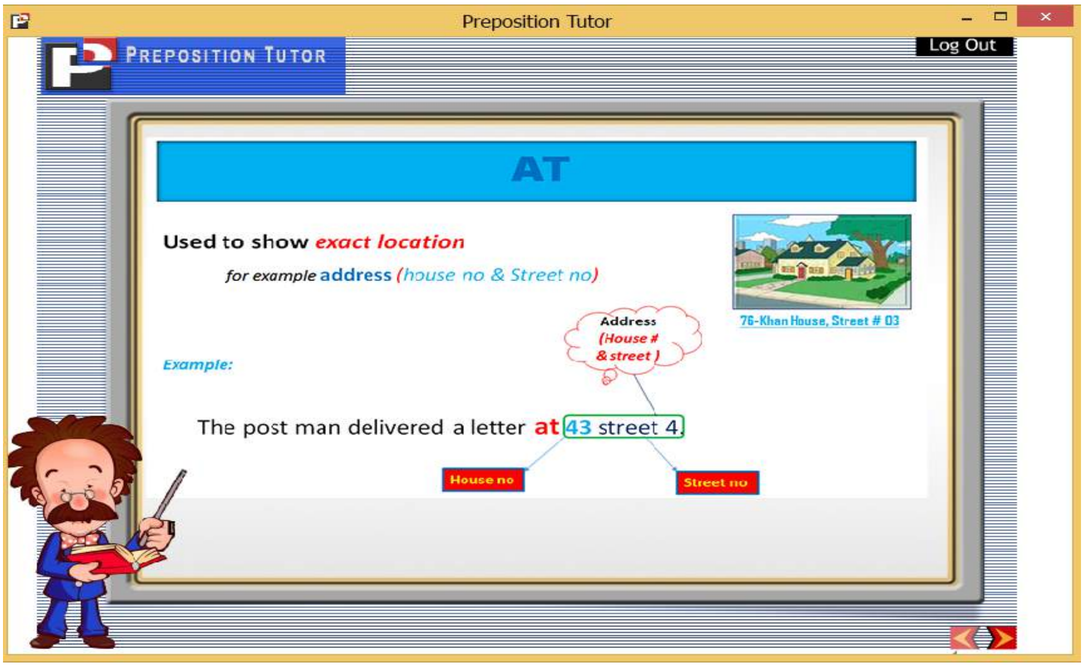

Figure 33: Learning content screen # 1

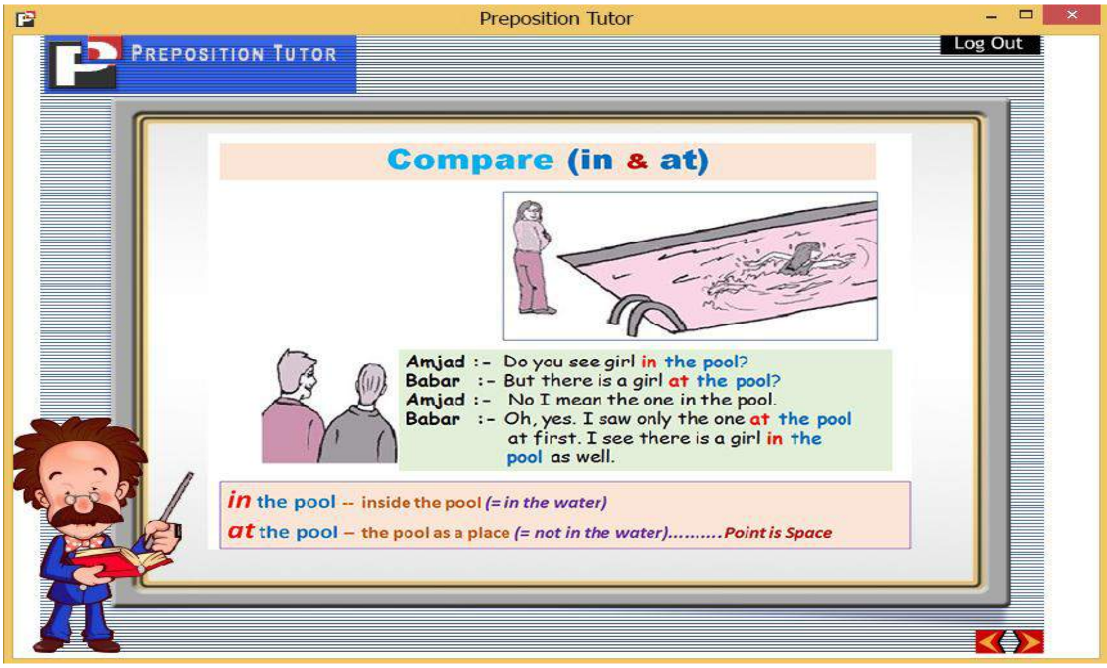

Figure 34: Learning content screen # 2

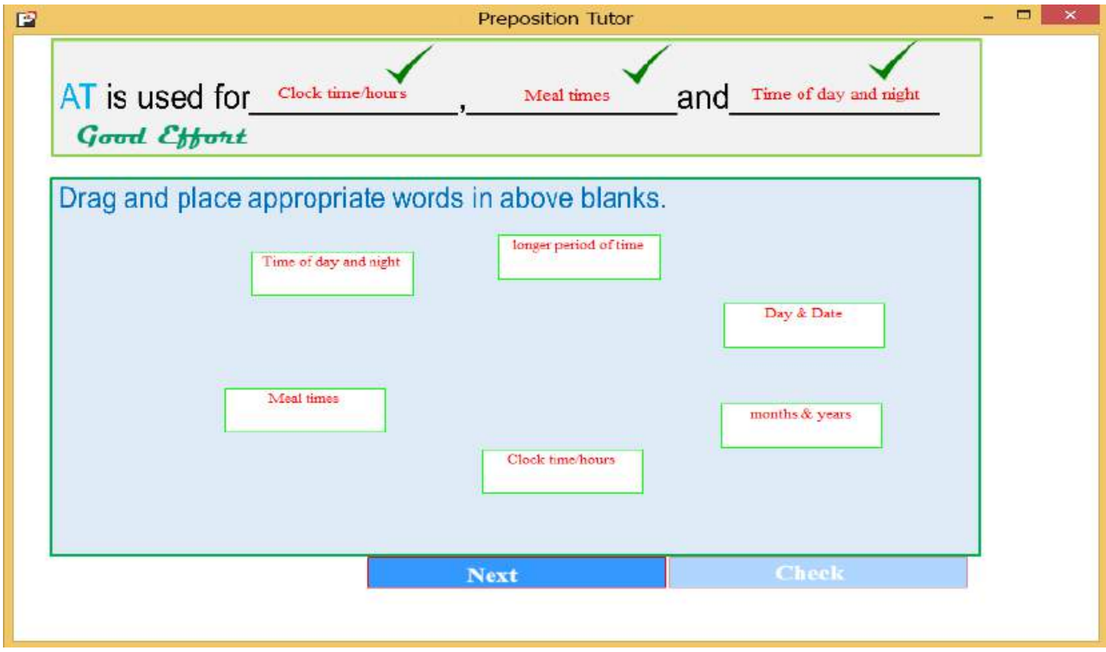

Figure 35: Formative assessment material screen # 1

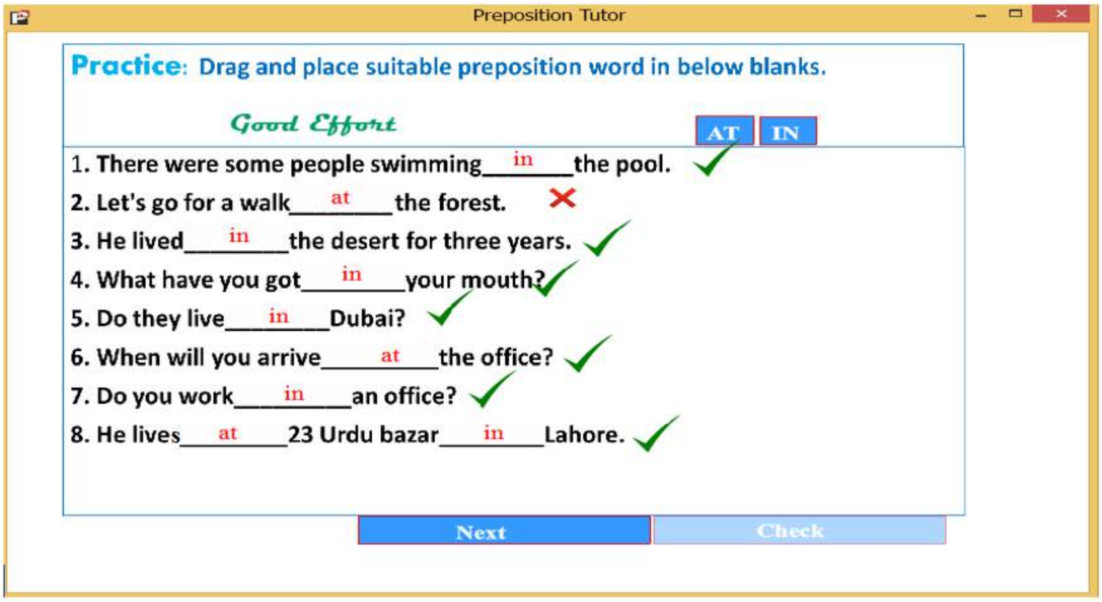

Figure 36: Formative assessment material screen # 1

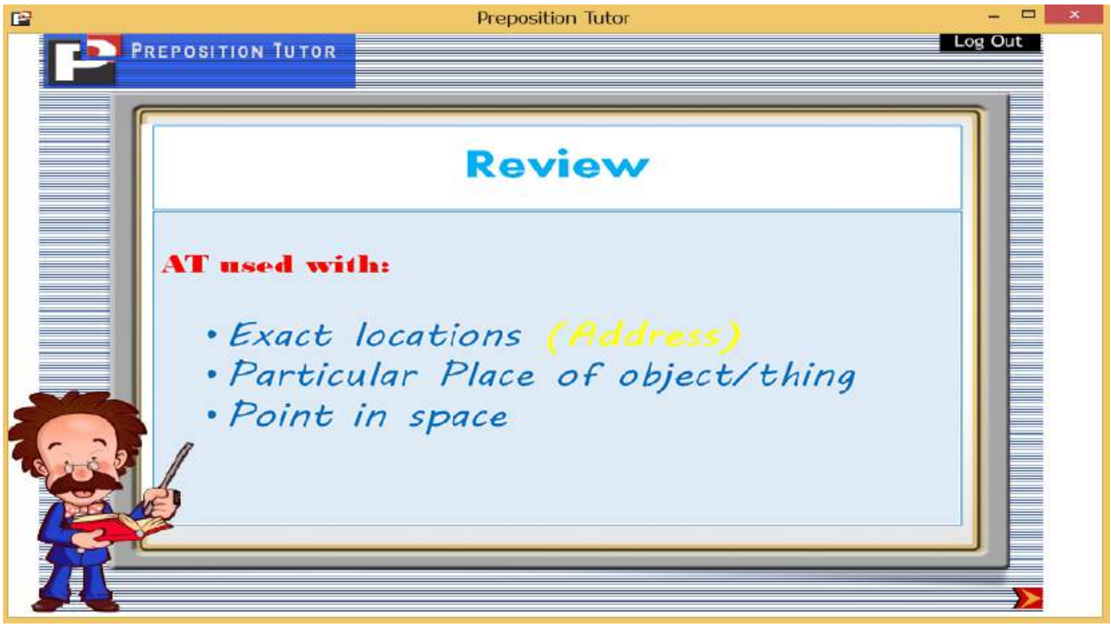

Figure 37: Review screen

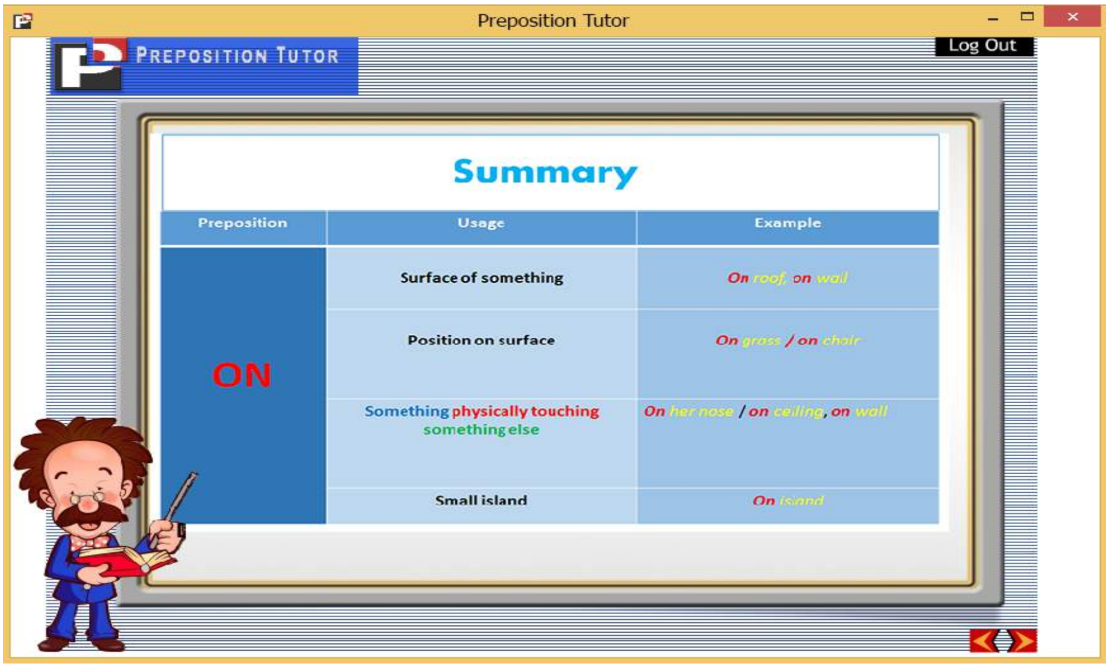

Figure 38: Summary screen

CHAPTER 7

EXPERIMENT AND RESULTS

The chapter present details of experiment conducted to test research hypothesis and to prove that proposed approach has potential to improve learning outcomes. The evaluation study was conducted in real setting using experimental and control group approach. The experiment consisted of three major parts. First part is related to the preparation of instruments/tools to identify students learning characteristics. Second is about the deployment of tools in real environment. Third was related to the actual execution of experiment and analysis of results.

7.1 Preliminary Phase

This section explains the preparatory activities performed prior to delve into experimentation. The major task completed was the preparation of instruments to identify learners' characteristics.

Participant Profile

The general target group required to assess the effectiveness of adaptive learning approach comprised on 9th and 10th grade students of local public schools. A desirable requirement was the identification of students have variations in terms of learning/cognitive styles, WMC and prior knowledge specifically in preposition part of English grammar so that adaptive learning approach could be tested through diverse population. To accomplish this, different instruments were deployed among large number of students of four public schools.

Data Collection Instrument

The student data collected through different standard instruments. For example, self-designed tool was used to assess student's level of knowledge in preposition, WMTB-C was used to assess differences of memory and learning/cognitive styles were identified through ASSIST. The ASSISST and self-designed tool were validated by independent experts to ensure their effectivity in measuring intended parameters. The adoption and validation process is explained below.

7.2 Adoption and Validation of Research Instruments

The validation of tools was made through iterative process such as experts reviewed the instruments and suggested changes. Tools were resubmitted after making proposed changes for further review.

Self-Designed Tool

To assess student's level of knowledge in English grammar preposition a tool was designed which consist of English sentences related to "at", "in", "on" of preposition of time and place with four choices of answer. The test was validated by two independent experts of English domain. After developing pretest it was presented to first expert to ensure its validity. He checked and advised to shuffle the sentences and include some sentences for which preposition words are not used. The research advisor also suggested few minor changes. After incorporating changes instrument was presented to another English expert he ensured that instrument can be deployed to measure student's level of preposition knowledge.

ASSIST

To measure students learning approaches ASSIST was used that is a five point Likert scale, ask student to indicate extent of their agreement or disagreement to each statement. The five point of scale were: *"strongly agree"*, *"somewhat agree"*, *"unsure"*, *"somewhat disagree"*, *"disagree"*. The tool has good level of validity and reliability and it was widely utilized in Europe specifically in higher education. The author *(University of Edinburg, United Kingdom)* of ASSIST was consulted for guidance regarding the use of ASSIST in Pakistan at school level. He ensured to utilize tool confidently to achieve research objective after acculrating it with the guidance of recommended Pakistani professor. The recommended expert suggested to adopt tool as bilingual (English and Urdu). The objective of bilingual adoption was the easy understanding of instrument by population as the native language of population was Urdu. Some other changes were recommended such as interpolation of terms relevant to higher education with terms uses at school education. The tool measures three different learning approaches including deep, surface and strategic. This research was intended to measure surface and deep approach along with sub dimensions *(cognitive styles)* of deep such as serialist and holist. Hence, the items related to strategic approach were omitted. The scale related to each approach have further subscales for example "seeking means", "relating ideas", "use of evidence" for deep approach and "lack of purpose", "unrelated memorizing", "syllabus -boundness" and "fear of failure" were related to surface approach. Additionally, subscales to indicate student's preferences for learning material and teaching style were also available both for surface and deep approach.

WMTB-C

WMTB-C is a standard tool to assess WMC of children of age group 5-15. The computerized version of tool was used to assess student's WMC. A simple training guideline was developed to make familiar students with the operation of tool before utilizing it in real setting. The tool was based on the multi component model of Baddeley including central executive phonological loop and visual sketchpad. To assess both visuospatial sketchpad and phonological loop separate tests were available in online version of WMTB-C. The visual test showed picture with specific pattern along with five choices with different pattern, one of them have relation to main picture. The students have to identify the right picture from given choices. The verbal test consist of six levels, it starts from showing a single sentence of English for example “Scissors cut paper” with given below “correct” and “wrong” options. Students have to choose option s/he thinks correct and after choosing option a textbox appear where student have to enter the last word of already shown English sentence. The amount of sentences increase upon student correct responses. At last level six English sentences are shown and student have to mention correct/incorrect choice for each sentence and have to place last word of each sentence in given text field. The visual test measure visual WMC of learner whereas verbal test measure verbal WMC of learners. This research concentrated only on the measurement of verbal WMC because adaptive learning system delivers learning material mainly using textual representation.

7.3 Pilot Testing

A pilot study was conducted using sample of 20 students to try out research instruments. The students of grade 9th and 10th were randomly enrolled in pilot study. The major objective was the authentication of tools in terms of their appropriateness and reliability. It was verified that instruments were easily understandable by representative sample of population and results found valid and reliable. Pilot study indicated that participants require about 35 minutes completing both ASSIST and Knowledge tool. That is much time, so to avoid negative effect on student’s motivation the tests were conducted in two separate sessions.

The questionnaires were processed and found that yielded results were valid and reliable. For example, respondent answers were not contradictory such as ASSIST results clearly showing deep *(along with serialist or holist preference)* and surface learners. Similarly, knowledge tool measured learners’ low or high knowledge. After processing questionnaires participants were interviewed, everyone was asked about the approach he/she used to study. We found similar answer to the responses we got through tools which assured that tool produced actual preferences of learners.

