

An adaptive educational system that caters for combination of two
models of learning styles

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Abstract

This thesis aimed to explore the affect of combining two models of learning styles (VARK, and Honey and Mumford) in terms of students' learning gains and satisfaction. VARK focuses on how the students perceive learning, while Honey and Mumford examines how an individual would like to learn. A web-based educational system was built to test the combination of the two models of learning styles. A study to examine the feasibility of the system was carried out on 129 participants to explore whether the system presented tutorials according to their individual learning styles. A second study to investigate learning gains and user satisfaction was carried out on 149 participants. Satisfaction was divided into three main concepts: usability, preference and perception of learning. Learning gains were tested by giving participants a pre-test, a post-test and a confirmatory test. Participants were divided into four groups and had the lesson presented according to one learning style of either the VARK or Honey & Mumford model, both of the participants' learning styles or with no personal customization. The results found that participants who used the two models of learning styles showed higher learning gains and had higher levels of satisfaction across all three factors; compared to those using only one or no learning style. Furthermore, those using only one learning style showed higher learning gains and had higher levels of satisfaction than those with no learning style. The application of these findings would be of benefit to educational institutions' decision makers, educators, students and e-learning designers.

Adaptation is a key feature of the system of research. It is intended for future work; preliminary research has shown that the users profile and learning item will change over time. This important finding is worth exploring in future research.

Dedication

This study is dedicated to my parents who have been yearning to see me with my PhD
after long five years of absence

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List of Publications by the Candidate

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Chapter 1

Introduction

1.1 Aim

Most universities are now moving to online and distance learning systems to meet the needs of different types of learners [1]. Indeed, ‘e-learning’ is already being used by a number of universities [2], which offer online courses and degree programs. The online and distance learning systems can be used either to replace face-to-face learning or to assist students with face-to-face learning. Numerous different learning styles have been identified, which take into account individual differences in the way people learn. The learning styles theory implies that how much individuals learn has more to do with whether the educational experience is geared toward their particular style of learning than whether or not they are “intelligent”. Individuals perceive and process information in very different ways, therefore, there is a necessity for a learning system to take into account as many details as possible in terms of the learning styles of the users [3]. It is important to note that users can have more than one style that suits them, the learning system should therefore be able to adapt its presentation according to more than one learning styles model. All systems that have been developed to date, however, have only used one learning styles model, if using any at all.

The aim of this study is to examine the difference in learning gains and satisfaction between different groups of learners. One of the goals of this study is to develop a system that presents tutorials to learners using more than one learning style model to examine this difference. The aim is to use two learning styles in order to address the learner from two different points of views; different individuals have a tendency to both perceive and process information differently. The research is based on two models; VARK [4], and Honey & Mumford [5], which will be discussed in more detail throughout the following chapters in this thesis. Before the final study and after building the system a study will be conducted to examine if the learners could recognise the presentation of the system. By offering more than one learning style model, it is hoped that users will recognise that the system has used two of their learning styles and as a result will have a more positive attitude to the lesson than those presented with customisation to according to one or no learning styles.

In this introductory chapter, the general research agenda is presented. Section 1.2 describes the motivation of the research. Section 1.3 discusses adaptive hypermedia systems. Section 1.4 discusses Learning styles. Section 1.5 discusses the integration of learning styles into adaptive applications. Section 1.7 describes the research objectives and approaches. Section 1.8 below presents an outline of this thesis.

1.2 Motivation

One of the most fundamental objectives of a teaching process is to effectively convey the subject or message to the learners. Traditionally it has been a face-to-face practice in which both the teacher and learner have an opportunity to go about the issue in a direct and flexible way. In case either of the two have any difficulty in their respective role (i.e. problem faced by teacher and/or student in their respective teaching and/or learning positions) they have the privilege to give it more than one try to make the overall practice more useful. Face-to-face communication is thus considered to be the most successful teaching technique.

Since face-to-face learning is the most successful way of teaching, to maximise the resemblance with the real face-to-face teaching a student needs to be considered from different angles and the presentation of the lessons needs to be personalised. However, current e-learning systems do not offer as direct and interactive learning environment as face-to-face learning does - in the latter case, students have better opportunities to communicate with the teacher. E-learning models are therefore required to be very carefully and systematically designed in order to deliver a learning environment that is as effective as possible; the most appropriate factor to consider in e-learning would be to deliver customised lessons taking into account individual student's preferences and aptitudes.

This thesis deals with the topic of adaptive hypermedia and adaptive web-based systems specifically looking at the application of adaptive hypermedia in the context of e-learning with attention to learning styles theory.

1.3 Adaptive Hypermedia System

The term hypermedia relates to hypertext, which is essentially non-sequential text where pages or nodes are connected by *links*. Users can jump from page to page by following a set of links which allows them to *browse*. If there are many links, however, the user can be faced with the problem of navigational freedom where users can experience disorientation [6]. This is also referred to as the ‘lost in hyperspace’ problem. When people read books this is usually done in a linear fashion; whilst browsing however, it can be difficult to choose from the many links and users can jump from page to page in any order. This poses extra cognitive demands on the user from having to maintain several tasks or ‘follow several trails’, which leads to information overload or ‘cognitive overhead’ [6]. To deal with this, hypermedia systems could ultimately ‘guide’ users through the information that is related to the users’ interests. This is where the term *personalisation* can be introduced: this is the process of presenting information in a way suitable for each individual user.

The average hypertext system does not offer this and as a result a new generation of hypermedia systems *Adaptive Hypermedia Systems (AHS)* was born in the 1990’s to address the problem. This idea employs various techniques to collect user information and then uses the information gathered to provide personalised information to the users. *Adaptation*, therefore, refers to the fact that these systems change (adapt) their behaviour for each individual user. It can change different aspects of the information, such as the media used, the length of the presentation, the level of difficulty, style, etc., all depending on the user's capabilities and preferences. Links offered to the user and the presentation of these links can also be changed. The user is guided towards relevant information so that they can reach interesting information more easily and quickly. At the same time AH does not restrict users, keeping the navigation freedom of traditional hypertext. It shows the relevance of links but lets users move freely through the pages of an application (even if the links are not relevant). Traditionally in the field of adaptive hypermedia these forms of adaptation are distinguished as adaptive presentation (or content adaptation) and adaptive navigation support (or link adaptation) [7].

An application area that has benefited hugely from adaptive hypermedia is adaptive educational hypermedia systems (AEHS). This is where every AEHS is able to perform adaptation to each individual user’s knowledge to assist them in learning all the

material. The fact that different people have different learning approaches, namely that people perceive and process information in very different ways, will be referred to as learning styles throughout this thesis.

These differences will be referred to as learning styles throughout this thesis. The goal of the current research, therefore, is to bridge the gap by developing a system that is capable of adapting to individual's learning styles. Currently in the literature, there exist systems which use one learning styles model to address individual's learning styles – the current thesis aims to go further and incorporate two learning styles models. By using two combined models of learning styles, the current study aims to add to the knowledge and increase the '*adaptive power*' of many other existing AHS which use only one model of learning styles, and to examine the learning gains of students who learn using two learning models of learning styles.

1.4 Learning Styles

Simply put, learning styles are different approaches or ways of learning. It is commonly believed that individuals learn best in different ways, sometimes using a variety of different learning styles. Based on this concept, the idea of individualised "learning styles" originated in the 1970s, it gained popularity during the 1980's and 1990's, but seems to have lost some popularity in the recent years. The concept has its origins in the early idealistic philosophy of Williams James and the psychology of Carl Jung [8]. Research into learning styles illustrates how learners retrieve and map any new information presented to them [9], and studies have identified a variety of individual preferences in the understanding of information [10-13].

Learning styles indicate a user's preference for different types of information or different ways of navigating or interacting with the information space. Researchers study the learning styles from different viewpoints, such as the medium in which students prefer to receive information. For example, users with a visual style preference prefer pictorial material, where-as users with a verbal style, prefer to receive more textual description, which could be in the form of written text or perhaps even spoken audio. Other styles come from an experiential point of view; they acknowledge that experience is an important part of learning. Learning styles are presented to fit the needs of individuals, to teach them in a way which they can gain the best out of applying the learning style, to know how to help people to learn in an efficient way [14-16]. Chapter 2 will discuss the concept of learning styles theory in more detail.

One of the problems that has been identified, however, by critics of learning styles, is that various definitions are provided by different authors resulting in no universally recognised definition. Furthermore, research into matching a student's learning styles with the instructional material is mixed. Some authors have shown that user's performance is much better if the teaching methods are matched to the user's learning styles [16, 17], whilst others have shown that there are no significant differences between the learning gains when the design of instruction material with learning styles is matched/mismatched [18, 19]. One of the aims of this thesis is to carry out experimental studies in order to contribute to the field of learning styles and adaptive systems together, and add to the literature an innovative system with a formal evaluation, of which there are few to find.

The plan for this research is to build a system that caters for more than one model of learning styles. In this research two models will be used. These two models should not conflict with each other. They must also have not any significant relationship between the different styles of the two models. This test will be explained in chapter five. From the programming perspective, if both of the models are quadrants, i.e. have four sub sections; it will be easier to develop the system.

1.5 Integration of learning styles into adaptive applications

The integration of learning styles into adaptive applications is a recent development in the field of computer science. It is not an easy process and as such very few studies have investigated the relationship between the two [20-25]. These systems use only one model of learning styles. Some of the systems applying learning styles models will be discussed further in Chapter 2.

By and large, the learning styles of users are assessed through psychological questionnaires and psychometric tests. The problem with this however, is that the questionnaires are quite long. This is due to the hard fact that determining learning characteristics is very difficult. Some researchers claim that these tests are not always reliable and valid [19, 26]. Furthermore not all characteristics they measure are stable and invariable across different subject domains [19, 26].

Despite the criticisms, it was considered that it would be worthwhile developing a system that enabled the material to be presented in a way that best suited each individual learner. This belief stemmed from a combination of factors from the researcher's teaching experience to increased awareness of the potential benefits of such an adaptive system in the field of education. It was important that the system was evaluated and provided more than just one learning style as learners optimum learning styles may not be addressed by one model alone. Hence, the current research was established and the experimental hypotheses formulated.

1.6 Student Model and Learning Item Profile

Profiles, i.e. "student model" and "learning item profile" store all the information of the learning styles to enable the system to adapt the presentation according to individual learning styles [158, 161]. On occasions where the user likes an item this preference is stored in the user' profile by adding more scores according to the preferred learning item. The profile of the learning item stores information about those who preferred it.

The system keeps a record of each student's unique learning profile by using two sets of four fields within a table according to the defined learning styles of the two learning models used. These fields contain weightings of the four types of learning styles from each of the two tests as follows:

VARK: Visual, Aural, ReadWrite and Kinaesthetic

Honey & Mumford: Activist, Reflector, Theorist and Pragmatist

The student model is initialised when a new student logs into the system. Each user is categorised according to the learning style in which he scores highest (in this system the highest score tends to represent the preferred style of the user). For example: a user will be considered to have visual style if he/she gets the highest score under the Visual category in his profile. Similarly, someone who gets highest marks under the section of Aural will be regarded as having an Aural style. Just like users, any learning item's profile is also regarded according to the highest scores associated with it.

When a student takes a lesson, the profile is recalled and used to deliver lesson content that fits the student's learning style most closely. There may be several sections of a lesson that deliver basically the same content but they will be presented in different forms that are suitable for specific learning styles. This means that one lesson will teach the same facts and theories but will be delivered differently from student to student in

an effort to supply teaching that fits the student's individual learning type (see Chapter 4 for more information).

The learning styles of users also might change over time[67], this system is capable of adapting to this change by delivering the lesson according to the users new learning preferences. Additionally this adaptive ability of the system will enable changes to the profile of the learning item which may occur were an item was not previously tagged or has been tagged incorrectly. Enabling the profiles to change will enable the system to better the match and decide its suitability. Once the content has been taken the student is questioned about the suitability of the content. If a student decides that it did indeed fit with his/her learning styles, the previous learning style profile is updated. The system takes the learning style of the content and adds a weighting to the current student profile depending upon the choice (see Chapter 8 for more information).

1.7 Research objectives and approaches

In the current research the following points are investigated:

- How to automatically determine the user's learning style by a machine prior to using the system.
- How to combine two different well known learning styles (VARK and Honey and Mumford) and integrate them into an adaptive system.
- How to design presentation of learning material automatically for each type of learner according to the selected learning style.
- The ability of the user to distinguish between the presentations according to two of their learning styles, one or no personal tailoring according to their learning styles.
- Determine the learning gains and satisfaction of the users as differentiated by users who are presented with the lesson using two of their learning styles, one or no personal tailoring.

In order to address these points, it was necessary for this researcher to carry out a review of existing learning styles models and adaptive systems. Once the models had been chosen, the researcher had to find the best way to present the instructional material according to the different learning styles within each model so that the same information (lesson content) could be delivered in different ways for each individual

user. As such, the researcher had to develop a system that was able to update the content according to each user as they interacted with the system to deliver a personalised lesson. Various pilot studies were carried out to ensure the working of the system and validity of the survey tool which essentially assessed the success of the study as a whole. Both quantitative and qualitative data were gathered to provide the researcher with varying input to analyse. The researcher aimed to go further than the existing adaptive systems by developing a system that incorporated two different learning styles models. This was to provide more flexibility for the users and to investigate if there was indeed an added effectiveness of having more than one learning styles model. It was hypothesised that when presented with a lesson according to two of their learning styles, compared to with one or no personal customisation, users will have a higher learning gains and express higher levels of satisfaction.

1.8 Outline of the thesis

Chapter 1 provides the introduction to the thesis and gives an overview to the research aim, motivation, objectives, and structure of the thesis.

Chapter 2 outlines the research questions and hypotheses in more detail. It reviews the background studies that are related to the aims of the research. The chapter presents the concept of learning styles and discusses various widely known models of learning styles. An explanation of intelligent tutoring systems and educational systems is presented, as well as an overview of the concept of adaptation explaining what the relationship between the two systems is.

Chapter 3 puts forth the route that the researcher had to adapt in order to perform the research. It shows the research design, tools and stages. This chapter details how the data collection took place and describes how the experimental design was developed.

Chapter 4 describes the system that was built; the stages of developing the system in particular are looked in detail. It demonstrates how the idea was then put into practice. This chapter concludes with the results of the pilot study and interviews carried out to provide essential feedback on the system prototype.

Chapter 1 Introduction

Chapter 5 presents the results of the “Testing feasibility of the system” study, how participants responded to the system. This addresses the main research question focussing on whether or not users recognised that the system was adapting to their learning styles. It also examines various other issues such as the organisation of the site and ease of use.

Chapter 6 presents the results of the evaluation study that was carried out to test user’s learning gains and satisfaction. This study aimed to provide a formal evaluation of the system.

Chapter 7 summarises the main findings and achievements of the study overall. Some limitations to the study are discussed followed by ideas and recommendations for future research.

Chapter 8 describes the work that is suggested for future work, and the exploration of different scenarios of the adaptation.

Finally, Chapter 9 reports the thesis conclusions and findings. It also highlights the research limitations, and recommendations. Directions for future work are also provided.