The WMTB-C was operated tool in computer lab. The irregularities of browser, electricity and student difficulty during operation were noted and measures were taken to avoid such irregularities. For example latest version of Firefox was installed rather than older version of Internet Explorer (IE). A basic training instruction was demonstrated in lab to explain the operation of tool before starting activity. Additionally students were fully supervised/supported during operation in order to perform activity efficiently and effectively. After completing and processing memory test, students were inquired about their information processing capacity during learning in classroom or in self-study. The responses found consistent to results generated by tool. Hence, pilot testing ensured that selected research instruments may utilize properly during field study as the gained information was reliable.

7.4 Field Study

Upon the successful results from pilot testing a field study was initiated in four public schools which were willing to provide access to classroom, students and computer lab during evaluation study. The basic objective of field study was identification of students characteristic value regarding their prior knowledge, working memory capacity and learning/cognitive styles from data collected through research instruments.

From identified student's characteristics students were classified into different groups according to combination of characteristics. These groups were utilized in main experiment. The representative sample was chosen using simple random sampling technique.

The study was planned and conducted carefully in order to make certain that the collected data is correct, valid and collected efficiently. The instruments were deployed among students of grade 9th and 10th during different sessions. The students were briefly instructed before circulating the objective of this exercise and explain how to work with both of the instruments. The five options of ASSIST were explained to students so that they choice the right one. The study took many days to complete as each paper based instrument deployed in different sessions. The paper based tools were deployed among whole class at once but for computer based tool students of one class participated in small groups owing to low ratio of computers in IT labs at schools. Therefore test took a lot of time. The collected data was processed as discussed below.

7.5 Data Processing

The collected data was recorded using IBM statistical package for social sciences version 20 (IBM-SPSS v. 20) to calculate student's main learning approach (deep/surface) along with sub dimensions of deep learner. The knowledge and WMTB-C tool results were also recorded into SPSS in order to determine the count of students fall into different categories. The score for deep and surface approach was produced by adding subscale scores. The resultant value indicates the learning approach of student.

The scoring was carried out through computer using SPSS. Each item of subscale was set as a variable in SPSS such as D04 which means deep item number 4. The subscale total was created by summing up different items. For example, Seeking Meaning (SM) = D04 + D17 + D30 + D43. Then by adding all the subscales Deep Approach (DA) was created for example DA = SM + RI + UE + II. In similar way, Surface Approach (SA) was created. There were two variables of interest including DA and SA whose values showed that a particular student either have deep learning approach or surface. Similarly, the value of variables such as Use of Evidence (UE) and Relating Ideas (RI) showed serialist or holist cognitive style of leaners related to deep approach. The values of Prior Knowledge (PK) were stored in SPSS using variable PK. The threshold value used to determine low and high value of PK was > 60 for high PK and < 40 for low PK. As it is previously mentioned, that this study is only limited to low and high categories of PK and WMC. So those who possess intermediate value or with lowest results in test (e.g. 0 to 15 marks) were filtered out and such results were not recorded in SPSS. The Working Memory (WM) results were stored in variable WMC. The tool WMTB-C categories individuals into low, intermediate and high category on the basis of successful completion of verbal test. Those who completed first two levels were categorize as *"low WMC"* and who completed up to level three or four were categorize as *"medium WMC"* and who completed all six levels were categorize as *"high WMC"*. Those students who fall in the category of intermediate and those who did not completed even first level were filtered out. The data of such students was not recorded in SPSS.

The requirement was to find different combinations of students' learning characteristics, the research aimed to investigate. From student's data we have noted the count of students inclined toward each dimension. The resulting simple random sample of students is summarized in the below tables.

Table 6: Details of random sample

	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid Male	317	61.55	80.05	80.05
Valid Female	79	15.34	19.95	100.0
Total	396	76.89	100.0	
Missing System	119	23.11		
Total	515	100.0		

Table 6 shows random sample that was taken to identify students with multiple characteristics. The random sample consist of (N=515) students including males and females. The students have missing value against prior knowledge and/or WMC. For example, lowest values either in prior knowledge and/or in WMC or intermediate value either in prior knowledge or in WMC and/or in both. The missing value in system was 119 that's 23% of the total sample and rest of the 77 % have values against all variables.

Table 7: Students with deep and surface approach

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid SRFA	117	22.71	29.55	29.55
Valid DEPA	279	54.17	70.45	100.0
Total	396	76.89	100.0	
Missing System	119	23.12		
Total	515	100.0		

Table 7 show the number of students with deep or surface learning approach. Among 77% the share of students with surface approach was about 23%, rest of the students were with deep approach. Hence, the valid percentage of students with deep approach was 70% and around 30% was with surface approach.

Table 8: Students with deep-serialist and deep-holist learning style

DEPA Total = 279	Serialist	Holist
	176	103
	63%	37%

Table 8 show that among deep learners, the large number of students have serialist style. For example, 63% deep learners have serialist learning style whereas 37% have holist learning style.

Table 9: Student differences regarding prior knowledge

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Low	295	57.28	70.57	70.57
High	123	23.88	29.43	100.0
Total	418	81.17	100.0	
Missing System	97	18.83		
Total	515	100.0		

The table 9 show that among sample of (N = 515), the 97 students (i.e. 19% of the sample) have missing values against prior knowledge. Among rest of the 418 (81%) students, majority 295 (57%) students’ fall in the category of low PK and rest of the 123 (24%) students possess high PK.

Table 10: Student differences regarding WMC

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	247	47.96	60.40	60.40
	High	162	31.46	39.60	100.0
	Total	409	79.42	100.0	
Missing	System	106	20.58		
Total		515	100.0		

Table 10 depicts student details related to WMC. It has shown that among (N=515) sample, the 106 (i.e. 21% of total sample) students have missing value against WMC. And among rest of 409 students (79%), majority of the students 247 (i.e. 48%) fall in the category of low WMC and remaining 162 (31%) were with high WMC.

Table 11: Students cognitive and non-cognitive capacities

Learning Approaches	**Prior Knowledge**		**Working Memory Capacity**	
	Low	High	Low	High
SRFA	76	41	83	34
DEPA	154	125	150	129

Table 11 shows the number of students with surface learning approach fall in low PK, low WMC and in high PK, high WMC. Similarly, depicting the number of students with deep learning approach fall in low PK, low WMC and in high PK, high WMC. It has found that relatively most of the students were with deep approach, low PK and low WMC.

Table 12: Detailed cognitive and non-cognitive capacities of students

		Prior knowledge		**Working memory capacity**	
		Low	High	Low	High
DEPA	Serialist	97	79	91	85
	Holist	63	40	59	44

Table 12 highlights the number of students with deep-serialist learning style, low PK, low WMC and high PK, high WMC. It also depict the number of students with deep-holist learning style have low PK, low WMC, high PK and high WMC.

Table 13: Combination of individual characteristics

Deep Serialist	Deep holist	Surface	Low-PK	High-PK	Low-WMC	High-WMC
51	.	.	51	.	51	.
46	.	.	46	.	.	46
40	.	.	.	40	40	.
39	.	.	.	39	.	39
.	32	.	32	.	32	.
.	25	.	25	.	.	25
.	27	.	.	27	27	.
.	19	.	.	19	.	19
.	.	50	50	.	50	.
.	.	26	26	.	.	26
.	.	33	.	33	33	.
.	.	08	.	08	.	08

Table 13 shows that random sample of students taken in this study have different combinations of learning characteristics of interest. As shown in above table, except only one, all other combinations of student's individual characteristics represent good number of students. Therefore, we can carry on empirical investigation by randomly selecting participants from each combination. On the basis of available data, twelve different groups of students were created each with unique combination of learning characteristics.

7.6 Evaluation Study

The evaluation study consists of two major phases which are as follows.

7.6.1 Experiment Preparation Phase

For experiment, the participants for each combination have been chosen which possess exactly equal level of knowledge. So that, whatever impact comes in posttest is due to the intervention, used to learn during experiment.

The sample size for experiment was determined on the basis of availability of students to engage in experimental session, access to number of computer for a specific period of time *(i.e. almost two weeks)* and on the expense of data collection.

The main hypothesis/research question was that whether it is more helpful for learner to learn through adaptive learning environment which presents material according to their cognitive and non-cognitive capacities or it is indifferent for them. They can learn equally well in both traditional learning environment and adaptive e-learning environment designed considering their learning needs.

To answer this research question or to test this hypothesis, it was required to properly state independent and dependent variables and design an experiment to collect related data to see impact on students learning. The Independent Variables (IV) were the combination of PK, WMC and deep/surface learning approach. The Dependent Variables (DV) were learning outcome, learning time and satisfaction. To investigate impact on learning, adaptive learning environment present learning content considering combination of students cognitive and non-cognitive characteristics including PK, WMC and learning style whereas their counterparts were taught without considering their cognitive and non-cognitive parameters.

The dependent variables were measured using data collection instrument such as posttest that was isomorphic to pretest. The posttest consists of multiple choice questions ask participants to place right preposition word in given blanks of English sentences. Some other related questions were also included in posttests.

The learning outcomes were objectively assessed as the difference between the score of pretest and posttest. Similarly, learning efficiency was measured as the difference between time taken by control and experimental groups to complete the learning activity.

The variable satisfaction was measured through a qualitative posttest consist of questions which ask learners to express their opinion upon learning session as well through feedback taken by post session interviews conducted with each group after completing experimental session with them. The below table depict the summary of variables.

Table 14: Summary of Variables

Type	**Variables**	**Values**
IV	Prior Knowledge, WMC,	[low, high], [low, high]
	Learning Styles	[Deep (serialist, holist), Surface]
DV	Learning outcome	(pretest - posttest)
DV	Retention	Difference = (2nd posttest – 1st posttest)
DV	Satisfaction	I to 3 on Likert scale

7.6.2 Experiment Design

This section describe the design of experiment, details of learners participated in experimental evaluation, the location, setting & sessions of evaluation and data collection. Finally, data analysis approach is discussed.

	Experimental Group	**Control Group**
	N = 92	N=92
	Sub-groups	Sub-groups
Sub-Groups	1- LPK + LWMC + Deep-Serialist (n = 08) 2- LPK + LWMC + Deep-Holist (n = 08) 3- LPK + LWMC + Surface (n = 08) 4- LPK + HWMC + Deep-Serialist (n = 08) 5- LPK + HWMC + Deep-Holist (n = 08) 6- LPK + HWMC + Surface (n = 08) 7- HPK + LWMC + Deep-Serialist (n = 08) 8- HPK + LWMC + Deep-Holist (n = 08) 9- HPK + LWMC + Surface (n = 08) 10- HPK + HWMC +Deep-Serialist (n = 08) 11- HPK + HWMC +Deep-Holist (n = 08) 12- HPK + HWMC + Surface (n = 04)	1- LPK + LWMC + Deep-Serialist (n = 08) 2- LPK + LWMC + Deep-Holist (n = 08) 3- LPK + LWMC + Surface (n = 08) 4- LPK + HWMC + Deep-Serialist (n = 08) 5- LPK + HWMC + Deep-Holist (n = 08) 6- LPK + HWMC + Surface (n = 08) 7- HPK + LWMC + Deep-Serialist (n = 08) 8- HPK + LWMC + Deep-Holist (n = 08) 9- HPK + LWMC + Surface (n = 08) 10- HPK + HWMC +Deep-Serialist (n = 08) 11- HPK + HWMC +Deep-Holist (n = 08) 12- HPK + HWMC + Surface (n = 04)
Learning Intervention	Adaptive e-learning system presents content considering cognitive and non-cognitive capacities of learners and improve learning using adaptive strategy.	Learning through bool and/or notes, or may be taught by regular instructor in traditional classroom.
Objective measure	Immediate posttest to measure learning gain Delayed posttest to measure retention (after 1 day)	
Subjective measure	Feedback test to measure satisfaction	

Figure 39: Design of Experiment

7.6.2.1 Participants

The evaluation study was conducted using (184) students of grade IX and X who belong to public schools. The sample was equally divided into two experiment and control groups. Each group consists of twelve subgroups formed on the basis of student's unique combination of learning characteristics. Among twelve, eleven subgroups consists of (08) participants and one consists of (04) participants (figure 39). The experimental and control subgroups have similar combinations of learning characteristics as shown in above figure. The major differentiating factor between control and experimental group was that the proposed adaptive learning system provide content to each experimental subgroup according to their unique combination of learning characteristics. On the other hand, traditional learning environment was not concurred with individual learning characteristics of control group subjects. Due to this, significant better learning performance was expected from the experimental subgroups in comparison to control sub groups.

The subjects of experiment were mainly male students; few groups also consist of female students. The average age of subjects was between 13 to 16 years. The participants were asked by school administration, be available for experiment activity and complete learning session and posttests. The participants were eager and motivated to learn through computer. They have perception that due to this, Government may provide them laptop/tab so they have taken full interest in experiment.

7.6.2.2 Location and Equipment

A separate session was conducted for each sub-group. The experimental sessions were held in the computer labs of local public schools. The technical setup before the commencement has performed on allocated computers. A separate room adjacent to computer lab was allocated for the participants of the control group.

7.6.2.3 Evaluation Sessions

Twelve separate evaluation sessions were conducted with each experimental subgroup which completed during period of four weeks. In general, the time of 120 minutes was allocated for each evaluation session based on the experience of initial evaluation. The time of 120 minutes was allocated specifically for teaching/learning session excluding time required for brief training session to get participants familiar with the operation of tool as well as time to complete objective and subjective posttests. Each session was given 5 minutes to briefly explain them the operation of tool. The 15 minutes were allocated to complete the objective test and 10 minutes more to express their level of satisfaction regarding adaptive e-learning approach using subjective test.

It was conveyed to participants that system recommend learning contents on the basis of their level of knowledge and cognitive capacities. During the evaluation session the researcher only provided technical assistance on the occurrence of any technical issue (e.g. monitor display etc.).

The experimental group was taught concepts through adaptive e-learning system whereas control group learnt concepts using standard grammar and notes.

The control and experimental group had edge over each other such as experimental group had an advantage of availability of learning material designed specifically considering their learning needs. The learner can revise the concept as many times as he/she wants. The students of control group prepared learning material on their own using book or grammar but they have advantage of teacher interaction as they can consult teacher during evaluation session to clarify the concepts. They can also collaborate with each other to discuss the concept.

The regular instructor guided students of control group regarding the preparation of material and allows them to visit him in case of any question or difficulty they face while preparing lesson.

At the end of session, both control and experimental subgroups were given posttests. A subjective test was given only to participants of experimental subgroups to know their satisfaction regarding adaptive learning system.

7.6.2 Experiment Execution Phase

Following section describe the details of each evaluation session in terms of participant's behavior, attitudes and responses, time taken to complete the learning task, facial expression and comments regarding the system. As the experiment conducted in separate sessions using smaller groups so each experimental sub-group was observed closely.

Group-1: Low PK, Low WMC & Deep-Serialist

The experimental session remained continued for 63 minutes specifically for learning the lesson. During supervised session it was observed that learners took full interest in grasping material. They have learnt concepts carefully, some students recorded important element on their notebook. Most of the students performed successfully during practice material. The participants completed lesson in less time *(i.e. 15 min)* than their counterparts of control group as they have took 78 minutes to complete the learning activity. In a brief post interview session, participants of experimental subgroup expressed that they received learning content with appropriate details and explanations which help them in easy understanding of the concepts. The information presented in separate blocks assisted to easily memorize the concepts. Moreover, the presentation of practice material after each concept really strengthens their memory and comprehension. They found happy with the system.

Group-2: Low PK, Low WMC & Deep-Holist

The experimental subgroup took 52 minutes to complete the lesson. They learnt concepts efficiently with the help of system. They seemed happy with the system and its interaction. Owing to learning speedily, students commit mistakes during practice so got revisions of missing knowledge. They quickly revise the learning content and re-attempt practice material to proceed further. The participants showed positive view about adaptive learning system. They expressed that interaction with the system improve their focus on learning. Second, system recommendations to revise the part of material that was not learnt well enhance understanding. Their counterparts in control group relatively took more time (i.e. 70 minutes) to complete lesson with similar details.

Group-3: Low PK, Low WMC & Surface

The participants of experimental group took more time (i.e. 85) than the participants of control group (80 minutes). The participants of experimental sub-group found confused so initially they committed many mistakes in assessment material and consequently revised full length content, that's why they spent relatively more time on learning. The practice and revision gradually improve their learning and confidence. For example, gradually they make successful attempts and feel happy and bit confident than before. They expressed that learning experience was better than classroom where they have no opportunity to practice each knowledge item with feedback support and revision. They found content useful as it taught concepts using basics with simple but multiple examples. They learnt and got memorized through immediate feedback and frequent revisions of full or partial content. The examples specifically those explaining difference in use of preposition in respect of specific context helped them to easily understand the tricky concepts. They felt that they had learnt much by system in comparison to regular class.

Group-4: Low PK, High WMC & Deep-Serialist

The participants of experimental sub-group completed lesson in 43 minutes. They perceive that information related to each concept including facts, detailed explanation and examples presented in separate blocks on single page helped them to quickly process and comprehend the concepts. They appreciated the system as it allows them to complete lesson quickly that is not possible in traditional class due to average pace of teacher. Hence, in traditional classroom they learn same amount of information during two class sessions, each consists of 40 minutes. The participants of control subgroup control subgroup took almost 65 minutes to complete the same topic.

Group-5: Low PK, High WMC & Deep-Holist

The participants of this subgroup completed lesson almost within 33 minutes. They appreciated system which enabled them to process information efficiently that was not possible in traditional classroom. It is noted that students see broader picture and think over it to capture the whole concept behind it, then quickly see the details and attempt practice material. In case of mistakes, revision were recommended in which they identify what mistake they had made and learn it quickly and successfully perform in formative assessment. Their counterpart in control group completed topic within 54 minutes.

Group-6: Low PK, High WMC & Surface

The participants of experimental subgroup learnt lesson within 54 minutes whereas their counterpart fall in control group completed lesson in 63 minutes. The participants related to experimental subgroup express that system presented material using basics of concept with different examples, visual illustrations which help them to easily understand the concepts.

Group-7: HPK + LWMC + Deep-Serialist

The subjects of this subgroup learnt carefully and focus on details of concepts. The experimental subgroup completed lesson in 80 minutes whereas their fellow in control group completed lesson in 90 minutes. The participants of experimental subgroup expressed that delivery of suitable learning content enabled them to comprehend the tricky concepts and associated practice material supported in memorization. Hence, they would prefer to learn through computer assisted technology during school and at home.

Group-8: HPK + LWMC + Deep-Holist

The participants found happy during learning through adaptive system. They expressed that learning content satisfying their learning needs so that they easily and efficiently learnt tricky concepts. They completed lesson in 66 minutes while their counterparts in control group took almost 80 minutes to complete the lesson.

Group-9: HPK + LWMC + Surface

The learner of experimental subgroup took less time in completion of lesson. They accomplished learning task in 90 minutes whereas control group took almost 100 minutes for same. The participants of experimental subgroup expressed that visual illustrations and explanation of concepts in smaller steps enabled to comprehend the lesson. Further, the immediate feedback and revisions also contributed in understanding and memorizing the concepts.

Group-10: HPK + HWMC +Deep-Serialist

The experimental and control subgroups have minor difference (i.e. 03 minutes) regarding learning time taken to complete the learning activity. The participants of experimental subgroup express that system should enable them to explore concepts at different level of details *(i.e. application, analysis, creativity)* and answer if any question comes into their mind. The content delivered by system restricts their learning and did not give them control to explore freely. They did not enjoy learning through adaptive system.