Chapter 2

Literature Review

Learning has been defined as the process of acquiring new knowledge, behaviours, skills, values, preferences or understanding, and may involve synthesising different types of information. Traditionally, learning took place via human instruction. Nowadays, more and more learning is taking place via various computer systems, from classroom based learning to sporting techniques [27]. This thesis focuses on the learning via ‘e-learning’ which deals with Internet-based networked computer-enhanced learning.

It is an established fact that computers have been used in education for over 30 years [28], and the number of computerised instructional systems is rapidly increasing [29]. Technology has evolved significantly since the invention of the first computer and with it many new concepts have emerged [30]. ‘Adaptive hypermedia systems’ or ‘intelligent tutoring systems’, which a few decades ago were non-existent, are now terms which are commonly known in the field of computer science. These concepts will be discussed in more detail later on in the chapter. First, an overview of learning styles will be presented as the aim of the current research is to combine the two fields in order to produce a system that is capable of catering to each person’s individual learning ‘needs’. The chapter will conclude with the research questions and hypotheses.

2.1 Learning Styles

The term “cognitive styles” was first used by American psychologists [31-33] to understand the individual differences in perception, analysis and categorisation. Awareness of learning styles theory has increased and developed over the years; some researchers have developed an umbrella term “meta-styles” [34] to address the multitude of existing cognitive/learning styles.

2.1.1 Definition of Learning Styles

Gregorc (1979) defines learning styles as “...distinctive behaviours, which serve as indicators of how a person learns from and adapts to his environment. It also gives clues as to how a person’s mind operates” [35]. Garger and Guild describe learning

Chapter 2 Literature Review

styles as "...stable and pervasive characteristics of an individual, expressed through the interaction of one's behaviour and personality as one approaches a learning task" [36]. Grasha (1996), has defined learning styles as "...personal qualities that influence a student's ability to acquire information, to interact with peers and the teachers, and otherwise to participate in learning experiences" [37]. James and Gardner (1995) define learning style as the "complex manner in which, and conditions under which, learners most efficiently and most effectively perceive, process, store, and recall what they are attempting to learn"[10].

Fatt mentioned the importance of learning styles and states that no education programme can afford to neglect the learning needs of students [38]. Educationalists introduced learning styles as "...the attitudes and behaviours that determine our preferred way of learning"[5]. Vincent and Ross (2001) note that most professional educators "agree that learning styles exist and acknowledge the significant effect that learning styles have on the learning process" [39]. Both teachers and students should know about learning styles. It is important for students to know the way in which they learn best [38, 40]. When learning styles are identified, teachers should know the appropriate way to teach [41], and must put in mind the variety of learners [42]. Learning styles have been shown to be of benefit to learners by increasing both their motivation and performance. Chiya (2003) found that when tutorials were presented in a mismatch with learning styles a student is less motivated for studying unless he/she has a strong external motivation [43].

The researcher believes one model of learning styles does not sufficiently cover all aspects of the learning process or learner preferences. In the case of this study, the model of Honey and Mumford learning styles looks at how to interact with the learning, while VARK is from a different angle; it concerns how the learner perceive the information, or the dominant way to understanding and learning, by seeing, by hearing and discussion, by reading and writing, or by doing. That tells us that the Honey and Mumford model is still incomplete to describe everything about learning styles, and it looks at the learner from only one perspective. Both VARK and Honey and Mumford need each other to build a better way to look after learner from more than one perspective.

To re-iterate, learning styles can be described as the way a learner absorbs, remembers or processes new information according to different approaches. Sensing, logical understandings, seeing, acting, reacting, hearing, reasoning, exploring and picturing progressively affect the learning process. Tutoring techniques also differ. Teachers use various methods such as addressing others to reveal or guide learners to self- discovery; some spotlight on ideology and others on practical application; some stress memory and reasoning of understanding. People learn in different ways [44]; they never learn the same way [5]. Researchers have agreed on this fact and the importance to explore it. The underlying idea of learning styles approach is that a person learns more effectively when information is presented in a manner that matches their preferred method of acquiring and processing information.

2.1.2 Why are Learning Styles used?

Using learning styles is considered advantageous for the learning process [39]. It increases student motivation to learn [45], and makes lessons more lively and interesting [46]. When learning is presented according to a learners' preferences, it has been shown to induce effective learning [47, 48]. Hawk and Shah (2007) believe that the use of different learning styles enhances the learning and performance and expands conformability and capability of learning [44, 49].

Knowing a learner's own learning style not only has an influence on how they learn, but can also affect how they absorb and develop the information stated within the process [47]. It is an important factor in the learning process, as it determines the way and the style that will be taught; one also needs to be aware of how the learner can maintain information. Learning styles are presented to fit the needs of individuals; they will teach the students in a way where-by they can gain the best out of applying the learning style. They can also be used to help people learn in an efficient way [15]. Due to the great differences in the learning levels and abilities of students, often of different nationalities, and from different frames of reference, teachers need to find a suitable way of teaching to meet the range of learner's needs [39].

As such, it was decided in the current research to take the approach of using learning styles to motivate and increase student learning gains by incorporating them into the computer system. Including learning style theory in educational systems is still a research topic under active investigation [44]. Due to the differences that people have,

designing systems to accommodate individual differences and learning styles becomes one of the challenges that has to be accounted for in educational systems [50-53].

Research into learning styles has identified a variety of individual preferences to understand information. It examines how learners retrieve and map any new information presented to them [4, 5, 54]. A team of researchers from Newcastle University identified 71 models of learning styles, among which 13 were considered as the most important models depending on their theoretical importance in the field, their influence on other learning style models and their widespread use both academically and commercially [13, 19]. A complete review of the large number of learning styles is beyond the scope of this thesis. However, the following sections will discuss a few of the more prominent models, in an attempt to provide an overview of learning styles models exemplifying different categories of classification. A brief summary of some of these models will be outlined followed by the reason behind the assignation of the two particular learning styles used in the current study.

2.1.3 Categories and characteristics

Learning styles have been categorised broadly by different researchers – each varying the way of describing and categorising learning styles. The literature is filled with different modes of categorisation – each with its unique explanation as to why certain learning styles fit into certain categories. For instance, James and Gardner (1995) [10] categorise learning styles according to perceptual, cognitive, and affective dimensions, compared to Griggs (1991) [55] and Swanson (1995) [56] who use another set of categories: personality models, information processing models, social interaction models and instructional preference models. Learning styles have also been categorised by physical and sensory preferences, e.g., visual, auditory, ReadWrite, and kinesthetic [4] and by brain hemisphericity, Asselin and Mooney (1996) [57] who differentiate between right brain (global) and left brain (analytic) learners.

Before categorising various models of learning styles, the two hemispheres worth to be mentioned here. How the brain receives and observes information plays an important role in appreciative learning styles. Here, right and left hemispheres play a role, one of which is dominant over the other [58]. Both hemispheres are reason-oriented but with different approaches; hypnotically one hemisphere is prevalent over the other. The various senses, in their role as information processors, are known as sensory modalities.

Chapter 2 Literature Review

These are seen as offering potential working methods into how the human mind internally organises and subjectively attaches meaning to events [59, 60].

A learner who tends to learn in a step-by-step manner is categorised as left-brain dominant, called a “successive processor”. These learners start with details and work up to a complete understanding. They are called analytic learners who are talented in gaining knowledge, searching, learning everything by heart, logical, ambitious, and focusing on the core competence of everything. Analytic learners understand very easily by absorbing certain facts [61].

Learners, who tend to learn by starting with a wide scope and then go into detail, are categorised as right-brain dominant “simultaneous processor”. They are called holistic or global learners, who take action towards emotion, remember faces, use body language when speaking, tend to listen to music while studying. Global learners receive a vast range of information without linking it and are able to understand everything. Holistic learners focus mainly on physical and mental behaviour; they tend to understand real actions as a mirror of the total understanding.

Applying sensory modalities: This includes auditory, visual, tactile, and kinaesthetic learning styles.

The *auditory learner* retains information via hearing or talking, tone of voice, pitch, and speed. They attain their lessons through discussion, lectures, and seminars. The most effective way for these learners to obtain information is to read out loud or to record.

The *visual learner* achieves information via visualisation, reading, seeing, or watching certain visual clips. Body and facial language have a great effect on their understanding; they gain better understanding through videos, diagrams, handouts, and tend to write notes while learning to enrich their understanding.

The *tactile or kinaesthetic learner* is active. They understand by touching and feeling things. However, this type is not well represented in the general population, i.e. not many students are of this type.

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Physical needs: These needs have an effect on obtaining information. Some learners tend to walk or search around while studying, while others prefer to stay still. Others may want to eat, drink, or do something. Also time of study varies and plays a very important and critical part as some consider their active time is at night, while others prefer daylight.

Individuals' environmental preferences: This has to do with the learning environment, sound, light, temperature, and work-area. Sound: some students tend to listen to music, while others prefer it to be quiet. Light: some prefer bright lights, while others prefer dim lights. Temperature: some love cold weather, others warm weather. Finally, work area: some like it formal, while others prefer informal.

Social groupings: this concerns preferences for working alone or with peers, or under or away from authority. In this situation, the ultimate goal is to be able to learn effectively whilst feeling comfortable at the same time. Therefore, many options are available to suit every learner's style.

Individual's attitude: Varying one's references, aspects, and how one can handle things, all support the learning process. However, there are learners who want to stay with their frame of reference and do not want to change their perception, or improve what they value. Those who will not take the chance to have a paradigm shift will find this negatively affects their learning style.

Brain-based research shows that the brain performs many functions simultaneously which are continuously interacting with social and cultural contexts. This functioning for each individual is as unique as a human's learning style. Furthermore, different models use a variety of these concepts to describe the learning styles within each model. As such several researchers have attempted to categorise the models according to overlapping characteristics. There exist several different methods of categorisation, as mentioned above in the introduction to this section. For the purpose of this thesis, the three dimensions of learning offered by James and Gardner (1995) [10] will be used to differentiate between learning styles: perceptual, cognitive and affective.

2.1.3.1 Perceptual

The perceptual dimension of learning relates to physical and sensory elements that correspond to the body's response to external stimuli. This includes a range of perceptual elements such as visual, auditory, tactile and kinaesthetic. Two models that could be categorised as perceptual include Dunn and Dunn's model and the VARK model.

2.1.3.1.1 Dunn and Dunn's model

Dunn and Dunn's learning styles model [62] became very popular internationally and is widely used in the United States of America. According to the Dunn and Dunn model (Figure 2-1), learning styles are divided into 5 major strands called stimuli: (1) Environmental, (2) Emotional, (3) Sociological, (4) Physiological, and (5) Psychological. These stimuli can provide valuable information regarding student's individual preferences, as was found from the feedback received of the students answering the Productivity Environmental Preference Survey (PEPS). These preferences were selected because of their wide ranging and natural interface with students.

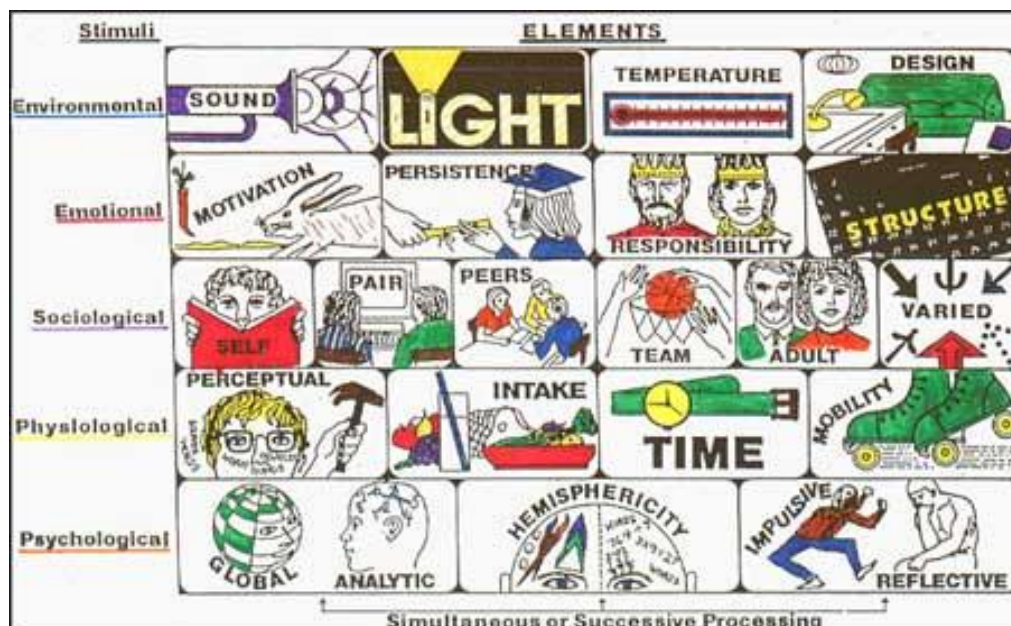


Figure 2-1: Dunn and Dunn's model [63]

Environmental preferences are related to natural phenomenon: light, sound, temperature and view of surroundings. Some learners like to study in a cool and quiet environment while others cannot stand it. Some tend to study while listening to music, while others cannot.

Emotional preferences deal with motivation, inspiration, persistence, perseverance and structure. Some learners have to start a new project before the previous one ends, while others like to do many tasks at the same time.

Sociological preferences handle individualised or group gathering as well as teaching links. This means some learners tend to learn alone or with peers. Others tend to learn in a routine manner.

Physiological preferences deal with perceptual, timing and mobility preferences and are based on beliefs. Some people tend to be in their high energetic status at night while others prefer daytime.

Psychological preferences, address the hemispheric and analytic modes. The hemispheric learner addresses the left and right brain, processing the impulsive versus reflective style; this describes how some people overreact without thinking, (irrational people) while others examine every single detail before moving ahead.

Dunn and Dunn based their theory on productivity style, in which each learner has his/her own maturity and mental preferences. They also stated that taking a step ahead in the learning system may arise from focusing on learner preferences and potentials. However, it is not only a target, e.g. what the student wants to learn, but also the subject, that the learner must consider when developing various plans and strategies to make him/her aware of different points of view and to improve their information and preferences. The authors of the Dunn and Dunn model believe that learning styles are fixed or at least are very difficult to change.

2.1.3.1.2 VARK

This theory expands upon earlier neuro-linguistic programming models that examine how the human mind processes information. It states that information is processed through the senses and as such focuses on *how* the learner receives information. VARK, developed by Fleming in the late seventies [4, 64], is yet another model that supplies learners with a sketch of their learning preferences. The preferences are simply a guide as to how the users interact with the learning process and gain information.

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VARK stands for *Visual or Aural or ReadWrite or Kinaesthetic*. The model states that preferences may change with age, travel, work, relationships and experience, but in most cases some basic preferences will stay unchanged. It also highlights the multimodal learner who has many changeable preferences.

Results obtained from the VARK questionnaire treat users differently according to their preference. Different cultures are not an obstacle in the VARK questionnaire as it accustoms a learner by various preferences and tests to improve and suit their preferences. Experiments show important gender differences, showing that men have more kinaesthetic reactions, and women more ReadWrite reactions. In addition, students who prefer role-play have kinaesthetic preference while those who tend to prefer discussion are most likely aural learners.