Group-11: HPK + HWMC +Deep-Holist

Both experimental and control subgroups have nominal difference (i.e. 02 minutes) in terms of completing learning activity. They opined that system delivered good learning material but it restrict their learning only to delivered content. It did not allow to explore material from different perspectives. It should enable them to discuss concepts with others for better understanding.

Group-12: HPK + HWMC + Surface

The group has low number of subjects. They also have not big difference in term of learning time taken to complete learning session. The participants of experimental subgroup expressed that they have good learning experience with system. The presentation of material was useful.

7.6.3 Experiment Evaluation Phase

Two posttests were conducted to evaluate student's learning, one immediately after the completion of learning session, second was conducted a day after the learning session. The second posttest was conducted keeping in view the forgetting curve introduced by Ebbinghaus in his research. Author asserted that individual's lose most part of the learned information during first hours of learning. For example, after eight hours on average less than 40% individuals remembered learnt knowledge items. It is further asserted that knowledge could be best remembered through practicing learnt material [203] [204] [205].

7.6.3.1 Collection of Data through Tests

The results of posttest-1 and posttest-2 conducted with twenty four sub-groups of experimental and control groups are presented in below tables *(Table 15 to Table 26).*

Posttest Comparison:

Table 15: Experimental and Control sub-group 1

Experimental Group			Control Group		
Std_Id	**Posttest-1**	**Posttest-2**	**Std_Id**	**Posttest-1**	**Posttest-2**
a1e	91	90	**a1c**	75	70
a2e	93	93	**a2c**	71	65
a3e	81	82	**a3c**	60	60
a4e	88	85	**a4c**	73	67
a5e	87	86	**a5c**	64	50
a6e	72	72	**a6c**	61	53
a7e	63	60	**a7c**	67	50
a8e	80	80	**a8c**	64	51
Avg:	81.87	81.0		66.87	58.25

Table 16: Experimental and Control sub-group 2

Experimental Group			Control Group		
Std Id	**Posttest-1**	**Posttest-2**	**Std Id**	**Posttest-1**	**Posttest-2**
b1e	85	86	**b1c**	65	60
b2e	87	85	**b2c**	76	65
b3e	81	80	**b3c**	75	61
b4e	95	95	**b4c**	60	45
b5e	88	89	**b5c**	61	43
b6e	71	70	**b6c**	56	40
b7e	61	61	**b7c**	54	44
b8e	55	50	**b8c**	46	40
Avg:	77.87	77.0		61.62	49.75

Table 17: Experimental and Control sub-group 3

Experimental Group			Control Group		
Std_Id	**Posttest-1**	**Posttest-2**	**Std_Id**	**Posttest-1**	**Posttest-2**
c1e	75	72	**c1c**	56	50
c2e	78	73	**c2c**	60	52
c3e	88	76	**c3c**	65	50
c4e	77	73	**c4c**	64	51
c5e	67	64	**c5c**	41	40
c6e	61	61	**c6c**	58	43
c7e	56	52	**c7c**	60	51
c8e	79	69	**c8c**	63	50
Avg:	72.62	67.5		58.37	48.37

Table 18: Experimental and Control sub-group 4

Experimental Group			Control Group		
Std Id	**Posttest-1**	**Posttest-2**	**Std Id**	**Posttest-1**	**Posttest-2**
d1e	96	95	**d1c**	67	60
d2e	98	98	**d2c**	77	64
d3e	76	76	**d3c**	74	72
d4e	55	49	**d4c**	69	64
d5e	87	85	**d5c**	61	60
d6e	83	83	**d6c**	57	47
d7e	76	78	**d7c**	59	49
d8e	91	92	**d8c**	71	64
Avg:	82.75	82.0		66.87	60.0

Table 19: Experimental and Control sub-group 5

Experimental Group			Control Group		
Std_Id	**Posttest-1**	**Posttest-2**	**Std_Id**	**Posttest-1**	**Posttest-2**
f1e	70	70	**f1c**	63	57
f2e	61	62	**f2c**	69	62
f3e	88	85	**f3c**	60	56
f4e	93	93	**f4c**	61	54
f5e	76	77	**f5c**	60	53
f6e	97	97	**f6c**	70	65
f7e	78	78	**f7c**	72	60
f8e	85	84	**f8c**	70	64
Avg:	81.0	80.75		65.62	58.87

Table 20: Experimental and Control sub-group 6

Experimental Group			Control Group		
Std_Id	**Posttest-1**	**Posttest-2**	**Std_Id**	**Posttest-1**	**Posttest-2**
g1e	88	88	**g1c**	58	53
g2e	55	50	**g2c**	65	63
g3e	78	78	**g3c**	67	60
g4e	67	67	**g4c**	53	50
g5e	79	77	**g5c**	53	51
g6e	87	85	**g6c**	50	44
g7e	82	80	**g7c**	46	41
g8e	84	84	**g8c**	48	40
Avg:	77.5	76.12		55.0	50.25

Table 21: Experimental and Control sub-group 7

Experimental Group			Control Group		
Std_Id	**Posttest-1**	**Posttest-2**	**Std_Id**	**Posttest-1**	**Posttest-2**
h1e	97	95	**h1c**	74	67
h2e	94	94	**h2c**	75	68
h3e	95	95	**h3c**	75	69
h4e	87	88	**h4c**	77	70
h5e	76	74	**h5c**	75	73
h6e	98	97	**h6c**	69	67
h7e	90	90	**h7c**	67	67
h8e	92	90	**h8c**	79	70
Avg:	91.12	90.37		73.87	68.87

Table 22: Experimental and Control sub-group 8

Experimental Group			Control Group		
Std_Id	**Posttest-1**	**Posttest-2**	**Std_Id**	**Posttest-1**	**Posttest-2**
J1e	95	95	**J1c**	79	76
J2e	94	94	**J2c**	70	65
J3e	87	87	**J3c**	71	65
J4e	86	86	**J4c**	63	60
J5e	85	84	**J5c**	85	82
J6e	88	87	**J6c**	78	77
J7e	76	78	**J7c**	80	76
J8e	93	93	**J8c**	67	60
Avg:	88.0	88.0		74.12	70.12

Table 23: Experimental and Control sub-group 9

Experimental Group			Control Group		
Std_Id	Posttest-1	Posttest-2	Std_Id	Posttest-1	Posttest-2
K1e	87	87	**K1c**	72	61
K2e	86	86	**K2c**	70	64
K3e	90	90	**K3c**	71	67
K4e	92	93	**K4c**	58	62
K5e	86	80	**K5c**	65	58
K6e	80	80	**K6c**	70	68
K7e	84	81	**K7c**	66	63
K8e	84	82	**K8c**	70	62
Avg:	86.12	84.88		67.75	60.12

Table 24: Experimental and Control sub-group 10

Experimental Group			Control Group		
Std_Id	Posttest-1	Posttest-2	Std_Id	Posttest-1	Posttest-2
L1e	95	95	**L1c**	90	92
L2e	98	97	**L2c**	96	94
L3e	85	85	**L3c**	64	62
L4e	96	96	**L4c**	90	88
L5e	82	82	**L5c**	81	81
L6e	90	90	**L6c**	85	83
L7e	93	93	**L7c**	84	82
L8e	84	85	**L8c**	89	89
Avg:	90.37	90.37		84.87	83.87

Table 25: Experimental and Control sub-group 11

Experimental Group			Control Group		
Std_Id	Posttest-1	Posttest-2	Std_Id	Posttest-1	Posttest-2
M1e	89	88	**M1c**	75	73
M2e	91	91	**M2c**	80	76
M3e	89	90	**M3c**	80	78
M4e	67	63	**M4c**	69	70
M5e	88	85	**M5c**	83	84
M6e	77	73	**M6c**	78	72
M7e	87	87	**M7c**	88	85
M8e	90	90	**M8c**	84	85
Avg:	84.75	83.37		79.62	77.87

Table 26: Experimental and Control sub-group 12

Experimental Group			Control Group		
Std_Id	Posttest-1	Posttest-2	Std_Id	Posttest-1	Posttest-2
N1e	87	84	**N1c**	71	70
N2e	76	70	**N2c**	73	71
N3e	85	80	**N3c**	70	62
Avg:	82.67	78		71.33	67.67

Table 27: Learning time differences

Groups	Control Group (mins)	Exp. Group (mins)	difference in mins
1	78	63	15
2	70	52	18
3	80	85	5
4	65	43	22
5	54	30	24
6	63	54	09
7	90	78	12
8	80	66	14
9	100	90	10
10	57	54	03
11	60	58	02
12	70	65	05

At the end of learner's interaction with adaptive learning system they were asked to fill a posttest questionnaire to obtain their feedback. The detailed information related to student's feedback presented by twelve experimental sub-groups is shown by below tables *(Table 28 – Table 39)*.

Total respondents = 08

	Questions	**Choices**	**# of students selected this choice**	**%age**
1	I like to learn in this way, I think it is something that works better than simply listening lectures in classroom.	Agree Disagree Indifferent	7 0 1	87.5 0 12.5
2	Did the learning material system presented you was corresponding to your level of knowledge, working memory capacity and learning approach.	Yes To some extent No	5 2 1	62.5 25 12.5
3	Did you find the lectures easy to read with the font style used?	Yes No	8 0	100 0
4	Did the system help you in any of your frustration by giving you examples, overview and details of the concept?	Yes To some extent No	7 1 0	87.5 12.5 0
5	How much effective did you find learning through system in comparison to classroom?	less effective effective much effective	0 5 3	0 62.5 37.5
6	Did you feel comfortable with colors used in the system?	Yes No	8 0	100 0
7	It was boring to show me the brief summary of learning material upon mistakes.	Yes Little bit No	1 0 7	12.5 0 87.5
8	Did the return to a previous domain concept for revision help you to learn the concepts better?	Yes To some extent No	7 1 0	87.5 12.5 0
9	Did the content presentation help you in understanding the concepts?	Yes No	7 1	87.5 12.5
10	Did you find language used in learning content easy?	Yes No	7 1	87.5 12.5

Table 28: Group 1 student's response

Total respondents = 08

	Questions	**Choices**	**# of students selected this choice**	**%age**
1	I like to learn in this way, I think it is something that works better than simply listening lectures in classroom.	Agree Disagree Indifferent	7 0 1	87.5 0 12.5
2	Did the learning material system presented you, was corresponding to your level of knowledge, working memory capacity and learning approach?	Yes To some extent No	6 2 0	75 25 0
3	Did you find the lectures easy to read with the font style used?	Yes No	7 1	87.5 12.5
4	Did the system help you in any of your frustration by giving you examples, overview and details of the concept?	Yes To some extent No	5 3 0	62.5 37.5 0
5	How much effective did you find learning through system in comparison to classroom?	less effective effective much effective	0 6 2	0 75 25
6	Did you feel comfortable with colors used in the system?	Yes No	6 2	75 25
7	It was boring to show me the brief summary of learning material upon mistakes.	Yes Little bit No	0 1 7	0 12.5 87.5
8	Did the returns to a previous domain concept for revision help you to learn concepts better?	Yes To some extent No	7 1 0	87.5 12.5 0
9	Did the content presentation help you in understanding the concepts?	Yes To some extent No	6 0 2	75 0 25
10	Did you find language used in learning content easy?	Yes No	7 1	87.5 12.5

Table 29: Group 2 student's response

(Total respondents = 08)

	Questions	**Choices**	**# of students selected this choice**	**%age**
1	I like to learn in this way, I think it is something that works better than simply listening lectures in classroom.	Agree Disagree Indifferent	7 1 0	87.5 12.5 0
2	Did the learning material system presented you, was corresponding to your level of knowledge, working memory capacity and learning approach?	Yes To some extent No	7 0 1	87.5 0 12.5
3	Did you find the lectures easy to read with the font style used?	Yes No	7 1	87.5 12.5
4	Did the system help you in any of your frustration by giving you examples, overview and details of the concept?	Yes To some extent No	6 0 2	75 0 25
5	How much effective did you find learning through system in comparison to classroom?	less effective effective much effective	0 4 4	0 50 50
6	Did you feel comfortable with colors used in the system?	Yes No	7 1	87.5 12.5
7	It was boring to show me the brief summary of learning material upon mistakes.	Yes Little bit No	0 0 8	0 0 100
8	Did the returns to a previous domain concept for revision help you to learn concepts better?	Yes To some extent No	7 1 0	87.5 12.5 0
9	Did the content presentation help you in understanding the concepts?	Yes To some extent No	7 1 0	87.5 12.5 0
10	Did you find language used in learning content easy?	Yes No	6 2	75 25

Table 30: Group 3 student's response

(Total respondents = 08)

	Questions	**Choices**	**# of students selected this choice**	**%age**
1	I like to learn in this way, I think it is something that works better than simply listening lectures in classroom.	Agree Disagree Indifferent	5 1 2	62.5 12.5 25
2	Did the learning material system presented you, was corresponding to your level of knowledge, working memory capacity and learning approach?	Yes To some extent No	7 1 0	87.5 12.5 0
3	Did you find the lectures easy to read with the font style used?	Yes No	7 1	87.5 12.5
4	Did the system help you in any of your frustration by giving you examples, overview and details of the concept?	Yes To some extent No	5 2 1	62.5 25 12.5
5	How much effective did you find learning through system in comparison to classroom?	less effective effective much effective	0 6 2	0 75 25
6	Did you feel comfortable with colors used in the system?	Yes No	7 1	87.5 12.5
7	It was boring to show me the brief summary of learning material upon mistakes.	Yes Little bit No	0 1 7	0 12.5 87.5
8	Did the returns to a previous domain concept for revision help you to learn concepts better?	Yes To some extent No	5 3 0	62.5 37.5 0
9	Did the content presentation helps you in understanding the concepts?	Yes To some extent No	5 2 1	62.5 25 12.5
10	Did you find language used in learning content easy?	Yes No	8 0	100 0

Table 31: Group 4 student's response

(Total respondents = 08)

	Questions	**Choices**	**# of students selected this choice**	**%age**
1	I like to learn in this way, I think it is something that works better than simply listening lectures in classroom.	Agree Disagree Indifferent	5 1 2	62.5 12.5 25
2	Did the learning material system presented you, was corresponding to your level of knowledge, working memory capacity and learning approach?	Yes To some extent No	6 1 1	75 12.5 12.5
3	Did you find the lectures easy to read with the font style used?	Yes No	7 1	87.5 12.5
4	Did the system help you in any of your frustration by giving you examples, overview and details of the concept?	Yes To some extent No	6 1 1	75 12.5 12.5
5	How much effective did you find learning through system in comparison to classroom?	less effective effective much effective	0 6 2	0 75 25
6	Did you feel comfortable with colors used in the system?	Yes No	7 1	87.5 12.5
7	It was boring to show me the brief summary of learning material upon mistakes.	Yes Little bit No	0 1 7	0 12.5 87.5
8	Did the returns to a previous domain concept for revision help you to learn concepts better?	Yes To some extent No	5 3 0	62.5 37.5 0
9	Did the content presentation help you in understanding the concepts?	Yes To some extent No	5 3 0	62.5 37.5 0
10	Did you find language used in learning content easy?	Yes No	8 0	100 0

Table 32: Group 5 student's response

(Total respondents = 08)

	Questions	Choices	# of students selected this choice	%age
1	I like to learn in this way, I think it is something that works better than simply listening lectures in classroom.	Agree Disagree Indifferent	7 0 1	87.5 0 12.5
2	Did the learning material system presented you, was corresponding to your level of knowledge, working memory capacity and learning approach?	Yes To some extent No	7 1 0	87.5 12.5 0
3	Did you find the lectures easy to read with the font style used?	Yes No	7 1	87.5 12.5
4	Did the system help you in any of your frustration by giving you examples, overview and details of the concept?	Yes To some extent No	6 2 0	75 25 0
5	How much effective did you find learning through system in comparison to classroom?	less effective effective much effective	0 5 3	0 62.5 37.5
6	Did you feel comfortable with colors used in the system?	Yes No	7 1	87.5 12.5
7	It was boring to show me the brief summary of learning material upon mistakes.	Yes Little bit No	0 0 8	0 0 100
8	Did the returns to a previous domain concept for revision help you to learn concepts better?	Yes To some extent No	8 0 0	87.5 12.5 0
9	Did the content presentation help you in understanding the concepts?	Yes To some extent No	7 1 0	87.5 12.5 0
10	Did you find language used in learning content easy?	Yes No	7 1	87.5 12.5

Table 33: Group 6 student’s response

(Total respondents = 08)

	Questions	**Choices**	**# of students selected this choice**	**%age**
1	I like to learn in this way, I think it is something that works better than simply listening lectures in classroom.	Agree Disagree Indifferent	7 1 0	87.5 12.5 0
2	Did the learning material system presented you was corresponding to your level of knowledge, working memory capacity and learning approach.	Yes To some extent No	5 3 0	62.5 37.5 0
3	Did you find the lectures easy to read with the font style used?	Yes No	7 1	87.5 12.5
4	Did the system help you in any of your frustration by giving you examples, overview and details of the concept?	Yes To some extent No	6 2 0	75 25 0
5	How much effective did you find learning through system in comparison to classroom?	less effective effective much effective	1 5 2	12.5 62.5 25
6	Did you feel comfortable with colors used in the system?	Yes No	7 1	87.5 12.5
7	It was boring to show me the brief summary of learning material upon mistakes.	Yes Little bit No	0 0 8	0 0 100
8	Did the returns to a previous domain concept for revision help you to learn the concepts better?	Yes To some extent No	7 1 0	87.5 12.5 0
9	Did the content presentation help you in understanding the concepts?	Yes To some extent No	6 2 0	75 25 0
10	Did you find language used in lectures easy?	Yes No	7 1	87.5 12.5

Table 34: Group 7 student's response

(Total respondents = 08)

	Questions	**Choices**	**# of students selected this choice**	**%age**
1	I like to learn in this way, I think it is something that works better than simply listening lectures in classroom.	Agree Disagree Indifferent	7 0 1	87.5 0 12.5
2	Did the learning material system presented you, was corresponding to your level of knowledge, working memory capacity and learning approach?	Yes To some extent No	7 1 0	87.5 12.5 0
3	Did you find the lectures easy to read with the font style used?	Yes No	7 1	87.5 12.5
4	Did the system help you in any of your frustration by giving you examples, overview and details of the concept?	Yes To some extent No	5 2 1	62.5 25 12.5
5	How much effective did you find learning through system in comparison to classroom?	less effective effective much effective	0 6 2	0 75 25
6	Did you feel comfortable with colors used in the system?	Yes No	6 2	75 25
7	It was boring to show me the brief summary of learning material upon mistakes.	Yes Little bit No	0 1 7	0 12.5 87.5
8	Did the returns to a previous domain concept for revision help you to learn concepts better?	Yes To some extent No	7 0 1	87.5 0 12.5
9	Did the content presentation help you in understanding the concepts?	Yes To some extent No	5 3 0	62.5 37.5 0
10	Did you find language used in learning content easy?	Yes No	8 0	100 0

Table 35: Group 8 student's response

(Total respondents = 08)

	Questions	Choices	# of students selected this choice	%age
1	I like to learn in this way, I think it is something that works better than simply listening lectures in classroom.	Agree Disagree Indifferent	7 0 1	87.5 0 12.5
2	Did the learning material system presented you, was corresponding to your level of knowledge, working memory capacity and learning approach?	Yes To some extent No	7 1 0	87.5 12.5 0
3	Did you find the lectures easy to read with the font style used?	Yes No	6 2	75 25
4	Did the system help you in any of your frustration by giving you examples, overview and details of the concept?	Yes To some extent No	6 2 0	75 25 0
5	How much effective did you find learning through system in comparison to classroom?	less effective effective much effective	0 6 2	0 75 25
6	Did you feel comfortable with colors used in the system?	Yes No	7 1	87.5 12.5
7	It was boring to show me the brief summary of learning material upon mistakes.	Yes Little bit No	0 0 0	0 0 100
8	Did the returns to a previous domain concept for revision help you to learn concepts better?	Yes To some extent No	8 0 0	100 0 0
9	Did the content presentation help you in understanding the concepts?	Yes To some extent No	7 1 0	87.5 12.5 0
10	Did you find language used in learning content easy?	Yes No	7 2	87.5 12.5

Table 36: Group 9 student's response

(Total respondents = 08)

	Questions	**Choices**	**# of students selected this choice**	**%age**
1	I like to learn in this way, I think it is something that works better than simply listening lectures in classroom.	Agree Disagree Indifferent	2 1 5	25 12.5 62.5
2	Did the learning material system presented you, was corresponding to your level of knowledge, working memory capacity and learning approach?	Yes To some extent No	2 4 2	25 50 25
3	Did you find the lectures easy to read with the font style used?	Yes No	7 1	87.5 12.5
4	Did the system help you in any of your frustration by giving you examples, overview and details of the concept?	Yes To some extent No	2 3 3	25 37.5 37.5
5	How much effective did you find learning through system in comparison to classroom?	less effective effective much effective	5 2 1	62.5 25 12.5
6	Did you feel comfortable with colors used in the system?	Yes No	7 1	87.5 12.5
7	It was boring to show me the brief summary of learning material upon mistakes.	Yes Little bit No	1 3 4	12.5 37.5 50
8	Did the returns to a previous domain concept for revision help you to learn concepts better?	Yes To some extent No	2 3 3	25 37.5 37.5
9	Did the content presentation help you in understanding the concepts?	Yes To some extent No	2 2 4	25 25 50
10	Did you find language used in learning content easy?	Yes No	8 0	100 0

Table 37: Group 10 student's response

(Total respondents = 08)

	Questions	**Choices**	**# of students selected this choice**	**%age**
1	I like to learn in this way, I think it is something that works better than simply listening lectures in classroom.	Agree Disagree Indifferent	3 1 4	37.5 12.5 50
2	Did the learning material system presented you, was corresponding to your level of knowledge, working memory capacity and learning approach?	Yes To some extent No	3 3 2	37.5 37.5 25
3	Did you find the lectures easy to read with the font style used?	Yes No	8 0	100 0
4	Did the system help you in any of your frustration by giving you examples, overview and details of the concept?	Yes To some extent No	3 3 3	37.5 25 37.5
5	How much effective did you find learning through system in comparison to classroom?	less effective effective much effective	4 3 1	50 37.5 12.5
6	Did you feel comfortable with colors used in the system?	Yes No	6 2	75 25
7	It was boring to show me the brief summary of learning material upon mistakes.	Yes Little bit No	2 3 3	25 37.5 37.5
8	Did the returns to a previous domain concept for revision help you to learn concepts better?	Yes To some extent No	1 3 4	12.5 37.5 50
9	Did the content presentation help you in understanding the concepts?	Yes To some extent No	2 3 3	25 37.5 37.5
10	Did you find language used in learning content easy?	Yes No	7 1	87.5 12.5

Table 38: Group 11 student's response

(Total respondents = 03)

	Questions	Choices	# of students selected this choice	%age
1	I like to learn in this way, I think it is something that works better than simply listening lectures in classroom.	Agree Disagree Indifferent	2 0 1	66.66 0 33.33
2	Did the learning material system presented you, was corresponding to your level of knowledge, working memory capacity and learning approach?	Yes To some extent No	2 1 0	66.66 33.33 0
3	Did you find the lectures easy to read with the font style used?	Yes No	3 0	100 0
4	Did the system help you in any of your frustration by giving you examples, overview and details of the concept?	Yes To some extent No	1 2 0	33.33 66.66 0
5	How much effective did you find learning through system in comparison to classroom?	less effective effective much effective	1 2 0	33.33 66.66 0
6	Did you feel comfortable with colors used in the system?	Yes No	3 0	100 0
7	It was boring to show me the brief summary of learning material upon mistakes.	Yes Little bit No	0 2 1	0 66.66 33.33
8	Did the returns to a previous domain concept for revision help you to learn concepts better?	Yes To some extent No	1 2 0	33.33 66.66 0
9	Did the content presentation help you in understanding the concepts?	Yes No	2 1	66.6 33.33
10	Did you find language used in learning content easy?	Yes No	3 0	100 0

Table 39: Group 12 student's response

7.6.4 Result Analysis Phase

The section discussed the results of each subgroup in the light of data collected in evaluation phase.

An independent t-test was conducted for statistical analysis of pre-test as shown in below table. The test results showed that all subgroups of control and experimental groups had no significant difference before the execution of experiment. That is, all the subgroups had statistically similar level of knowledge before taking the learning unit.

		N	**Mean**	**S.D.**	***t***
G-1	Experimental group	8	38.00	1.77	-143
G-1	Control group	8	38.12	1.72	
G-2	Experimental group	8	36.00	2.00	.00
G-2	Control group	8	36.00	1.51	
G-3	Experimental group	8	36.00	2.00	.00
G-3	Control group	8	36.00	1.51	
G-4	Experimental group	8	38.00	1.69	.00
G-4	Control group	8	38.00	1.19	
G-5	Experimental group	8	38.00	1.69	.00
G-5	Control group	8	38.00	1.19	
G-6	Experimental group	8	38.00	2.20	.00
G-6	Control group	8	38.00	1.51	.00
G-7	Experimental group	8	65.00	3.07	.00
G-7	Control group	8	65.00	1.77	.00
G-8	Experimental group	8	65.00	1.31	.00
G-8	Control group	8	65.00	1.93	.00
G-9	Experimental group	8	61.00	1.07	.00
G-9	Control group	8	61.00	.76	.00
G-10	Experimental group	8	69.00	1.77	.00
G-10	Control group	8	69.00	1.07	.00
G-11	Experimental group	8	68.00	1.31	.00
G-11	Control group	8	68.00	1.07	
G-12	Experimental group	4	68.00	1.83	.00
G-12	Control group	4	68.00	1.41	

Table 40: Descriptive data t-test result of the pre-test score

Group-1, 2 and 3:

The comparison of average score of above mentioned control and experimental sub groups 1, 2 and 3 is shown in figure 40. It was assumed that students even with low prior knowledge of subject, low WMC and any learning style including deep-serialist/deep-holist or surface can exhibit better learning performance if learning material provided to them considering combination of their learning characteristics. The results confirmed that subjects of experimental sub group 1, 2 and 3 performed better by achieving 15%, 16.25%, 14.25% respectively more score than subjects of control sub group 1, 2 and 3 in post test-1 and 22.75%, 27.25%, 19.13% respectively more score in post test-2. These results came primarily due to the delivery of such a learning content which cater the learning needs of learners in respect of their learning capacities and preferences. The design of learning content addressed the limitations of experimental subgroups in terms of their prior knowledge of subject, WMC as well as unique learning preference of each sub group (i.e. either deep-serialist, deep holist or surface) through suitable presentation strategies. For example, content for sub group 1 *(low PK, low WMC, Deep-serialsit)* shown in figure 8, converse basic usage of preposition words using simple examples. To cater learner's low WMC multiple strategies have been used including smaller chunks, meaningful graphical illustrations and color variations to emphasize necessary parts of the concepts to remember or recall at least main points. At the bottom of each content, a separate block of information presents logical details of each concept and explains its connection with previously learnt related concept. Similarly, the content for sub group 2 *(low PK, low WMC, Deep-holist)* shown in figure 9, gives overview of topic and underline logical relation in different concepts to cater learning preference of deep holist learners. The relevant details are further presented to avoid learning deficiency of holist learners as they are tend ignore details. The starting point of teaching and strategies used to support memory both for sub group 2 and 3 were similar to sub group 1 as the learning parameters were same. For sub group 3, *(low PK, low WMC, Surface)* the content (figure 10) presented relatively more simple instruction with basic details, more visual representations and smaller chunks, keeping in view that surface learners comparatively have low memory trace and overall weak knowledge base than their deep counterparts. More examples, including example words and example sentences were used so that memorization could take place as well as later material could be reproduced. The delivery of such a suitable learning content eventually helped each sub group to learn more easily and better. The inclusion of practice material with each knowledge item also contributed towards better results.

The system also help to realize students their deficiencies in relation to learnt material and attempt to bridge gap by offering repetition learning material *(partial/complete)* that enabled permanent learning. The instant feedback encouraged surface learners towards learning activity.

Regarding learning efficiency, the experimental sub group 1 and 2 took 15 and 18 minutes less learning time respectively, due to clear easy to read and understand instructions. The experimental subgroup 3, took 5 minutes more to complete learning activity than counterpart control sub group owing to taking more repetitions offered by system on the basis of their performance in practice material (figure 41).

In contrast, control sub groups (1, 2 and 3) studied through standard learning material that was not matching to their individual learning characteristics, which led to more learning time and difficulty in understanding. The student's comprehension about the delivered material was not regularly assessed, so they forgot most part of the learnt information.

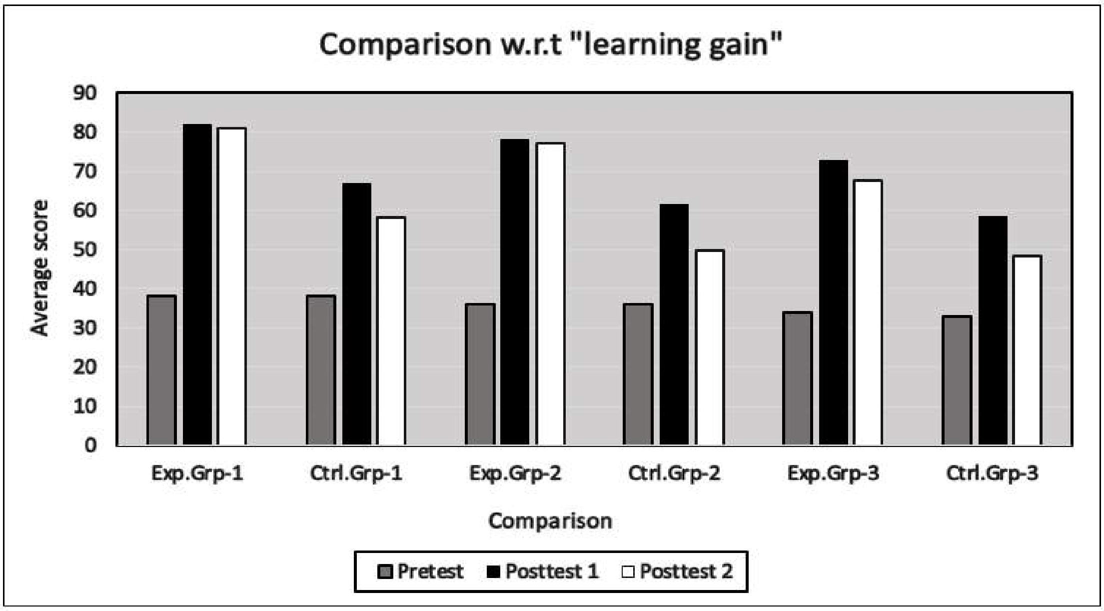

Figure 40: Learning performance of control and experimental subgroup 1, 2 and 3

Tables 41 and 42 show ANCOVA results of the post test-1 and post test- 2 using pre-test as covariate. The results revealed that participants in the experimental sub-groups 1, 2 and 3 had significantly better learning outcomes than participants of the control sub-groups 1, 2 and 3 in post test-1 with ($F = 9.03$ and $P < .02$), ($F= 6.55$ and $P<.03$), ($F= 11.95$ and $P<.01$) and in post test-2 with ($F = 33.87$ and $P < .01$), ($F= 16.22$ and $P < .01$), ($F= 43.38$ and $P < .01$) respectively. This significant difference in terms of learning outcomes came mainly owing to the delivery of suitable learning content to each experimental subgroup in accordance to their learning needs.

	N	Mean	S.D.	Std.Error.	F.Value	P.Value
G-1. Experimental	8	72.62	10.51	4.70	9.03	<.02
G-1. Control	8	58.37	7.65	4.70		
G-2. Experimental	8	77.87	14.11	7.64	6.55	<.03
G-2. Control	8	61.62	10.23	7.64		
G-3. Experimental	8	72.62	10.51	4.12	11.95	<.01
G-3. Control	8	58.37	7.65	4.12		

Table 41: Descriptive data and ANCOVE of the posttest-1 score

	N	Mean	S.D.	Std.Error.	F.Value	P.Value
G-1. Experimental	8	67.50	8.01	3.268	33.87	<.01
G-1. Control	8	48.37	4.37	3.268		
G-2. Experimental	8	77.00	15.38	6.766	16.22	<.01
G-2. Control	8	49.75	10.39	6.766		
G-3. Experimental	8	67.50	8.01	2.904	43.38	<.01
G-3. Control	8	48.37	4.37	2.904		

Table 42: Descriptive data and ANCOVA of the posttest-2 score

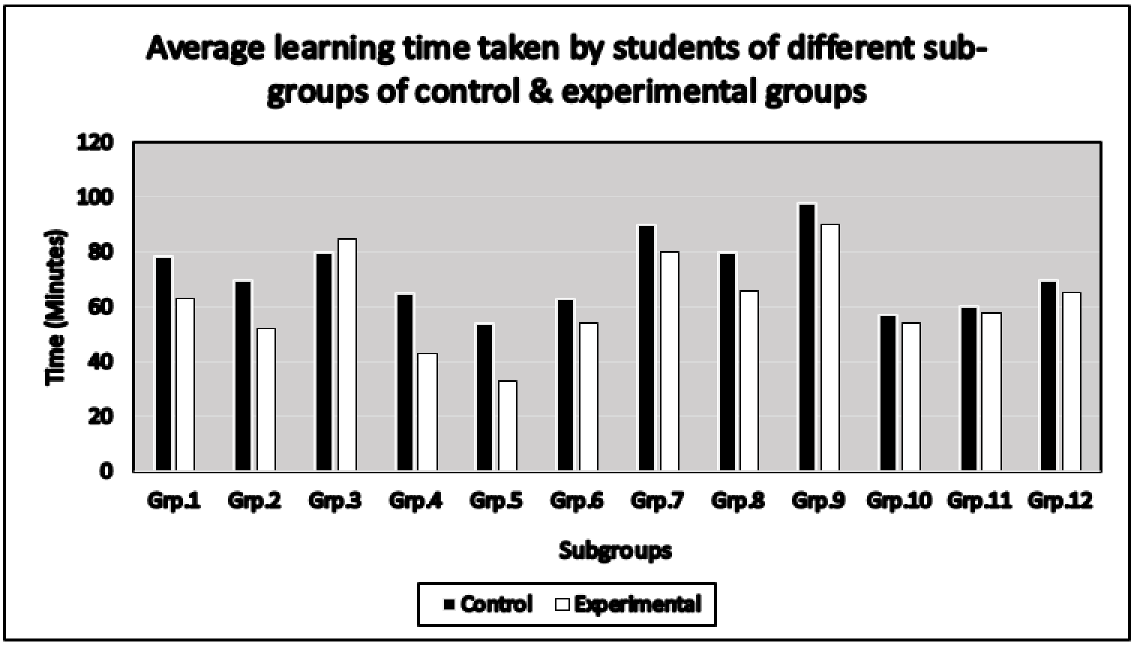

Figure 41: Learning efficiency of control and experimental subgroups

Analysis of student feedback related to experimental subgroup-1, 2, and 3 provides us following information. Same information is presented graphically in figure 42, 43 and 44.

- Most of the students preferred learning through adaptive approach rather than traditional classroom.
- Most of the students felt that the adaptive system provided them content according to their learning needs.
- Most of the students said that system helped them by giving examples, details or overview.
- Most of the students felt that content presentation helped them in comprehending learning material.
- Most of the students felt that of revision of learning material improved their understanding of learning material.
- Most of the students were comfortable with language of learning content, only 25% participants of subgroup-3 found it difficult.

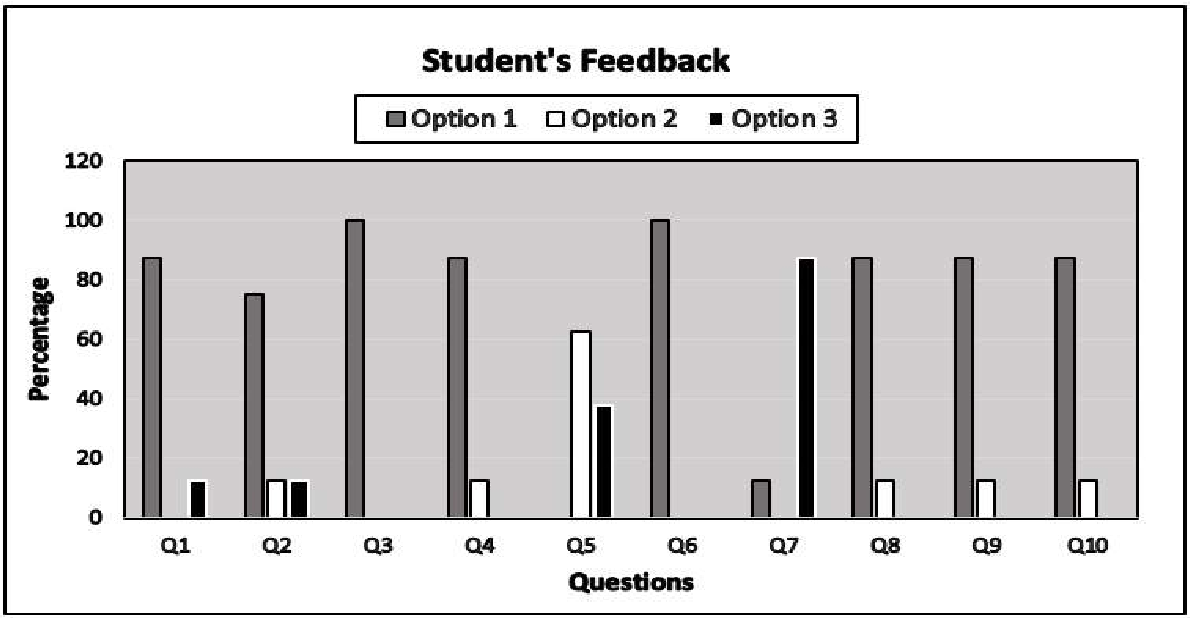

Figure 42: Graphical presentation of student's feedback (subgroup 1) on interaction with adaptive learning system