The VARK method shows how a person perceives information. Studies have shown that those who work in design have high visual and those in text have high ReadWrite, and so on in various careers. In addition, it was found that those who have aural preferences may face problems with those having no preference in this area. Some people noticed the difference in their lives after exploring their learning styles. It is not only video, photographs, television and computer-based learning styles which are good for visual learners but also the *way* in which the information is presented. Kinaesthetic learners tend to prefer real situations. Aural learners tend to prefer computer-based programs. Analysis shows age differences, with people under the age of 35 having stronger kinaesthetic preferences, whereas those over the age of 35 having stronger ReadWrite leading preferences. This applied to both teachers and students [65]. The authors claim that knowing one's type and style helps learners to use strategy and criteria to improve their level; that is what will make the difference in their learning process. Note that this opposes the claims that Dunn and Dunn [62] made that learning styles are fixed or at least are very difficult to change.

One of the major strengths of VARK is that it does not rely on semantic criteria, instead, it is based on real life experience. Therefore, the learners do not face difficulties in completing the questionnaire. When designing questionnaires for assessing the various learning style preferences of students using VARK, it is imperative to draw questions resembling real life situations. This adds practicality to the questionnaire.

Furthermore, the students cannot judge the questions which prevent potential unrealistic results [66].

To discuss the validity of VARK, it has been mentioned that one of the strengths of VARK is that it was built based on experiences from real life. Learners became confident of the validity of VARK. The questions are consistent among the four variables. In the event that a researcher needs to focus on a single variable, it is required that a number of questions are added [66]. The latest version of VARK was improved after critiques received from communication experts. VARK is now considered to be more culturally balanced [67].

Despite criticisms from some quarters [67], the VARK model has been tested in several cross cultural scenarios for its effectiveness and students have been found to exhibit preferences in accordance with their preferred learning style as identified through VARK. The inferences drawn from VARK should be used cautiously with a thorough understanding of its limitations as with the passage of time student learning styles undergo several changes [67]. Therefore VARK tests conducted over a long span of time may yield different findings for the same individual. Consequently VARK should be used only in studies that are limited to a short time frame to ensure validity of results.

All of the four learning preferences (V, A, R and K) have a very weak correlation amongst themselves and behave relatively independently. It was also found that there was no strong correlation between the variables VAR and K. It is also worth mentioning that VARK questionnaire results are given as individual scores, instead a descriptive measurement or a learner type is given. VARK was not designed for long periods of time as it can be affected by age and experience. For example, a learner can change profile if he reattempts the questionnaire after 12 months. Even though the VARK profile of a person changes over time, the core preferences are rarely found to change [67].

2.1.3.2 Cognitive

Another category that was identified by James and Gardner [10], is the cognitive style of learning, which describes the way in which learners receive, store, retrieve, transform and transmit information [68]. It also incorporates the idea of right versus left brain functioning, global versus analytical orientation and field dependence versus field

independence; i.e. right brained, global and/or field dependent learners tend to view things broadly whereas left brained, analytical and/or field independent learners tend to require detailed outlines.

2.1.3.2.1 *Kolb's Theory*

Kolb's model is the first model that will be discussed as it is the origin and the backbone of many other models. Kolb's model [12, 69], as shown in Figure 2-2, combines the two bipolar aspects of cognitive development well known by many psychologists: the "abstract-concrete dimension" and the "active-reflective dimension". The terms 'concrete' and 'abstract' refer to how the learner takes in information; while the terms 'active' and 'reflective' refer to how they internalise the information. The first factor is gained from direct contribution of non-influenced observation. The second factor is gained from handling substantial objects to dealing with hypothetical notions. Those polar limitations are used by Kolb to set a four-stage cycle of learning. It begins with the attainment of concrete experience (CE) that leads to reflective observation (RO) on that experience. On this basis, theory construction or abstract conceptualisation (AC) takes place. The concepts are then tested through active experimentation (AE). This cycle, through its experimentation, acquiesces new real experiences, knowledge and understanding [70].

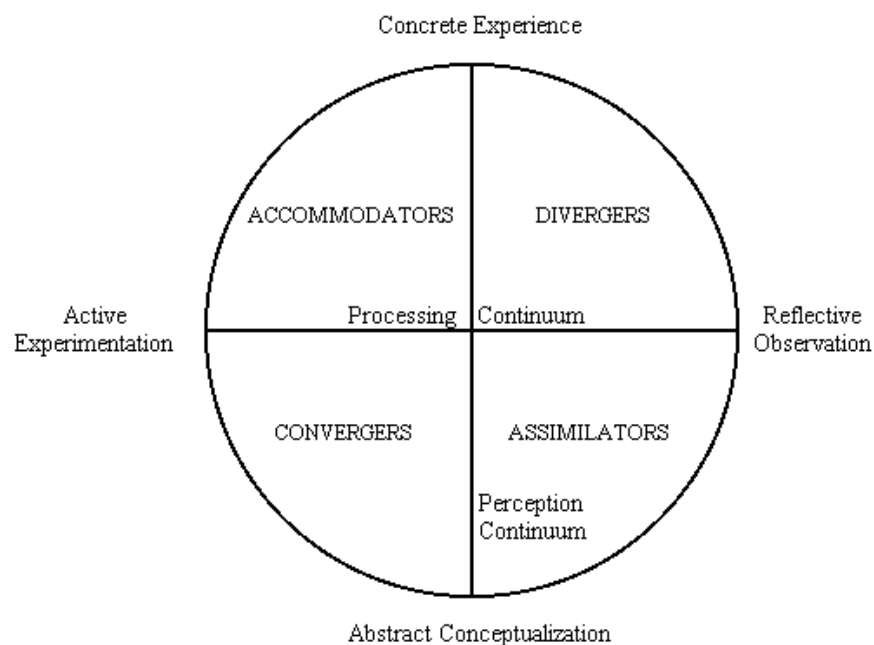


Figure 2-2: Kolb's model [12]

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Kolb categorised styles according to the following four categorisations based on the two cognitive dimensions as illustrated in Figure 2-2 above:

- Divergers reveal experiences based on different perceptions; i.e. CE and RO strength; they process information concretely and process it reflectively. They are referred to as imaginative learners because they integrate experiences with the self and need to be personally engaged in the learning process.
- Assimilators build up a hypothetical structure on the basis of their experiences; i.e. RO and AC; they perceive information abstractly and process it actively. They are pragmatists.
- Convergers apply the theory practically; AC and AE; they perceive information abstractly and process it reflectively. They are attentive to detail.
- Accommodators set those results for a new learning processes; CE and AE; they process information concretely and process it actively. They are risk-takers who relish change and flexibility.

The logic behind the cycle is that immediate concrete experiences provide the learner with a starting point for observations and reflections. As these are understood and assimilated, it can be applied to abstract concepts which can then be tested in new situations. The Kolb model states that learning is an endless loop – a continuous non-stop process. A learner may start at any place on the cycle, as each step leads to the other. For example: a learner could begin at phase 2 which is concerned with attaining some information and meditating on it before reaching any conclusions. These four stages of Kolb's model are interrelated together in a supportive way to help the learner "experience", "review", "conclude" and "plan".

The Kolb Learning Style Inventory is a tool to diagnose each learner's style, to find their strengths and weaknesses. To get to know one's learning style is a step toward empowering the learner, which in turn allows the learner to accomplish high targets through their learning life.

The problem with using this model for the current system is that none of these stages is totally accomplished by itself. Each phase has an equally essential role to support the

process and each phase requires time to apply. Also, timings differ from one stage to another. For the most part, people prefer certain stages to others. This preference leads to instability in the whole process.

Some of the critiques about Kolb's model:

- Curtis Kelly [71] found the results dubious. He stated "The wording in the questions seemed vague and the results did not jive with my own view of my preferred learning style"[71].
- Garner [72] argued that there is some theoretical weakness and contradictions in Kolb's model of learning styles; whether represent stable traits or flexible state.