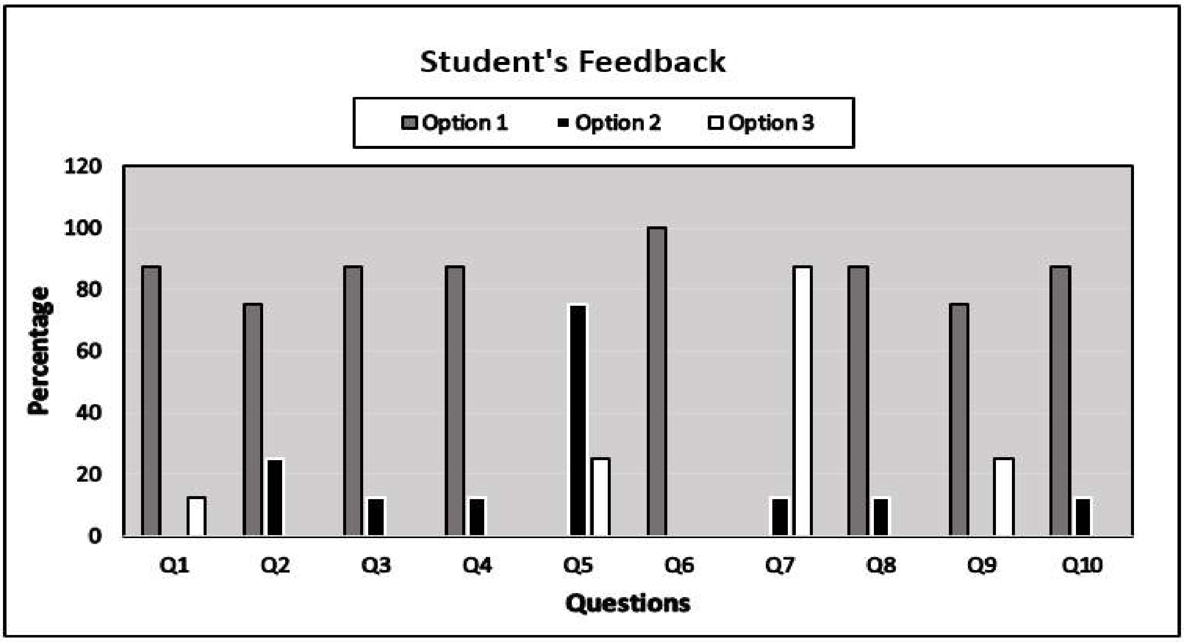

Figure 43: Graphical presentation of student's feedback (subgroup 2) on interaction with adaptive learning system

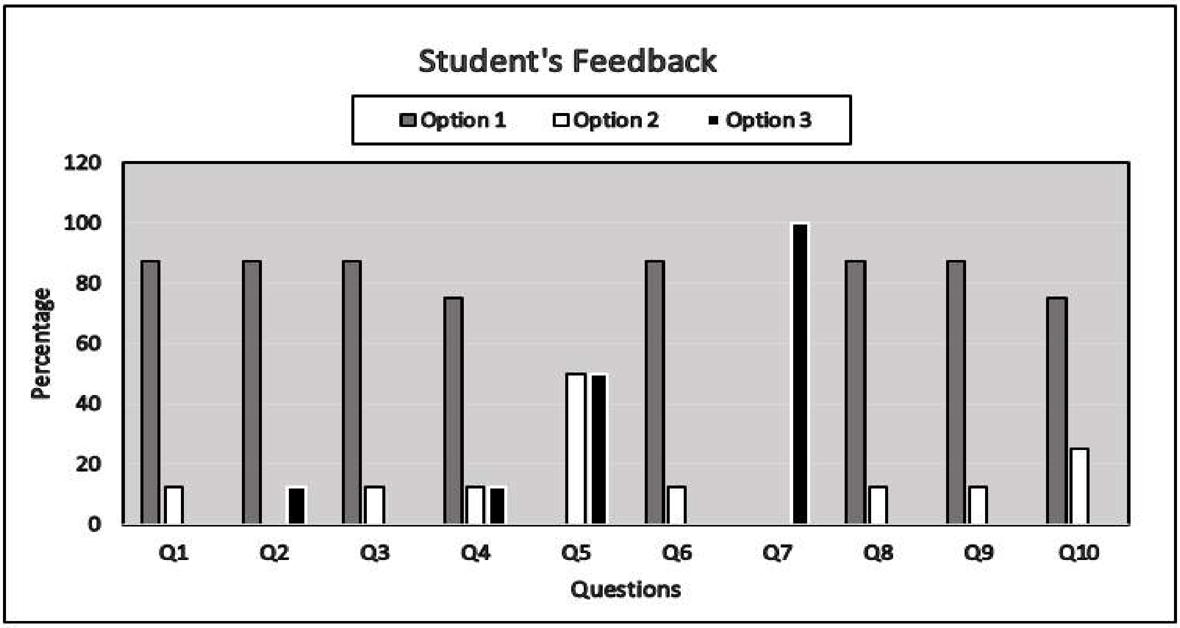

Figure 44: Graphical presentation of student's feedback (subgroup 3) on interaction with adaptive learning system

Group-4, 5 and 6:

The comparison of average score of control and experimental sub groups including sub-group 4, 5 and 6 is showed in figure 45. It was believed that student's with low prior subject knowledge, high WMC and any learning style including deep-serialist/deep-holist or surface can demonstrate better learning progress in very less learning time when instruction presented to them according to their learning characteristics. The results revealed that subjects of experimental sub-group-4, 5 and 6 performed better by achieving 15.88%, 15.38%, 22.5% respectively greater score than participants of control sub-group-4, 5 and 6 in post test-1 and 22%, 21.88%, 25.87% respectively greater score in post test-2. The possible reason behind such improved learning gain and significant learning efficiency was the provision of learning content which address the learning needs of experimental subgroups (4, 5, and 6) in terms of their limitation related to PK, strength of WMC and particular learning preferences. The content was designed to deliver larger chunks of information together with considering their learning requirement related to low PK and specific learning preference. Hence, each sub group gained relatively better score and successfully finish lesson in much less time than their counterparts of control sub groups (figure 41). Group-6 *(i.e. with surface learning style)* surprisingly attained greater score but consumed more learning time in comparison to experimental subgroup 4 and 5.

The group-6 gained high score due to immediate feedback mechanism and repetition of knowledge items which reinforced their memory trace as well as knowledge base. The repetition on the other hand effected their learning efficiency to some extent in comparison to experimental sub group 4 and 5 but still have better learning efficiency than their counterparts of control group. On the contrary, in traditional learning setting students found unmatched content and did not have any opportunity to practice learnt material and conduct learning activity repetitively.

Moreover, the comparison within experimental sub groups (i.e. 4, 5, 6 vs. 1, 2, 3) showed that the sub groups with high memory (i.e. sub group 4, 5 & 6) learnt in significantly less time relative to sub groups with low memory (i.e. sub group 1, 2 & 3). This happened mainly due to the availability of learning material (containing larger chunks) in accordance to their memory processing capacity. On the other hand, the sub groups with low WMC (1, 2 & 3) gained learning score almost equal to the sub groups with high WMC (4, 5 & 6). The subgroups with low WMC showed learning progress equal to subgroups with high WMC because low WMC subgroups received content, designed to support low memory so that they easily memorize and understand learning material. Their counterpart of control group did not received content having support for low memory that's why they remain unable to show improved progress. The groups with high WMC showed significant better improvement in terms of learning time because they found larger chunks of learning material (concept with all details on single or consecutive pages) as per their processing capacity that's why they outperformed than counterparts of control group who have to learn all details of concept discussed on different pages of grammar, class notes/book and/or even require explanation from teacher or peer.

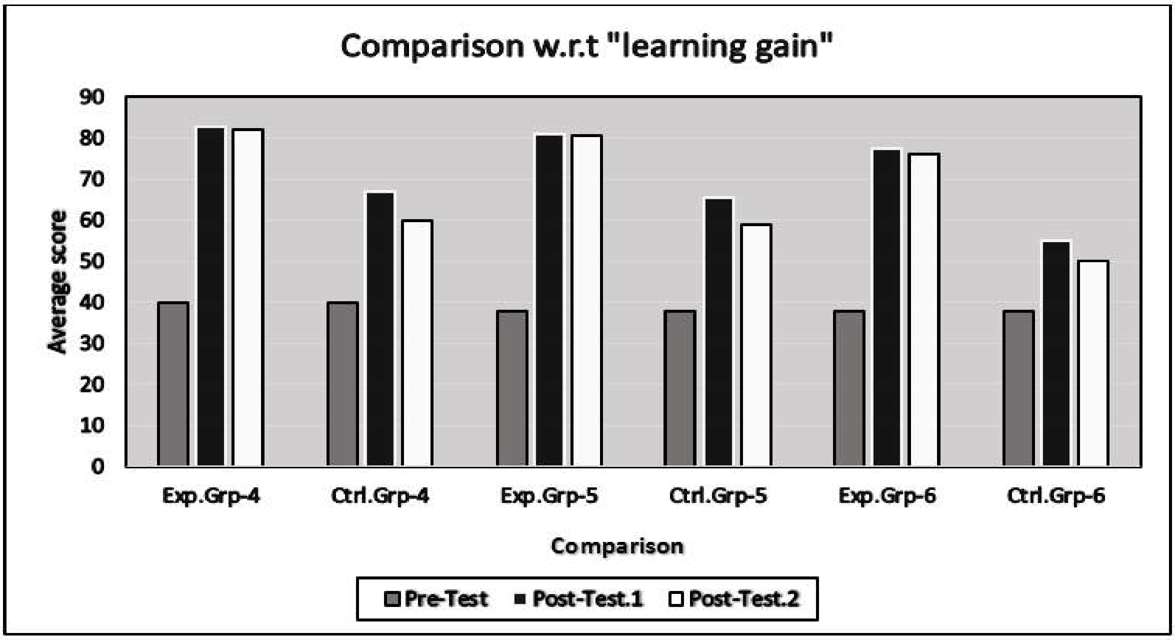

Figure 45: Learning performance of control and experimental sub-group 4, 5 and 6

Table 46 and 47 presents the ANCOVA result of the post test-1 and post test- 2 using pre-test as covariate. It has revealed that the participants in the experimental sub-groups 4, 5 and 6 had significantly better learning outcomes than participants of control sub-groups 4, 5 and 6 in post test-1 with (F = 7.89 and P < .01), (F = 8.97 and P < .01), (F = 21.39 and P < .01) and in post test-2 with (F = 33.87 and P < .01), (F = 16.22 and P < .01), (F = 43.38 and P < .01) respectively. These significant results come about due to the provision of learning content to each sub group according to their learning characteristics. Hence, learning gain and retention of experimental subgroups get improved in comparison to control subgroups.

	N	Mean	S.D.	Std.Error.	F.Value	P.Value
G-4. Experimental	8	82.75	13.92	5.653	7.89	<0.1
G-4. Control	8	66.87	7.25	5.653		
G-5. Experimental	8	82.75	13.92	5.299	8.97	<0.2
G-5. Control	8	66.88	7.25	5.299		
G-6. Experimental	8	77.50	11.22	4.87	21.39	<0.1
G-6. Control	8	55.00	7.71	4.87		

Table 43: Descriptive data and ANCOVA of the posttest-1 score

	N	Mean	S.D.	Std.Error.	F.Value	P.Value
G-4. Experimental	8	82.00	15.47	6.267	12.32	<0.1
G-4. Control	8	60.00	8.30	6.267		
G-5. Experimental	8	82.00	15.47	6.228	12.47	<0.2
G-5. Control	8	60.00	8.29	6.228		

G-6. Experimental	8	76.13	12.35	5.33	23.56	<0.1
G-6. Control	8	50.25	8.41	5.33		

Table 44: Descriptive data and ANCOVA of the posttest-1 score

Analysis of student feedback related to experimental subgroup-4, 5, and 6 provides us following information. Same information is presented graphically in figure 48, 49 and 50.

- Most of the students preferred learning through adaptive approach rather than traditional classroom.
- Most of the students felt that the adaptive system provided them content according to their learning needs.
- Most of the students said that system helped them by giving examples, details or overview.
- Most of the students felt that content presentation helped them in comprehending learning material, only 12.5% participants of subgroup-4 learners have different response.
- Most of the students felt that of revision of learning material improved their understanding of learning material.
- Most of the students were comfortable with language of learning content, only 12.5% participants of subgroup-6 found it difficult.

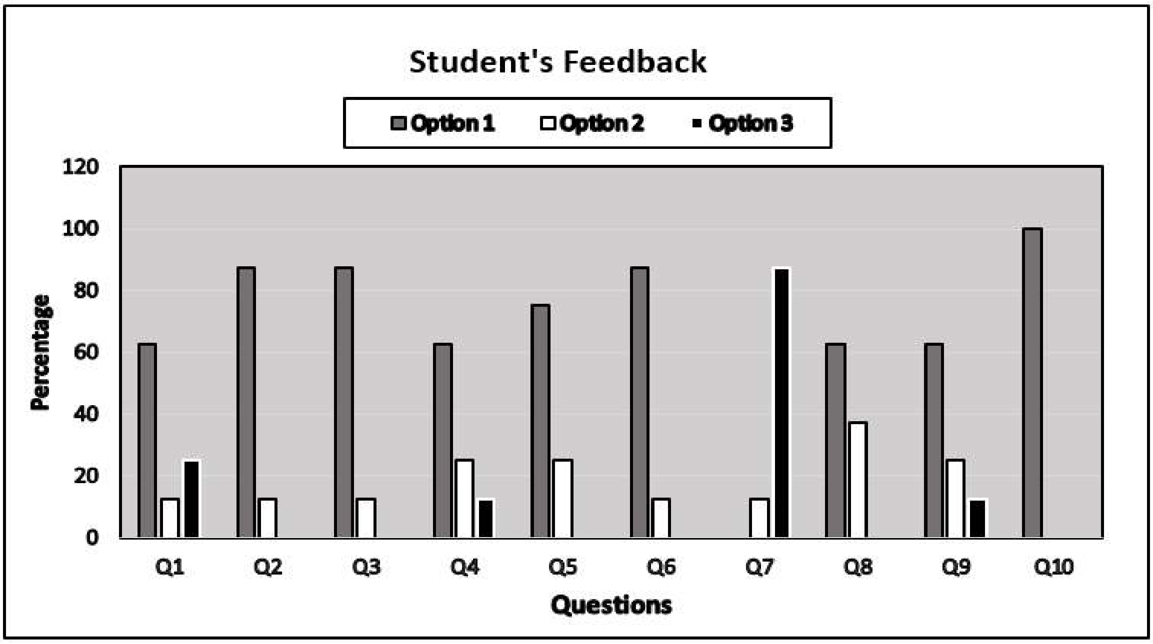

Figure 46: Graphical presentation of student's feedback (subgroup 4) on interaction with adaptive learning system

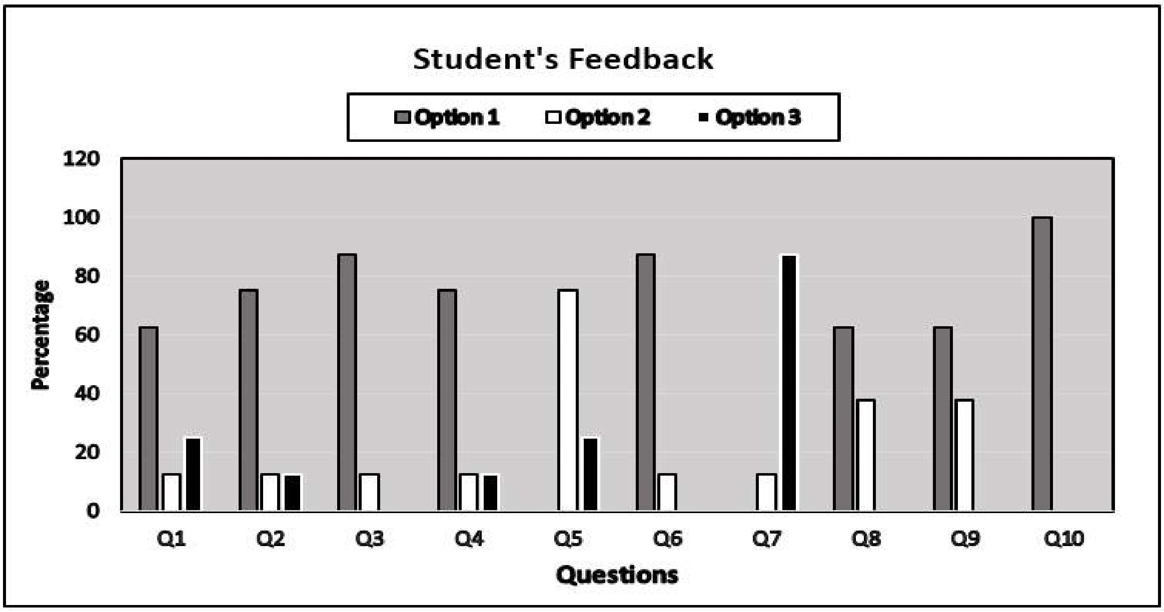

Figure 47: Graphical presentation of student's feedback (subgroup 5) on interaction with adaptive learning system

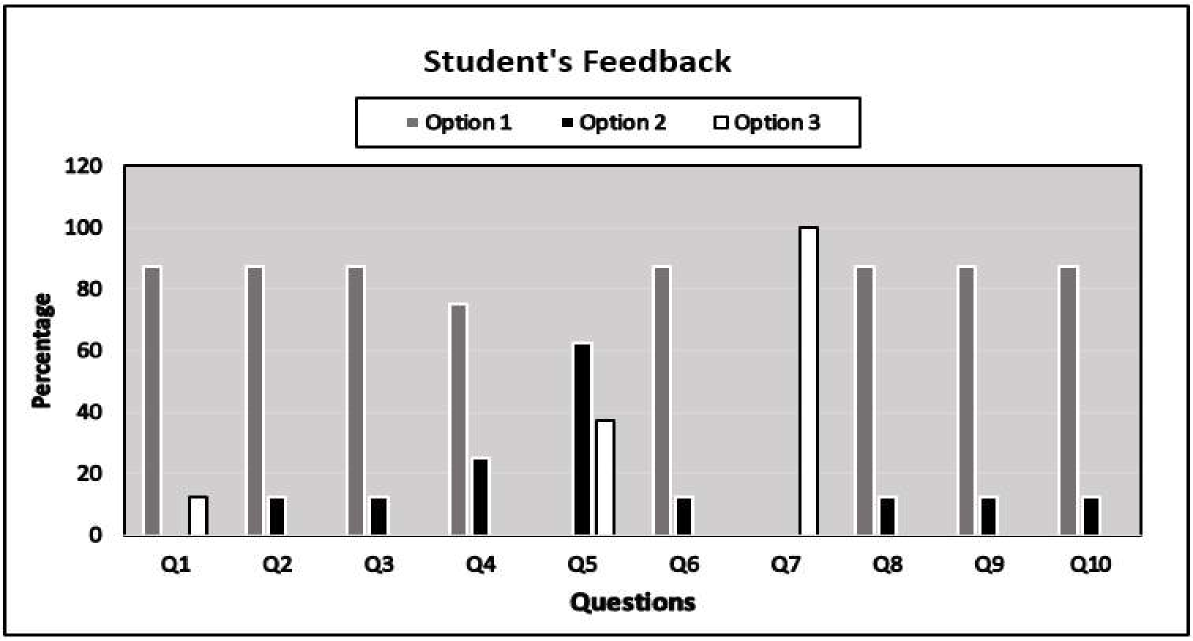

Figure 48: Graphical presentation of student's feedback (subgroup 6) on interaction with adaptive learning system

<u>Group-7, 8 and 9:</u>

The comparison of average score of control and experimental groups including sub-group 7, 8 and 9 is presented in figure 49. It was postulated that learners with high PK but low WMC and any learning style including deep-serialist/deep-holist or surface learning style could perform better if adaptive learning environment support them during learning process. The results confirmed, as the participants of experimental sub group 7, 8 and 9 performed better by achieving 17.25%, 13.88%, 18.37% correspondingly more score in post test-1 and 21.5%, 17.88%, 24.76% respectively more score in post test-2 in comparison of control sub group 7, 8 and 9. The students of experimental sub groups 7, 8 and 9 has also outperformed in terms of learning efficiency by taking 12, 14 and 10 minutes less learning time respectively (figure 41). The possible reason behind such learning progress was the ability of adaptive learning environment to recommend learning contents as per students' knowledge level memory capacity and learning preference. Hence, learners get motivated to learn new information supported by their existing knowledge base. Additionally, the design of contents also considered learners limitations related to WMC as well as specific learning preferences which further effect their understanding. Hence, the proposed approach reinforced learning process by delivering matching learning contents to each subgroup, performance based repetition and feedback mechanism that was missing in traditional learning environment.