For these reasons it was decided not to incorporate Kolb's model into the system.

2.1.3.2.2 *Honey and Mumford Approach*

Honey and Mumford's (1986) model [5] approached four main styles: "Theorist", "Activist", "Reflector" and "Pragmatist". Figure 2-3 shows the four styles of Honey and Mumford and how they relate to Kolb's learning cycle.

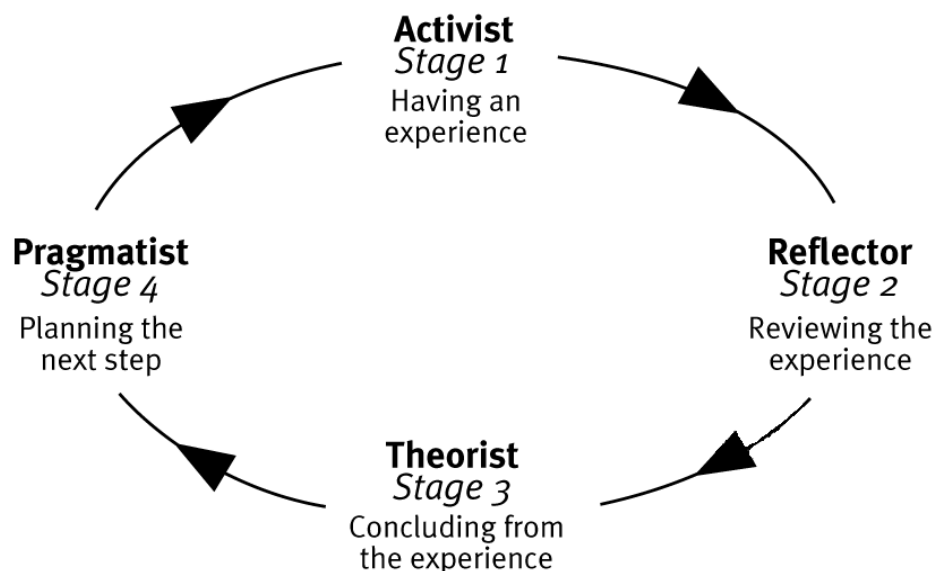


Figure 2-3: Honey and Mumford learning styles [5]

The Honey and Mumford model [73] is less complicated than that of Kolb as they refer to the four styles as being four separate learning styles unlike Kolb who defined them as parts of the learning cycle stages. The authors stated that "Trainers too often assume that learners are empty buckets waiting to be filled by the training method the trainer favours. The fact that the buckets are of different sizes, and/or leak and/or are upside down is conveniently overlooked". They believe that no single style has an overwhelming advantage over the other; each has strengths and weaknesses. From this they developed the four different styles which are described in more detail below.

Theorists

Theorists adapt and integrate comments into multifaceted but rationally sound theories. They sense problems in a rational way of thinking. Their attitude is that of a perfectionist, in which they do not gain peace of mind until a logical condition is reached. Examining, evaluating and creating are their goals... *"If it's logical it's good"*. Questions they frequently ask are: *"Does it make sense?" "How does this fit with that?" "What are basic assumptions?"* Logical thinking and approach are always their trend in solving problems.

Pragmatists

Pragmatists are eager to try and to apply ideas immediately. Once they understand a concept, they want to apply it. They are energetic in trying to put their knowledge into practice and to conduct the first experiment to get results. They are extroverts, searching for the new, applying any theoretical ideas, confident in themselves and in what they value. They are open-minded and solution-oriented people. Their philosophy is: *"There is always a better way"* and *"If it works it's good"*.

Activists

Activists learn best from activities in which they try new experiences and challenges. They prefer short tasks involving problem-solving. Activists learn least from, and may react against, activities where they have a passive role (lectures, instructions, reading) or when they are required to assimilate, analyse and interpret lots of 'messy' data. They do not tolerate repeating or repeated practising of the same skills.

Reflectors

Reflectors need patience or encouragement to participate in activities. They need time to think and review their learning before acting. They are careful when they produce analyses or reports. They can make decisions if they are not under pressure or have to meet deadlines. Reflectors learn least when they feel forced. They find making decisions difficult if they have not been given sufficient data.

In this model, different types of learners are taken into account allowing for individual differences in the learning process. It differs from that of Kolb in that each category is representative of a specific learning style rather than being along a continuum, making it easier to incorporate into a system within the scope of the work for this thesis.

Recently the Honey and Mumford test is being used by a large number of companies in the management field. It has become very popular. Scientifically, the stability of results obtained through LSQ were found to yield similar results on the same set of individuals with the same tests conducted twice at an interval of 2 weeks (0.89 level of correlation) [74]. It is beneficial to test 50 students twice; however, 2 weeks are not enough to give a full judgment about the validity. It was stated that the Honey and Mumford model had constructive validity but not predictive validity. The authors of the model responded to this stating that they did set out to build a psychometric test, rather it is to stimulate learners to think about the way they learn.

Despite being criticised, LSQ never claimed to be a psychometric tool, its utility lies in helping to define an individual's learning style. All users should therefore use their discretion while applying the results of LSQ in their studies and should treat it as a reference to design their own set of questions based on their specific case to case requirements.

2.1.3.2.3 4MAT

Another model which stems from the Kolb theory is 4MAT. McCarthy (1980) explored a new aspect in Kolb's ideas; she identified eight types of learners based on the concrete, abstract, reflective and active and how they correlate with the way in which people absorb information (divergers and assimilators) and how they make sense of

experience (convergers and accommodators) [61, 75]. She classified learners according to a quadrant drawing, whether they are on the left or right side of it. The quadrant is numbered from 1-4 according to different types of learners: 1R, 1L, 2R, 2L and so on. This cycle is based on the four learning styles listed below:

- **Type 1: Innovative/original learners:** these learners are interested mainly in personal senses; they relate everything to reason and they link the gained information with real experience that might add value to their life. Cooperative learning, brainstorming, and integration of content areas are the most applicable learning style to those users.
- **Type 2: Analytic/logical learners:** those learners are mainly attracted to facts. They enjoy lecturing, examining, searching, and persevere to get the best out of every material they accomplish.
- **Type 3: Common sense learners:** they are practical learners who apply trial and error concepts. They focus on experiments and activities.
- **Type 4: Dynamic/active learners:** they are mainly independent personalities. They tend to acquire information by themselves and have the capability to teach others willingly.

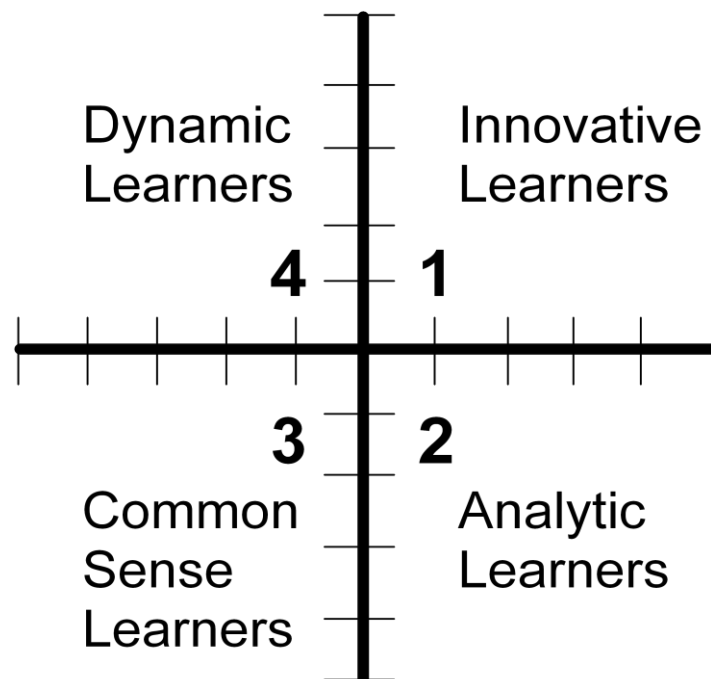


Figure 2-4: 4MAT quadrant [61]

2.1.3.3 Affective

The final category which James and Gardner identified is the affective dimension which relates to aspects of personality. The most well-known learning styles model that emphasises personality is the Myers-Briggs Type Indicator (MBTI) [76], which classifies learning styles according to personality types as specified by Carl Jung's theory of psychological types [77]. It deals with how people focus and deal with the outer world.

Myers-Briggs Type Indicator (MBTI)

There are four dimensions of this model which when combined can create sixteen different personality types. This model assesses the relative strength of each of the processes described below:

Extraversion (E) versus Introversion (I): this relates to where a person derives their energy from and how they relate to the world – the inner self or the outer environment.

Sensing (S) versus Intuition (N): this relates to what people rely on to perceive their world – their senses, i.e. one of the five senses or their so-called 'sixth sense', i.e. hunches or intuitions.

Thinking (T) versus Feeling (F): this relates to how people make decisions – based on logic and rules or more personal and humanistic considerations.

Judgers (J) versus Perceivers (P): this relates more to the nature of people and how they manage their life and deal with tasks.

One preference is chosen from each of the four pairs to establish a four-letter code which describes the person, e.g. an INFJ is someone who is a combination of Introvert, Intuitor, Feeler, and Judger.

Similarities between the MBTI and Kolb's model were noted. Firstly, they are both based on the work of Jung. Chapman [78] identifies the fact that the MBTI concept of thinking/feeling appears to be correlated with the concrete experience/abstract conceptualisation dimension in Kolb's model. Furthermore, the active/reflective aspect in Kolb's model correlates with the extraversion/ introversion aspect in the MBTI [79].

2.1.4 Multiple Intelligences

The theory of multiple intelligences was proposed by Howard Gardner in 1983 [14] in order to define the concept of intelligence more accurately (Figure 2-5). He stated that human beings are classified into eight personalities, which are independent of each other. Gardner explains, "Every normal individual possesses varying degrees of each of these intelligences, but the ways in which intelligences combine and blend are as varied as the faces and the personalities of individuals" (Howard Gardner, in a 1997 interview with Kathy Checkley) [80]. His book became a reference and an essential backbone for the most recent educational process that have been designed to enrich student achievements.

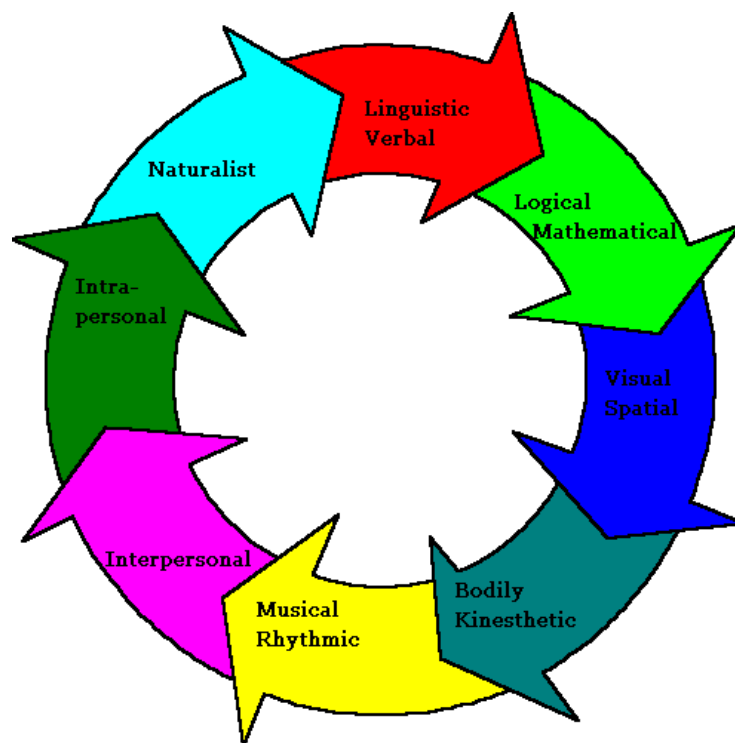


Figure 2-5: Multiple Intelligence Theory [14]

It is worth pointing out here that multiple intelligence theory has the same concept of learning styles. Multiple Intelligence theory reveals the learner's skills. According to this theory, a person who masters algebra easily is not necessarily more intelligent than a person who struggles to do so. The second individual may be stronger in another kind of intelligence, and as a result may best learn the given material through a different approach or may excel in a field outside of mathematics.

2.1.4.1 Classification of Multiple Intelligence (MI)

Gardner [14] identified 8 different categories into which people may fit:

1- Visual/spatial intelligence: This basically deals with the facility to identify the visual and with the rearranging of objects in three dimensions. Maintaining information is done by dealing with and thinking in pictures, graphics and creating mental layouts. Learners have high potential, as they get pleasure from looking at movies, maps, charts, and pictures, comparable to visual learners' style (VARK). They do extremely well at drawing, solving riddles and also have a good sense of talking, reading, writing, creating practical elements [81]. Their skills make them suited to occupations such as sculptor, inventor, architect, mechanic, or engineer.

2-Verbal/linguistic intelligence: These learners are good with words, language and understanding. They are auditory skilful people and good speakers. Words associated with them include: thinking-oriented, listeners, writers, and teachers. They are persuasive, humorous. Their future often lies in areas such as poetry, journalism, teaching, law.

3- Logical/mathematical intelligence: They are tactile and kinaesthetic learners, concerned with numbers, logic, and reasons. They are question-oriented, practical, solution-oriented, geniuses, mathematics operators, calculations professionals. Their future is likely to follow scientist, researcher, accountant, or computer programmer.

4- Bodily/kinaesthetic intelligence: These learners are sensitive to motion, meaning they can balance and have power over their body movements. They communicate through their motions. Their body language plays a great role in their life. Their future is most likely to be as an athlete, physical education teacher, dancer, actor, or fire-fighter.

5- Musical/rhythmic intelligence: These are musical-oriented individuals who evaluate the meaning and the senses of music and lyrics. Each stanza stands for something; they feel nature by music, have full awareness of it or the opposite, they think in patterns, stanzas, rhythms, and vocals. They sense music all over. Their future tends to be as a musician, disc jockey, singer, or composer.

6- Interpersonal intelligence: They have high communication skills, interpersonal attitude, are thoughtful, motivated, understanding, open minded, organised, have high paradigm-shift, have high verbal and non-verbal relations: by listening, caring, empathising, building trust and showing good will and being assertive. Their future is likely to be as a counsellor, salesperson, politician, or even a regular business person.

7- Intrapersonal intelligence, (not *interpersonal*): These individuals have high self esteem, as they know where they stand, and how their future should be; they are self-understanding, open-minded, logical, have their own vision, look forward to fulfilling it, and know their ups & downs. Their future is likely to be as researchers, theorists, and philosophers.

8- Naturalist intelligence: They are nature-lovers. Their mood varies with the existence of plants and animals in the surroundings. They like going out to natural scenes. Their future can be predicted as hunters, farmers, or biologists.

2.1.5 Concluding points from learning styles

After discussing and understanding some of the different learning styles, models, and theories of Multiple Intelligence, it becomes clear that each learner acts on their strength. People learn and understand in different ways; and each person has a unique way of interacting with learning situations. Linguistic and logical-mathematical ‘intelligences’ can no longer be given preferential treatment in the classroom situation as the concept of multiple intelligences reflects the existence and importance of other types of learners. Understanding and exploring learner types makes it easier for someone to choose their own learning style as well as gain a better understanding of themselves, which can lead to a highly beneficial learning experience. Furthermore, a student will have the confidence to change their learning process to get the best out of it, which normally leads to being able to accomplish the set target.