Further, the subgroups with low PK (i.e. subgroup 1, 2 & 3) and high PK (i.e. subgroup 6, 7 & 8) found opportunity to learn exactly according to their existing knowledge base. The low PK learners of experimental subgroups received content imparting basics of concepts which make them interested in learning and avoid to quit from learning due to difficult material. In contrast, low PK learners of control subgroups did not have such learning resource which present them basics of each knowledge item separating from its advance details.

The high PK learners of experimental subgroups got content to establish further knowledge on their existing knowledge base which motivated them to grasp new information and avoid to get bored from learning same information they already possess. On contrary, their counterparts of control subgroups have learning resources which did not clearly indicate that where to start as the knowledge items were intermingled so they have to filter information on their own which require further effort. They may waste lot of their time in reviewing knowledge items they already know and identifying items they have to learn in order to advance their knowledge of topic. Hence, learning material did not allow them to put their full potential on comprehending new information to strengthen their knowledge base.

All the experimental sub groups 1 to 9, showed better performance in learning gain and learning efficiency because each sub group received learning content in accordance to their unique combination of learning characteristics which collectively contributed towards learning improvement.

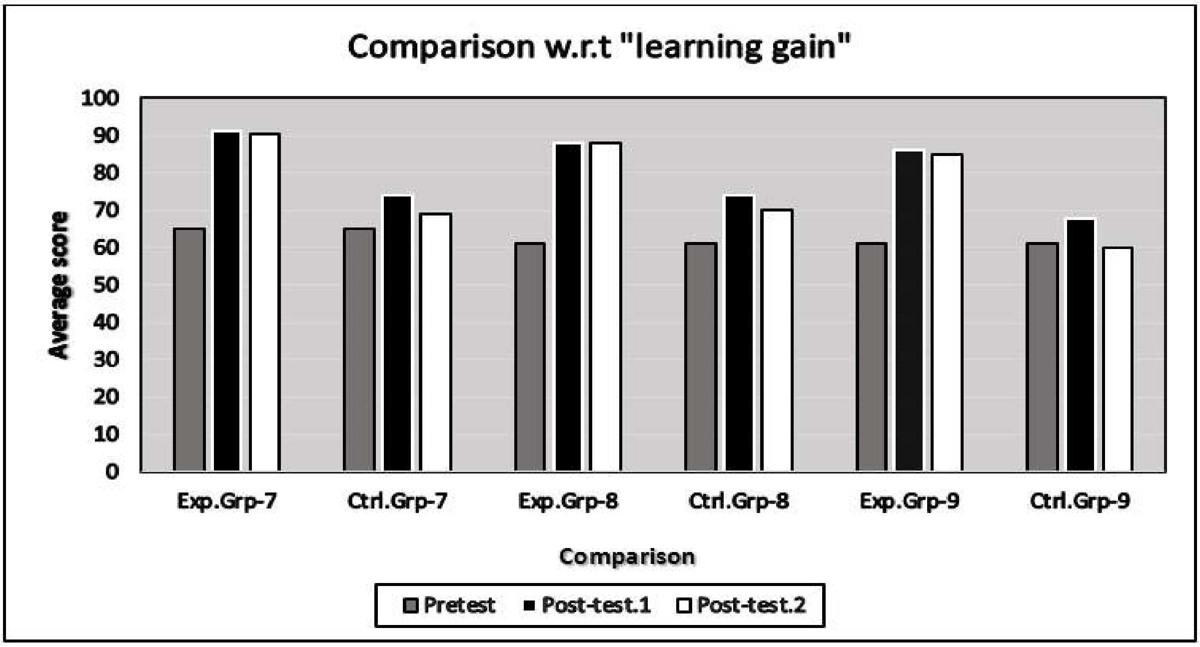

Figure 49: Learning performance of control and experimental subgroup 7, 8 and 9

The below table 45 and 46 shows the ANCOVA result of the post test-1 and post test- 2 using pre-test as covariate. It was found that the participants in the experimental sub-groups 4, 5 and 6 had significantly better learning outcomes than participants of control sub-groups 4, 5 and 6 in post test-1 with ($F = 45.72$ and $P < .01$), ($F = 19.23$ and $P < .01$), ($F = 75.58$ and $P < .01$) and in post test-2 with ($F = 78.43$ and $P < .01$), ($F = 26.28$ and $P < .01$), ($F = 116.22$ and $P < .01$) respectively. These significant results come about due to the availability of learning material to each sub group in accordance to their learning characteristics. Hence, learning gain and retention of experimental subgroups get improved in comparison to control subgroups.

	N	Mean	S.D.	Std.Error.	F.Value	P.Value
G-7. Experimental	8	91.13	7.10	2.55	45.72	<0.1
G-7. Control	8	73.88	3.98	2.55		
G-8. Experimental	8	88.00	6.19	3.16	19.23	<0.1
G-8. Control	8	74.13	7.49	3.16		
G-9. Experimental	8	86.13	3.72	2.11	75.58	<0.1
G-9. Control	8	67.75	4.62	2.11		

Table 45: Descriptive data and ANCOVA of the post-test-1 score

	N	Mean	S.D.	Std.Error.	F.Value	P.Value
G-7. Experimenta	8	90.38	7.31	2.43	78.43	<0.1
G-7. Control	8	68.88	2.10	2.43		
G-8. Experimental	8	88.00	5.76	3.49	26.28	<0.1

G-8. Control	8	70.13	8.56	3.49		
G-9. Experimental	8	84.88	4.91	2.02	116.22	<0.1
G-9. Control	8	63.13	3.23			

Table 46: Descriptive data and ANCOVA of the post-test-1 score

Analysis of student feedback related to experimental subgroup-7, 8, and 9 provides us following information. Same information is also presented graphically in figure 50, 51 and 52.

- Most of the students preferred learning through adaptive approach rather than traditional classroom, only 12.5% of subgroup-8 and 9 felt both approaches indifferent, and 12.5% of group-7 did not preferred adaptive approach over traditional approach.
- Most of the students felt that the adaptive system provided them content according to their learning needs.
- Most of the students said that system helped them by giving examples, details or overview, only 12.5% of subgroup-8 were not agree to this.
- Most of the students felt that content presentation helped them in comprehending learning material.
- Most of the students specifically group-9 felt that revision of learning material improved their understanding of learning material, only 12.5% of subgroup-8 were disagree.
- Most of the students were comfortable with language of learning content, only 12.5% of subgroup 7 and 9 found it difficult.

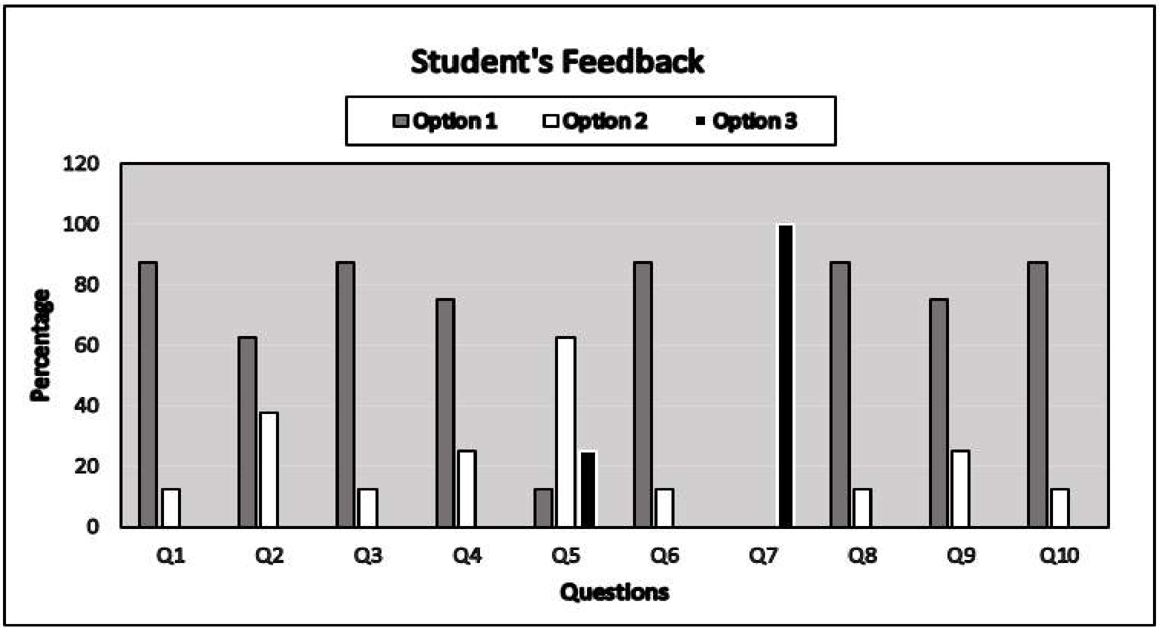

Figure 50: Graphical presentation of student's feedback (subgroup 7) on interaction with adaptive learning system

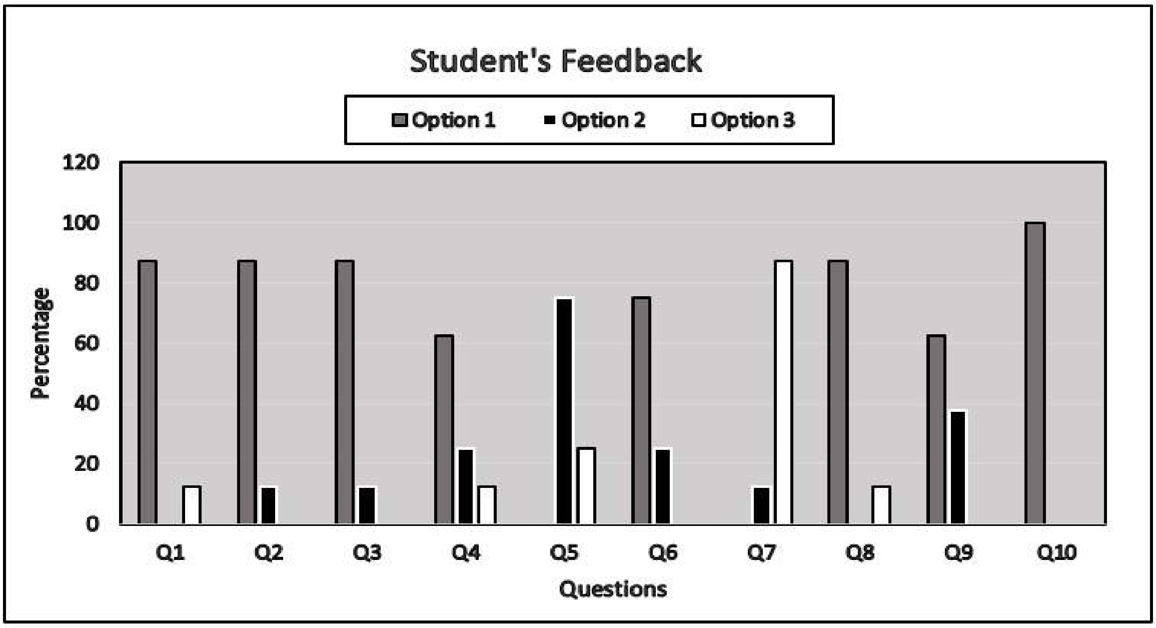

Figure 51: Graphical presentation of student's feedback (subgroup 8) on interaction with adaptive learning system

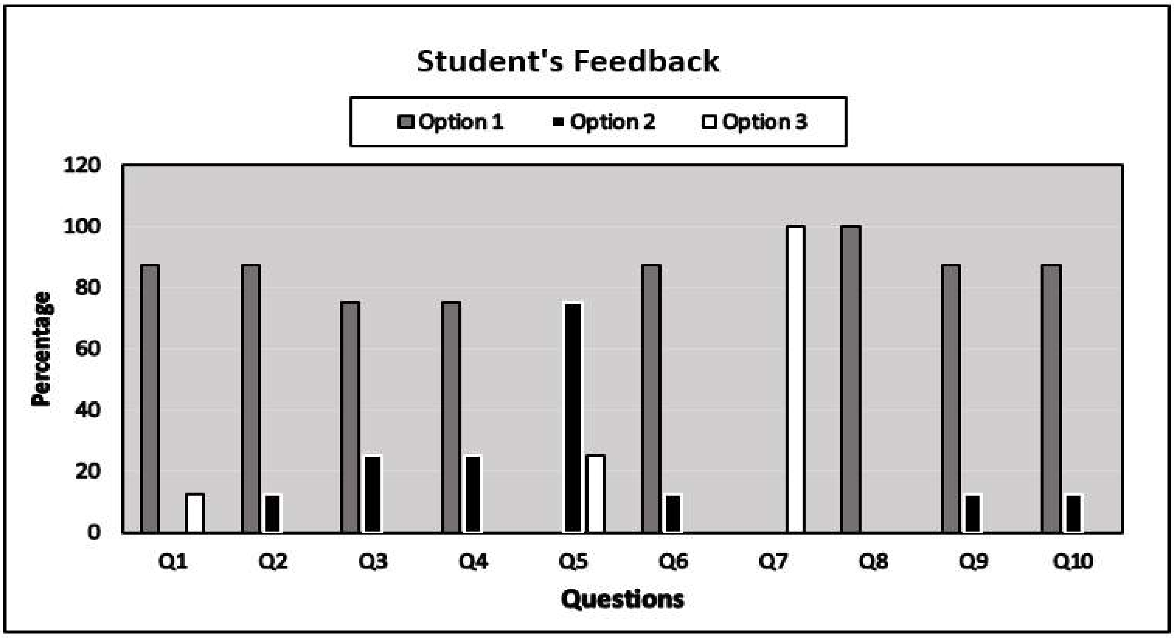

Figure 52: Graphical presentation of student's feedback (subgroup 9) on interaction with adaptive learning system

<u>Group-10, 11 and 12:</u>

It was expected that adaptive e-learning system could significantly improve the learning performance of learners with high PK, high WMC and any learning style including deep-serialist/deep-holist or surface through presenting them learning content according to their learning characteristics. The results found dissimilar to our expectation as no big difference was shown in terms of learning performance of experimental sub group 10 and 11 in comparison to control sub groups shown in figure 53. For example, the learning of experimental subgroup-10 enhanced by 5.5% in posttest-1 and 6.5% in post test-2. Similarly, learning of experimental subgroup 11 enhanced by 5.13% in posttest-1 and 5.5% in posttest-2. The learning of experimental sub group 12 was enhanced by 11.34% in post test-1 and 10.33% in post test-2 as shown in figure 53, but the subgroup consists of low number of participants.

Further, experimental subgroups also showed minor learning time differences (figure 41). The possible reason of these results was the deficiency in content to support learners of high cognitive capacities as the participants of both sub groups expressed that it would be better if e-learning system enable them to explore course material from application, and creative perspectives to foster English skills.

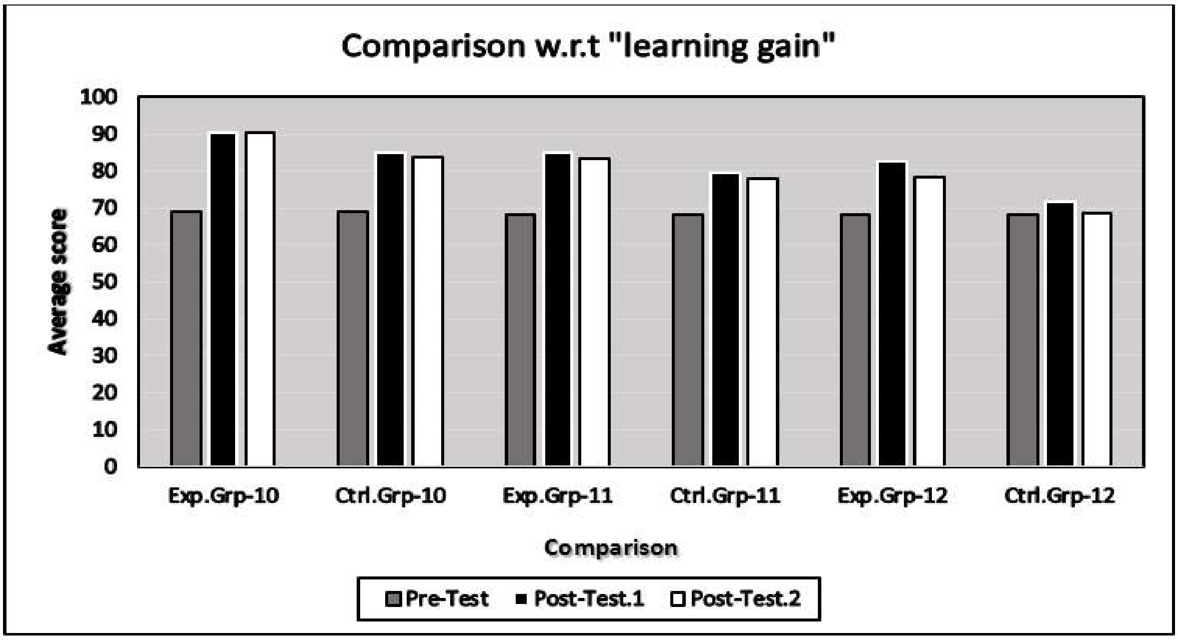

Figure 53: Learning performance of control and experimental sub-group 10, 11 and 12

The below table 47 and 48 indicate the ANCOVA result of the post test-1 and post test- 2 using pre-test as covariate. It was revealed that the participants in the experimental sub-groups 10 and 11 had not statistically significant learning performance in comparison to control sub-groups in post test-1 with (F = 1.90 and P > .05), (F = 1.87 and P > .01) and in post test-2 with (F = 2.68 and P > .05), (F = 1.67 and P > .05) respectively. The participants of experimental subgroup-12 showed significant better learning performance in both tests (F = 17.82 and P < .05, F = 7.83 and < .05) in comparison to counterparts of control subgroup as shown in table 10 and 11, but this group relatively consists of low number of participants so conclusions could not made.

	N	Mean	S.D.	Std.Error.	F.Value	P.Value
G-10. Experimental	8	90.38	6.07	3.99	1.904	>.05
G-10. Control	8	84.88	9.60	3.99		
G-11. Experimental	8	84.75	8.40	3.75	1.868	>.05
G-11. Control	8	79.63	5.83	3.75		

G-12. Experimental	4	83.50	5.07	2.78	17.82	<.05
G-12. Control	4	71.75	1.50	2.78		

Table 47: Descriptive data and ANCOVA of the post-test-1 score

	N	**Mean**	**S.D.**	**Std.Error.**	**F.Value**	**P.Value**
G-10. Experimental	8	90.38	5.76	3.97	2.68	>.05
G-10. Control	8	83.88	10.02	3.97		
G-11. Experimental	8	83.38	10.04	4.30	1.67	>.05
G-11. Control	8	77.88	6.13	4.30		
G-12. Experimental	4	79.75	6.85	4.02	7.83	<.05
G-12. Control	4	68.50	4.36	4.02		

Table 48: Descriptive data and ANCOVA of the post-test-1 score

Analysis of student feedback related to experimental subgroup-10, 11provides us following information. Same information is presented graphically in figure 54 and 55.

(Group 12 consists of low number of respondents (i.e. only 03) that's why not discussed here)

- Most of the students *(i.e. 62.5% of subgroup 10 & 50% of subgroup 11)* did not preferred learning through adaptive approach in comparison to traditional, 12.5% of both subgroup 10 and 11 were disagree to learning through adaptive learning approach.
- Only 25% students of subgroup 10 and 37.5% students of subgroup 11 felt that adaptive system provided them content exactly according to their learning needs, whereas 50% of subgroup 10 and 37.5% of subgroup 11 felt that adaptive system provided them content, some extent to their learning needs. Rest of the 25% learners of both groups expressed that they did not received learning content according to their needs.
- Only 25% students of subgroups-10 and 37.5% learners of subgroup-11 said that system helped them by giving examples, overview and details.
- Only 25% students of both subgroups felt that content presentation helped them in comprehending learning material, rest of the learners of both groups did not found it helping.
- Most of the students of both subgroups felt that revision of learning material did not found helping in improving their understanding of learning material. Only 25% of subgroup-10, and 12.5% of subgroup-11, felt that revision of learning material improved their comprehension.
- Most of the students were comfortable with language of learning content.

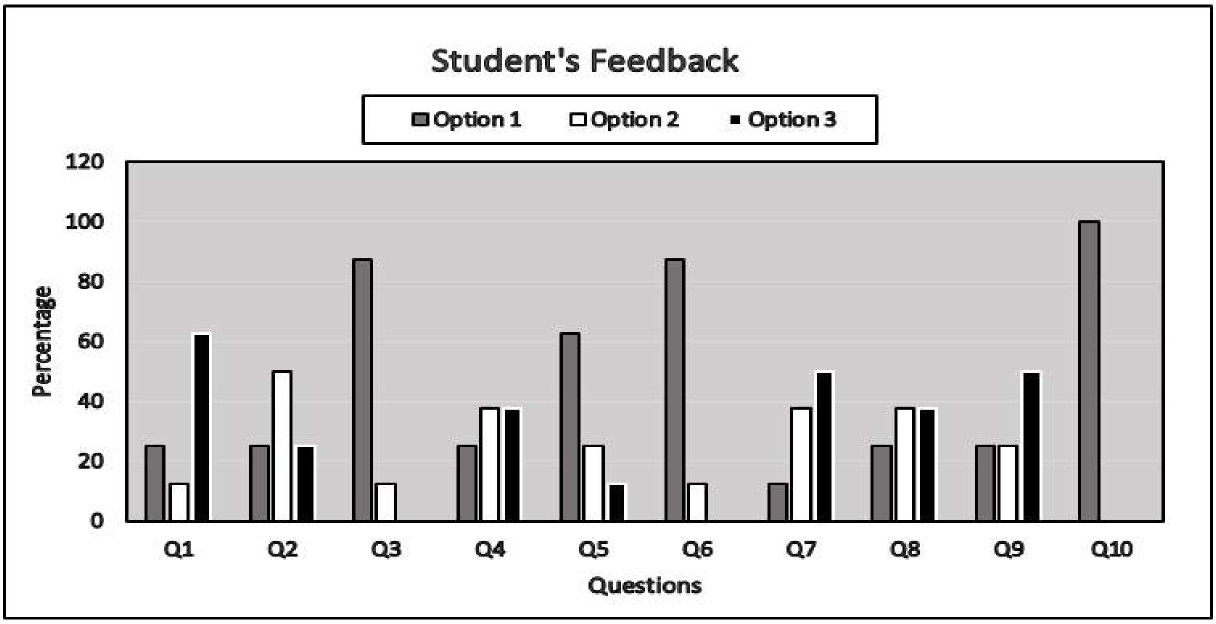

Figure 54: Graphical presentation of student's feedback (subgroup 10) on interaction with adaptive learning system

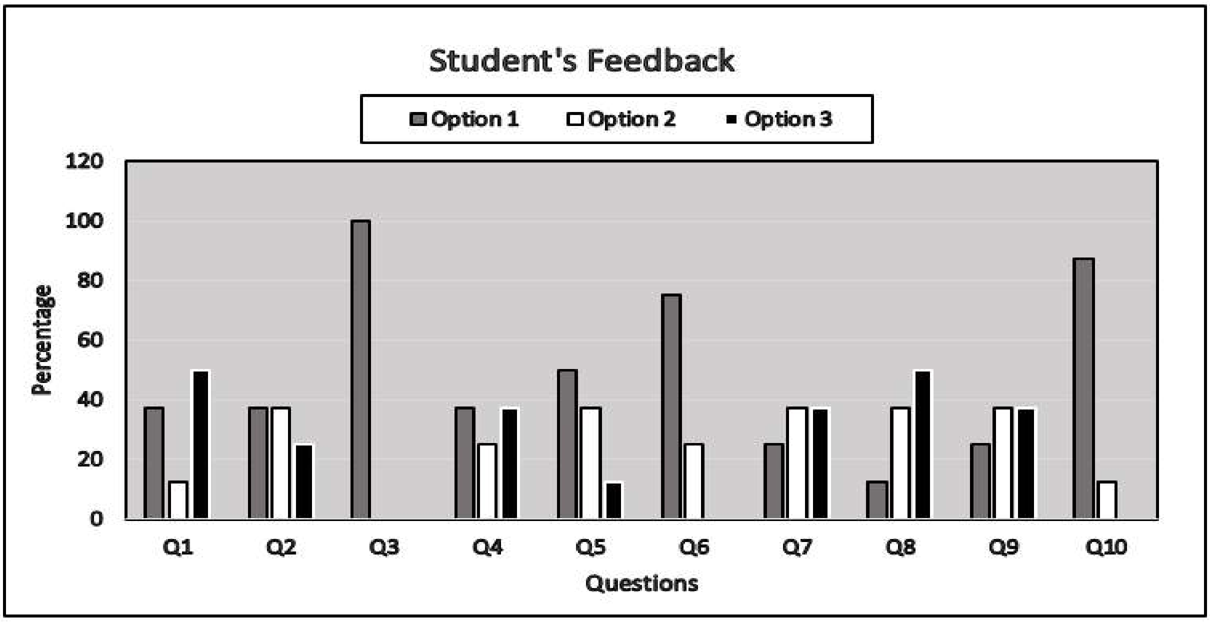

Figure 55: Graphical presentation of student's feedback (subgroup 11) on interaction with adaptive learning system

7.7 Discussion

Adaptive e-learning has been recognized as significant and challenging area striving to handle students learning issues through technology enabled programs in the context of traditional and online learning environment. A number of approaches and adaptive systems have been introduced to present a better learning experience to students. In such pursuit, large number of research studies have been conducted using learning styles mainly Felder Silverman Learning Style Model (FSLSM) to adapt content according to the different dimensions of learning style model. There are many learning styles having different dimensions as well as other effective parameters such as cognitive styles, cognitive abilities and affective states etc. which are still underexplored.

In this thesis, we have proposed an adaptive learning system based on the combination of learner's characteristics including Prior Knowledge (PK), Working Memory Capacity (WMC) and Learning Styles (LSs). The system utilized the combination of complementary parameters to present adaptive content. As our approach based on the combination of different parameters so we have identify different group of students, each with combination of similar characteristics in order to investigate the impact of adaptive learning approach on their learning performance.

A robust evaluation study was conducted using multiple experimental and control sub groups, each experimental control subgroup representing identical combination of learning characteristics. During evaluation sessions, each experimental subgroup learnt through adaptive learning system whereas counterpart control subgroups learnt in traditional classroom setting.

The adaptive e-learning system delivers learning content to each experimental subgroup in accordance to their learning characteristics. The learning progress of the participants of experimental subgroups was measured in comparison to control subgroups. The learning progress was measured in terms of learning gain, learning efficiency and learner satisfaction with adaptive learning approach.

Overall, the adaptive approach improved the learning outcomes of experimental sub groups. The results revealed that generally the learners who received adaptive learning content in accordance to their combination of individual characteristics including PK, WMC and LSs achieved almost 15% more score than their counterparts. Moreover, the learners who through adaptive e-learning system were quite satisfied and they have showed better retention of learnt concepts by achieving 19% more score than subjects of control subgroups. The participants of control subgroups on average showed 6.5% loss of learnt information while participants of experimental subgroups lost small amount of information (i.e. 1.4%). In terms of learning efficiency, the experimental subgroups have also showed better performance as they took less learning time to complete learning activity in comparison to control subgroups.

The major difference in students learning performance came from the adaptive delivery of easy to read, understandable and clearly written instructions according to different combinations of their three learning characteristics. The subjects of control subgroups learnt through standard contents, which were not designed as per their learning needs. This phenomena showed that all learners have ability to learn, so if instructions are imparted to them in accordance to their capabilities they could show better learning performance.

The results revealed that experimental subgroups either with low PK or low WMC generally with any learning style but more precisely with surface learning style had got more benefit through interaction with adaptive learning system. They performed better than control subgroups in terms of learning gain and learning efficiency. They found satisfied and interested to learn with adaptive learning approach. On the other hand, the students with high

PK, high WMC and either Deep-serialist or Deep-holist learning style have not shown significant better learning performance. They were not satisfied with the adaptive learning approach. These results are consistent to ELM-ART (Weber & Specht, 1997) which indicated that novice learners got more benefit from the adaptive approach relative to expert learners. Similarly, a recent study also found that novice learners got more advantage by adaptive e-learning than learner with advance knowledge (Flores et al., 2012).

Particularly, the comparison of experimental sub groups (1, 2 & 3) with experimental sub group (4, 5 and 6) showed that learners with high WMC can process much information in less time if they had opportunity to work at their pace. Similarly, results showed that by adaptive learning, learners even with low WMC can gain score at par to high WMC learners that is consistent to finding discussed in (Tsianos et al., 2009, 2010).

The subjective evaluation revealed that except Group-10 and Group-11, rest of the experimental subgroups were highly satisfied with adaptive learning approach. They have enjoyed the learning experience as the content were easy to read, understand and pertinent to their learning needs. They have indicated that this is a better approach than simply listening lectures contents. Revision of previously learnt material helped them to understand and retain concepts on long term basis. The indications of students satisfactory learning experience is similar to the evaluation results of INSPIRE (Papanikolaou et al., 2003).

The success of proposed approach is attributed to the different combinations of three learning characteristics. The improved learning performance is the collective impact of combination of individual characteristics. The results are identical to the finding of (Durrani & Durrani, 2010) which indicated that provision of learning content on the basis of prior knowledge and cognitive abilities have better impact on student learning rather than only to prior knowledge. Similarly, (Yang et al., 2013) research has also confirmed that adaptation based on multiple sources showed better impact on student learning outcome.

Overall, the students of experimental subgroups outperformed. One possible reason behind such results is that learning in traditional classroom is highly teacher centric and same instruction is delivered to all students. The concepts are taught to the students with minimal students' interaction. The student's comprehension about the delivered material is not regularly assessed as well as they have minimal opportunity during class to practice learned material under the supervision of a teacher. In contrast, adaptive learning system delivered learning content in accordance to learning needs of learners and allow them to practice learnt material with feedback support as well as offer adaptive revisions of content as per their performance in formative assessment which eventually strengthen learning and impact learning outcomes.

The evaluation results indicated that adaptive learning approach have potential to improve the learning performance of diverse students. The approach is promising, it is therefore recommended to develop adaptive learning systems for different domains using concept proved in this research.

CHAPTER 8

CONCLUSION AND FUTURE WORK

It is imperative to incorporate individual's information including his/her knowledge level, experience and cognitive/affective characteristics etc., into AESs. Without such information, it is not possible for an AES to deliver completely an individualized learning environment to serve everyone according to his/her learning needs. In AESs, SM is used to store learner information. Numerous AESs have been designed considering single aspect of learners. During last decade, major emphasize remained on the design of learning style based AESs which have shown mixed results in terms of improving student learning outcomes. Although many important learning style models have been introduced in literature but only few of them explored in adaptive learning systems. The learning styles related to the category of learning approaches have been completely ignored in previous research. It has been suggested that only the integration of learning styles into SM for the sake of adaptive learning is not enough. Other effective parameters should also be considered along with learning styles for the delivery quality learning experience. As it has been manifested that individuals may vary from each other in many ways and owing to such multiple differences they perform differently from each other during learning. The individual differences can enhance or hamper the learning progress of students. Therefore, it is understood that considering any single dimension of learner in AESs could not ensure quality learning experience. Hence, it is imperative to consider set of effective personalization parameters in terms of learning. Generally, the parameters should represent individual characteristics commonly found in student population and learning style should specifically be relevant to the learning culture of country. One of the shortcomings of existing AESs is that most of them based on single personalization parameter i.e. learning style dimensions which were selected without considering background, motivation and its relevance to learning culture. Secondly, instead of designing localized learning content consistent to each learning dimension, recycled learning material have been utilized in most of the existing studies. In this research, we have identified the most effective personalization parameters which were combined into SM for adaptive learning experience. The localized adaptive contents were designed and integrated in the prototype of adaptive learning system in order to deliver learners in accordance to their SM. The hypotheses examined in this thesis are as follows.

- Students with different Prior knowledge (PK), Working Memory Capacity (WMC) and specific learning/cognitive style when exposed to lecture contents as per their capacities and abilities can achieve equal or better learning outcomes as compared to those who are not given contents according to their individual needs.
  - When students with low PK, low WMC and deep serialist learning style were presented basic knowledge of topic in smaller chunks with

illustrations along with related details, explanation and examples they performed better in comparison to students with similar learning characteristics but contents were not available to them according to their learning needs.

   - When students with low PK, low WMC and deep-holist learning style were presented basic knowledge of topic using smaller chunks supported by illustrations and presentation in the form of overview of concept, showing relationships among knowledge elements followed by details of each bit of knowledge, they performed better in comparison to students with similar learning characteristics but content were not available to them according to their learning needs.
   - When students with low PK, low WMC and surface learning style presented learning content with much basics of topic using smaller learning chunks with visual support in much simpler form *(easy words)* using basic and simple examples, they performed better in comparison to those with similar learning characteristics but content were not available to them in accordance to their learning needs.
   - When student with low PK, high WMC and deep-serialist, deep-holist or surface learning style presented with larger chunks of basic knowledge using presentation strategy in accordance to their particular learning style, they exhibited better learning performance in comparison to those with similar learning characteristics but content were not available to them according to their learning needs.
   - When student with high PK, low WMC and deep-serialist, deep-holist or surface learning style presented learning content with advance knowledge of subject using smaller chunks with illustrations and suitable presentation strategies *(as per their particular learning style)*, they exhibited better learning performance in comparison to those with similar learning characteristics but content were not available to them in accordance to their learning needs.
   - When students with high capacities such as high PK, high WMC and deep-serialst or deep-holist learning style presented learning content according to their individual characteristics they did not showed significant better learning performance in comparison to their counterparts.

- Students with high WMC when presented learning content according to their processing capacity can learn efficiently in comparison to students with low WMC to whom learning content were also delivered according to their processing capacity.
   - The students with high WMC completed learning activity in much less time in comparison to those who have low WMC but similar in term of other parameters.

- Students who learn course using adaptive e-learning environment are more satisfying, having better understanding and retention of concepts than those who have not such facility.
  - Except subgroup 10 and 11, the participants of rest of the experimental subgroups appreciated adaptive learning approach and they felt satisfactory learning experience. Further, the retention level of students presented with content designed according to their learning needs found better than those who have not content in accordance to their learning needs.

In order to investigate hypothesis the research work was divided into different parts including theoretical background survey, design of adaptive e-contents and development of prototype of adaptive learning system prototype. Finally, an evaluation study was conducted in real settings to prove the hypothesis.

In theoretical background, the topics discussed include ICT integration in education, individual differences in e-learning context, content design guidelines, architecture of adaptive e-learning systems, user modeling and machine learning techniques. The second phase explain the categories of student groups formed on the basis of selected adaptive parameters and further discussed the design of e-contents for each group. The contents are developed considering strengths and weaknesses of each individual characteristics along with general design guidelines presented in literature. Further, the architecture of the system discussed along with the intelligent mechanism used to perform adaptation. The prototype of adaptive learning system is also discussed. Finally, evaluation study discussed the field study conducted to collect data through different tools for student modeling and experiment execution. The learning performance was assessed through pre-test and posttests. The results found both in objective and subjective form are discussed in detail.

The proposed hypotheses are proved and results are promising but there are some limitations which should improve and open opportunities for future research.

- The research study did not evaluate learning one by one, for example first judge learning outcomes based only on PK keeping other parameter constants, then WMC and keep other constants and so on in order to see that which parameter is most effective and which is least effective. Hence, further research is required to look at comparative effect of each parameter with combined approach impact so that most effective parameter(s) could be suggested.
- The evaluation study is conducted using small sample. Hence, it is suggested that further studies should carried out using large scale sample to provide further evidence.
- The learning contents used in this study were limited, design learning contents for a full course instead of few topics to test using adaptive learning

system in real learning environment for a longer period of time to collect further evidence.

- Incorporate metacognition strategies, animations and more visual aspects in content for greater learning impact.
- The proposed adaptive approach found advantageous for students with low PK, low WMC and any learning style than students with high PK, WMC along with deep-serialist and deep-holist learning style. Hence, it is required to integrate mechanism and strategies in the design of adaptive learning system specifically to benefit learner with high capabilities.
- Incorporate pedagogical instruments such as Blooms Taxonomy in order to foster deep learning as well as transform systematically surface learners into deep learning.
- Incorporate revised version of Blooms taxonomy which consists of knowledge and cognitive dimensions to foster higher order thinking skills among students.
- This research study focused on the combination of PK, WMC and LSs to impart personalized learning experience, some other important parameters including background, competence level and most importantly emotional parameters should be considered in future research because students exhibit time to time different emotional states which could influence learning process.
- The adaptation logic is tested in a limited scenario in which it has performed successfully but it should be tested in large scale study.
- Learning algorithm was not fully tested due to limited learner base and time duration. Anyhow it is evaluated during the research to some extent and the results confirm the effectiveness of the approach but it should be tested at large scale.