2.1.6 *Criticism of Learning Styles*

The concept of learning styles has created as much dispute as it has created attention. The truth is the phrase cognitive/learning style has no distinct meaning therefore, that is the source of the problem. There is no established concept and term in general; each and every individual who does research in the area tends to translate the concepts according to how they understand it. Even to the point where various words are applied to explain the same concept from one source to the other. Furthermore, surveys testing the level of stability of learning styles and their reliability as a legitimate component in teaching or studying demonstrate contradictory outcome. Instead of providing answers to available questions in the area, surveys frequently reveal more conflicting information leading dedicated researchers to completely discard the concept (Freedman and Stumpf 1980) [82]. Because of this uncertainty, the psychology of learning styles continues to be quite a faintly developed research area [26].

The fact that each model has a corresponding learning styles assessment makes it even more difficult for authors to agree on many issues. Each provides its own psychometric instrument to assess users' learning styles, which raises the following questions concerning the status of the learning style inventories [19]:

- Reliability: Do they measure the learning styles of the students consistently?
- Validity: Is it really a test of learning styles or of some other quality such as intelligence or personality?

A review by Coffield (2004) showed that despite being refined and revised for over thirty years, many models poorly satisfy the criteria [19]. The models vary markedly in quality – they are not all alike nor of equal worth.

Each model has its own purpose some of them were built to be used to enhance learning through the theory of learning styles, while other models, were intended for use in different conventional way.

Furthermore, the criticism has extended to some psychologists and neuroscientists who question the scientific basis for the learning styles models and theories on which they are based. Some educational psychologists believe that there is little evidence for the efficacy of most learning styles models, and that the models often rest on dubious

theoretical backgrounds [19]. Indeed Coffield and colleagues [13] quote the findings of two other researchers who found that for every nine studies that showed that learning was more effective when there was a match with learning styles, there are nine studies that show that learning is effective when in fact there is a mismatch. This leaves the concept of learning styles open to much criticism and confusion. Hence, the necessity of the current study to address the learning gains and satisfaction ratings of users when using two, one or no learning styles.

2.1.7 Learning styles and teaching styles

Learning styles are different from teaching styles. Various definitions of learning styles are in 2.1.1 above, one of the definitions was "...the attitudes and behaviours that determine our preferred way of learning"[5]. Similarly, various definitions of teaching styles are also available. Fischer and Fischer (1979) defined teaching style as "a pervasive way of approaching the learners that might be consistent with several methods of teaching" [83]. It is defined by Hoyt and Lee as "the way various teaching approaches are combined" [84]. Conti (1989) defined it as "the overall traits and qualities that a teacher displays in the classroom and that are consistent for various situations can be described as teaching style" [85]. Gregorc 1979 stated that teaching styles consist of an teacher's behaviour and the method used to teach the learner [35]. So, learning styles refer to the learners' preference, and teaching styles refer to the teaching methods used. Research has shown that there is a relationship between them. Studies [86, 87] have shown that when teaching styles match learning styles, students learn better.

2.1.8 Effects of Learning styles

Support for matching teaching styles to learning styles has come from both computer-based and multimedia-based instruction studies as well as classroom learning. Improvement in learning gains through the use of preferred learning styles has been measured by researchers in different ways, encompassing both improved test results and improved attitude towards study or the teaching style [88-90]. Studies carried out by Brudenell & Carpenter illustrate both of these findings: students taught according to a method that matched their learning styles performed statistically better than students taught by strategies that did not match their learning style [16, 88]. Moreover, students

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who were taught according to their learning styles also achieved significantly higher attitude scores [11, 16, 88, 89, 91, 92].

Additional studies have addressed the affect of preferred learning styles on student motivation and memory storage [89, 93]. Miller (2001) [89] has stressed the need for educators to teach according to students' learning styles after finding that use of preferred learning styles enhances students' motivation in addition to their performance. A more recent study involving 50 primary school children from a social sciences class was carried out by Özge & Bülent (2009) [93]. It investigated the application of teaching activities that took account of the students' visual/auditory and kinaesthetic learning styles in terms of their effect on students' academic proficiency level, attitudes to the course, and level of memory storage. Results found that the experimental group was significantly more successful than the control group in two out of the three aspects: academic proficiency level and the level of memory storage. However, student attitudes to the course did not differ significantly between the two groups.

The Özge & Bülent [93] study touches upon two more important issues in the literature that supports matching learning styles: researchers have not obtained conclusive results as to whether matching learning styles consistently improves motivation or student attitude to study, and students who prefer two particular learning styles, visual/auditory and kinaesthetic, appear to benefit more consistently from the application of their preferred learning style. In opposition to the results obtained by Özge & Bülent (2009) [93] and lending additional support to Brudenell & Carpenter (1990), Larkin-Hein (2000) [45] contends that the adoption of a learning style approach in the classroom improves student interest and motivation to learn. Additionally, Larkin-Hein stresses this is primarily because a learning style approach allows for alternative teaching strategies designed to accommodate a diverse population of learners (2000). This may be relevant in the fact that visual/auditory and kinaesthetic learning styles are not commonly incorporated into the traditional classroom. Tobias (1991) [94] goes even further to say that a failure to address certain common learning styles could ultimately results in students avoiding certain subjects that present lessons in a mismatched manner. Tobias' results support three of the four identified areas of improvement, but did not address motivation: students whose learning styles were compatible with the method of instruction retained information longer, could apply it more effectively, and

ultimately had a more positive disposition to the course than those students who were mismatched.

Other studies dispute whether matching learning styles to preferences is equally effective for all types of learners. Hodges & Evans (1983) [95] found visual/spatial learners achieved significantly better results when using their preferred learning style, whereas no significant difference was observed in the achievement of verbal/analytic learners when their preferred learning styles was used. There is evidence that tactile learners may be especially receptive to instruction that incorporates their preferred learning style. Research conducted by Roberts et al. (1999) [96] on the effectiveness of matching tactile-kinaesthetic learning styles on 72 fourth-grade students showed that learners with preferences for this learning style performed significantly better in post tests than non-tactile learners, and they also displayed a more positive attitude toward the tactually enhanced learning material. Martini (1985) [97] investigated the effect of matching and mismatching of learning styles on 114 students from the seventh grade, and while he found all students irrespective of their learning style to show significant improvements in their performance when matched with a complementary teaching strategy, students with tactile learning style preferences were most responsive to a matched learning environment.

A final distinction in the type of research being carried out on learning styles concerns the age of participants. Of the studies referenced above, the majority study the effects of matching learning styles in students of college age or older [16, 45, 88-90, 94, 95]. Only three refer to middle-school [97] and elementary school aged children [93, 98]. Literature within the last decade on learning styles applied in conjunction with online learning shows a similar trend: in Funda & Aynur's (2009) [99] meta-analysis, 40 of the 44 studies stating the age of participants assess the effects of matching learning styles in undergraduates, graduates and postgraduates, only 4 study learning styles in high school students, and none of the studies address learning styles in students below the high school level. While all of these researchers support matching of learning styles for the age groups they studied, it is striking that the research indicating a stronger result for students preferring a tactile-kinaesthetic learning style [97, 98] (Martini, 1985; Roberts et al., 2000) address adolescents or children. To date, the available literature does not fully clarify if or to what degree age may affects the effectiveness of matching various

learning styles to teaching styles, and the affect of matching learning styles to teaching styles in younger children appears to be under-researched.

Given the positive results obtained in the studies referred to above, as well as additional research by Kramer-Koehler et al. (1995) [91] concluding that the use of preferred learning styles