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APPENDIX-A
Questionnaires

Approaches and Study Skills Inventory for Students (ASSIST)

(Modified Version)

Dear Students: This questionnaire allows you to define that how you go about learning and studying. The method involves asking you a significant number of questions which are similar to some degree to provide good overall coverage of different ways of studying. Please respond honestly, so that your answers will **truly** refer to your **real** ways of studying, and work your way through the questionnaire rather **quickly. Ansar Siddique**

Name________________________ **Roll #**_________________________

Class________________________ **Section** (if any) ________________

School____

Instructions: Read each statement and tick (✓) the column you feel best represents how you learn.	**strongly agree**	**somewhat agree**	**unsure**	**somewhat disagree**	**disagree**
1. I usually set out to understand for myself the meaning of what we have to learn. میں عموماً جس بات یا چیز کو سیکھنا چاہتا ہوں اُس کا مطلب خود سمجھنے کی کوشش کرتا ہوں۔					
2. Often I find myself wondering whether the work I am doing here is really worthwhile. میں اکثر سوچتا ہوں کہ کیا یہ پڑھنا لکھنا میرے لئے واقعی ہی اہم ہے۔					
3. When I am reading I stop from time to time to reflect on what I am trying to learn from it. پڑھنے کے دوران میں کبھی کبھی رُک کر سوچتا ہوں کہ میں اِس میں سے کیا سیکھنے کی کوشش کر رہا ہوں۔					
4. When I look back, I sometimes wonder why I ever decided to come here. جب میں غور کرتا ہوں تو بعض اوقات حیران ہوتا ہوں کہ میں نے پڑھنے لکھنے کا فیصلہ کیوں کیا۔					
5.I try to relate ideas I come across to those in other topics or other courses whenever possible. جہاں تک ممکن ہو میں میں اپنے موجودہ خیالات کو دوسرے موضوعات یا کورس سے جوڑنے کی کوشش کرتا ہوں۔					

5 = strongly agree   4 = agree somewhat   3 = unsure   2 = disagree somewhat   1 = disagree

Instructions: Read each statement and tick (✓) the column you feel best represents how you learn.	**strongly agree**	**somewhat agree**	**unsure**	**somewhat disagree**	**disagree**
6.I find I have to concentrate on just memorizing a good deal of what I have to learn. میں نے جو کچھ سیکھنا ہوتا ہے اُس کے زیادہ تر حصے کو میں رٹہ لگانے پر زور دیتا ہوں۔					
7.Ideas in course books or articles often set me off on long chains of thought of my own. کورس کی کتابوں میں دیئے گئے خیالات میرے ذہن میں خیالات اور سوچوں کا ایک لمبا سلسلہ شروع کرتے ہیں					
8.I am not really sure what is important in lectures*(classroom)*, so I try to get down all I can. مجھے واقعی نہیں پتہ چلتا کہ کمرہ جماعت میں بیان کردہ باتوں میں سے کون سی بات اہم ہے اس لئے جتنا ہو سکے میں لکھنے کی کوشش کرتا ہوں					
9.I look at the evidence carefully and try to reach my own conclusion about what I am studying. میں کتابوں میں دیئے گئے شواہد کا بغور جائزہ لیتا ہوں اور مطالعہ سے اپنے نتائج اخذ کرنے کی کوشش کرتا ہوں۔					
10.I gear my studying closely to just what seems to be required for assignments*(activity/class work)* and exams. میں اپنے مطالعہ کا رخ صرف ان چیزوں کی طرف رکھتا ہوں جو کلاس ورک کرنے یا امتحان کے لیے ضروری ہوں۔					
11. When I read, I examine the details carefully to see how they fit in with what's being said. پڑھنے کے دوران وضاحت کے لیے دی گئی تفصیلات کو میں زیر بحث نقطہ سے جوڑ تا ہوں۔					
12.I often seem to panic if I get behind with my work. اگر میں اپنے پڑھنے لکھنے کے کام میں پیچھے رہ جاؤں تو اکثر گھبرا جاتا ہوں۔					
13. Regularly I find myself thinking about ideas from lectures*(classroom)* when I am doing other things. میں اپنے دوسرے کاموں میں مصروفیت کے دوران بھی کمرہ جماعت میں بیان کردہ باتوں کے بارے میں باقاعدگی سے غور کرتا ہوں۔					

5 = strongly agree *4 = agree somewhat* *3 = unsure* *2 = disagree somewhat* *1 = disagree*

Instructions: Read each statement and tick (✓) the column you feel best represents how you learn.	**strongly agree**	**somewhat agree**	**unsure**	**somewhat disagree**	**disagree**
14. I tend to read very little beyond what is actually required to pass. میں مجوزہ کتابیں جو پاس کرنے کے لیے ضروری ہیں ان سے زائد بہت کم پڑھتاہوں۔					
15. Some of the ideas I come across on the course I find really gripping. کچھ خیالات جو کورس سے میرے ذہن میں آتے ہیں مجھے اپنی طرف پوری طرح متوجہ کر لیتے ہیں۔					
16.Often I feel I am drowning in the sheer amount of material we are having to cope with. پڑھنے لکھنے کا کام اتنا ہوتا ہے کہ میں اکثر ڈرتا ہوں کہ کہیں میں اِس میں ڈوب ہی نہ جاؤں۔					
17. When I am reading a book, I try to find out for myself exactly what the author means. جب میں کوئی کتاب پڑھ رہاہو تاہوں تو میں مصنف کے مطلب کو خود سمجھنے کی کوشش کرتا ہوں۔					
18. There is not much of the work here that I find interesting or relevant. پڑھائی کا زیادہ تر کام مجھے دلچسپ اور اپنے سے متعلقہ نہیں لگتا۔					
19. Before tackling a problem or assignment, I first try to work out what lies behind it. کسی علمی سرگرمی یا مشق کو حل کرنے سے پہلے اُس کے پیچھے جو مقصد ہوتا ہے میں اُس کو سمجھنے کی کوشش کرتا ہوں۔					
20.I am not really interested in the course, but I have to take it for other reasons. میری پڑھنے لکھنے میں بالکل دلچسپی نہیں مگر کچھ اور وجوہات کی بنا پر میں پڑھ رہا ہوں۔					
21. When I am working on a new topic, I try to see in my own mind how all the ideas fit together. جب میں کسی نئے موضوع کو پڑھتا ہوں تو میں اُس سے متعلق تمام خیالات کو اپنے ذہن میں جوڑنے کی کوشش کرتا ہوں۔					

5 = strongly agree 4 = agree somewhat 3 = unsure 2 = disagree somewhat 1 = disagree

Instructions: Read each statement and tick (✓) the column you feel best represents how you learn.	**strongly agree**	**somewhat agree**	**unsure**	**somewhat disagree**	**disagree**
22. Much of what I am studying makes little sense: it is like unrelated bits and pieces. جو کچھ میں پڑھ رہا ہوتا ہوں اُس کی مجھے اکثر سمجھ نہیں آتی۔ کیونکہ مجھے اِن چیزوں کا آپس میں کوئی تعلق نہیں لگتا۔					
23.I like to play around with ideas of my own even if they don't get me very far. میں اپنے خیالات کو آزمانا پسند کرتا ہوں اگرچہ وہ مجھے مکمل طور پر کسی نتیجے تک نہ لے جا سکیں۔					
24.I often have trouble in making sense of the things I have to remember. مجھے اکثر ان چیزوں کو سمجھنے میں مشکل ہوتی ہے جو مجھے یاد کرنا پڑتی ہیں۔					
25.I find that studying academic topics can be quite exciting at times. بعض اوقات مجھے علمی موضوعات کا مطالعہ بہت اچھا لگتا ہے۔					
26.I concentrate on learning just those bits of information I have to know to pass. میں صرف ان چیزوں کو یاد کرنے پر توجہ دیتا ہوں جو پاس ہونے کیلئے ضروری ہیں۔					
27. Often I find myself questioning things I hear in lectures*(classroom)* or read in books. میں جو چیزیں کتابوں میں پڑھتا ہوں یا کمرہ جماعت میں سنتا ہوں اکثر اُن پر سوالات اُٹھاتا ہوں۔					
28. I like to be told precisely what to do in essays*(exercises)* or other assignments. میں چاہتا ہوں کہ مجھے واضح طور پر بتایا جائے کہ مشقوں میں یا کلاس ورک میں کرنا کیا ہے۔					
29.I sometimes get 'hooked' on academic topics and feel I would like to keep on studying them. میں بعض اوقات تعلیمی موضوعات میں محو ہو جاتا ہوں اور میری خواہش ہوتی ہے کہ ان پر مطالعہ جاری رکھوں۔					

5 = strongly agree   4 = agree somewhat   3 = unsure   2 = disagree somewhat   1 = disagree

Instructions: Read each statement and tick (✓) the column you feel best represents how you learn.	**strongly agree**	**somewhat agree**	**unsure**	**somewhat disagree**	**disagree**
30. I often worry about whether I will ever be able to cope with the work properly. میں اکثر پریشان رہتا ہوں کہ میں اپنے پڑھنے لکھنے کا کام صحیح طریقے سے کر بھی پاؤں گا یا نہیں۔					
31. It is important for me to be able to follow the argument, or to see the reason behind things. میرے لیے یہ جاننا ضروری ہوتا ہے کہ جو کچھ میں پڑھ رہا ہوں اِس کے پیچھے کیا دلیل یا وجہ ہے۔					
32. Often I lie awake worrying about work I think I would not be able to do. میں اکثر اُن کاموں کی پریشانی سے جاگتا رہتا ہوں جو مجھے لگیں کہ میں نہیں کر سکوں گا۔					

Please tick (✓) the column you feel suitable.	**definitely like**	**like to some extent**	**unsure**	**dislike to some extent**	**definitely dislike**
(a) Lecturers*(Teachers)* who encourage us to think for ourselves and show us how they themselves think. اساتذہ ہمیں خود سے چیزوں پر سوچنے کے لیے ہماری حوصلہ افزائی کریں اور ہمیں یہ بھی بتائیں کہ وہ خود کیسے سوچتے ہیں۔					
(b) Books which give you definite facts and information which can easily be learned. کتابیں ہمیں حقائق کی واضح معلومات دیں تا کہ ہم چیزوں کو آسانی سے سیکھ سکیں (اور ہمیں زیادہ محنت نہ کرنی پڑے)					
(c) Courses where we are encouraged to read around the subject a lot for ourselves. نصاب ایسا ہو جو ہمیں مضمون کے بارے میں اپنے طور پر بہت کچھ پڑھنے میں ہماری مدد کرے۔					

5 = strongly agree *4 = agree somewhat* *3 = unsure* *2 = disagree somewhat* *1 = disagree*

Please tick (✓) the column you feel suitable.	**definitely like**	**like to some extent**	**unsure**	**dislike to some extent**	**definitely dislike**
(d) Exams or tests which need only the material provided in our lecture notes. امتحانات میں صرف وہی پوچھا جائے جو ہم نے Notes میں لکھا ہو۔					
(e) Books which challenge you and provide explanations which go beyond the lectures. کتابیں ایسی ہوں جو ہمیں پڑھنے کی دعوت دیں اور کمرہ جماعت سے کہیں زیادہ چیزوں کی وضاحت کریں۔					
(f) Lecturers*(Teachers)* who tell us exactly what to put down in our notes. اساتذہ ہمیں بتائیں کہ امتحانات کے لیے کیا کچھ ضروری ہے اور اس کے Notes بنالو۔					
(g) Courses in which it's made very clear just which books we have to read. درسی کتب کا واضح طور پر پتہ ہو کہ ہم نے صرف یہی پڑھنی ہیں (تا کہ زائد کتب کو نہ پڑھنا پڑے)۔					
(h) Exams which allow me to show that I have thought about the course material for myself. امتحانات اس طرح کے ہوں جو مجھے میری اپنی سوچ سمجھ کے مطابق سوالوں کو حل کرنے کی اجازت دیں۔					

5 = definitely like *4 = like to some extent* *3 = unsure* *2 = dislike to some extent* *1 = definitely*

Finally, how well do you think you have been doing in your assessed work overall, so far? (*Please rate yourself* ***objectively****, based on the grades you have been obtaining).* **Tick (✓) any suitable option given below.**

ابھی تک کے کلاس ٹیسٹوں میں آپ کی کارکردگی کیسی ہے (نیچے دی گئی Options میں سے جو آپ کو اپنے مطابق لگ رہی ہے اس پر Tick کریں)۔

very well **quite well** **average** **not so well** **rather badly**

Thank you very much for spending time completing this questionnaire:

It is much appreciated.

Knowledge Tool (self-designed)

This test is designed to assess the level of knowledge (Low, High) of grade 9th& 10th students particularly in the concept of preposition of place and time (at, in, on). The technique involves asking you multiple questions related to the use of at, in & on reference to time and place. Dear students please read each statement carefully and choice suitable option corresponding to each item.

Name________________________ **Roll #**_________________________

Class________________________ **Section** (if any) _________________

School____

Note: Fill in the blanks with suitable preposition words.

1. My birthday is________May.

    (a) **at** (b) **in** (c) **on** (d) **none**

2. Who is standing________the window?

    (a) **at** (b) **in** (c) **on** (d) **none**

3. Hamid is playing tennis_______ Sunday.

    (a) **at** (b) **in** (c) **on** (d) **none**

4. Do not sit_______the grass.

    (a) **at** (b) **in** (c) **on** (d) **none**

5. Her grandma died_______March, 2005.

    (a) **at** (b) **in** (c) **on** (d) **none**

6. She sat_______her desk. 

    (a) **at** (b) **in** (c) **on** (d) **none**

7. We enjoyed a lot _______Eid day.

    (a) **at** (b) **in** (c) **on** (d) **none**

8. She grew up_______London.

    (a) **at** (b) **in** (c) **on** (d) **none**

9. There is a mirror_______the wall.

(a) **at** (b) **in** (c) **on** (d) **none**

10. Many of these temples were built__________16th century.

(a) **at** (b) **in** (c) **on** (d) **none**

11. He met me__________the entrance.

(a) **at** (b) **in** (c) **on** (d) **none**

12. We also have a holiday __________independence day.

(a) **at** (b) **in** (c) **on** (d) **none**

13. Her favorite flower shop is__________ 1423 Main Street.

(a) **at** (b) **in** (c) **on** (d) **none**

14. My brother's birthday is __________ the 5th of November.

(a) **at** (b) **in** (c) **on** (d) **none**

15. She lives_______an island.

(a) **at** (b) **in** (c) **on** (d) **none**

16. They are sitting _________chairs.

(a) **at** (b) **in** (c) **on** (d) **none**

17. He goes to England_________ every Christmas.

(a) **at** (b) **in** (c) **on** (d) **none**

18. Her grandma died_________2005.

(a) **at** (b) **in** (c) **on** (d) **none**

19. Where will you go ___________ next Friday?

(a) **at** (b) **in** (c) **on** (d) **none**

20. Ahmad is waiting for you_________the bus stop.

(a) **at** (b) **in** (c) **on** (d) **none**

21. _______Islamabad most people do not work _______Saturdays.

(a) **at** (b) **in** (c) **on** (d) **none**

22. The shop is_______the end of the street.

(a) **at** (b) **in** (c) **on** (d) **none**

23. The class starts__________ eight o'clock.

(a) **at** (b) **in** (c) **on** (d) **none**

24. When will you arrive_______the office?

(a) **at** (b) **in** (c) **on** (d) **none**

25. Do you work_______ an office?

(a) **at** (b) **in** (c) **on** (d) **none**

26. A big fly was sitting ________the ceiling.

(a) **at** (b) **in** (c) **on** (d) **none**

27. Where you go _____________ every Friday?

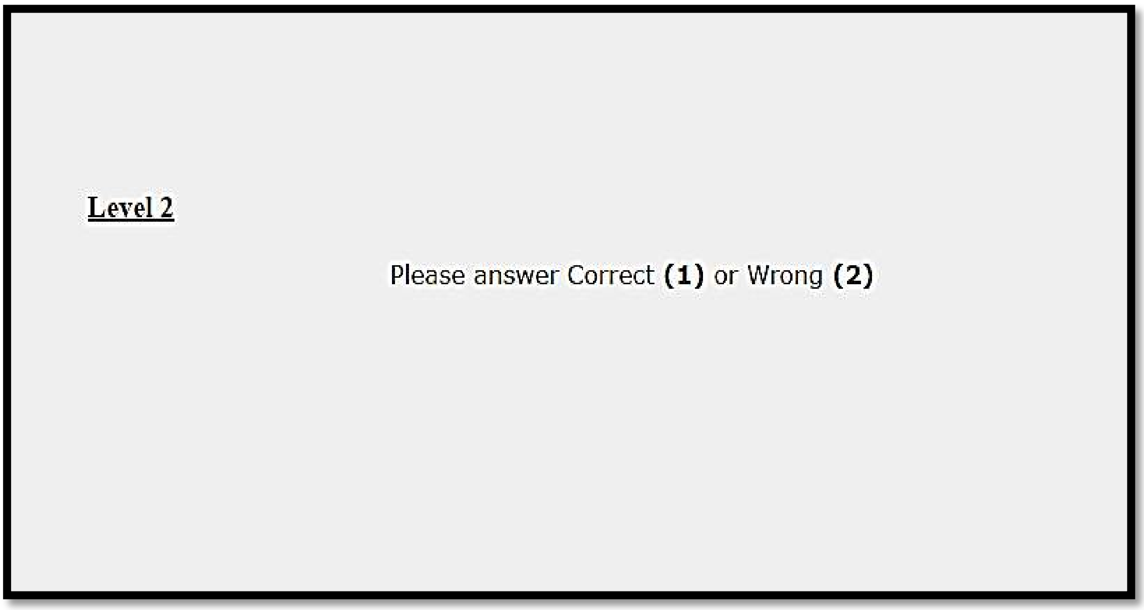
(a). **at** (b).**in** (c).**on** (d) **none**

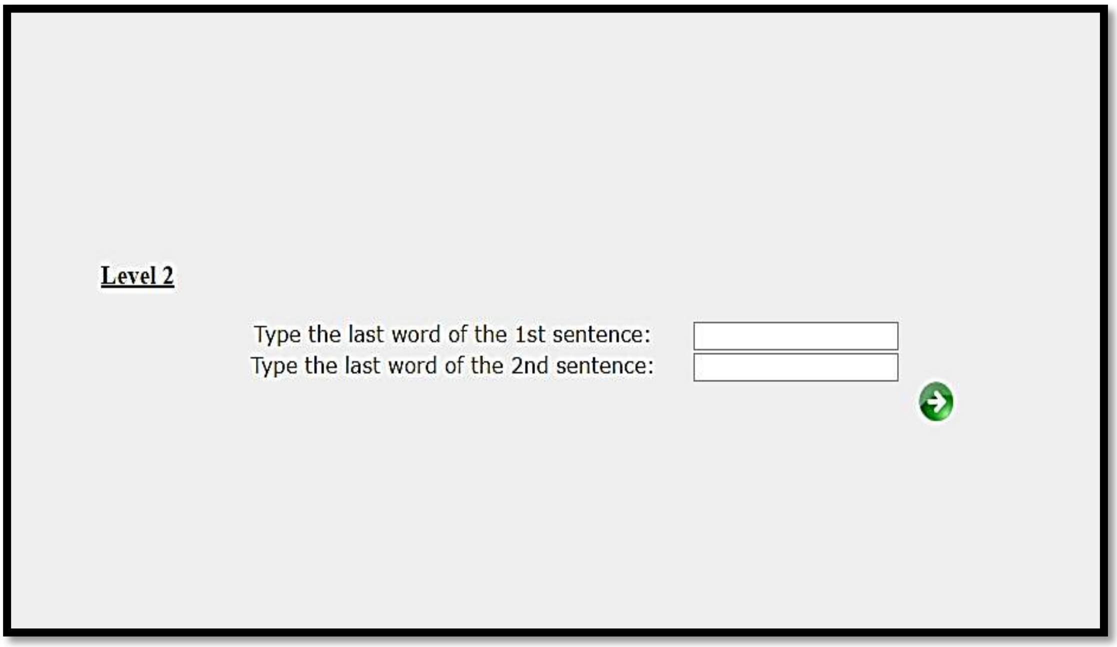
28. Because of delay we had to wait for three hours__________ the airport.

(a) **at** (b) **in** (c) **on** (d) **none**

WMTB-C

Below are the few screen shots of online test (WMTB-C) used to measure working memory of learners.




Level 2
Type the last word of the 1st sentence:
Type the last word of the 2nd sentence: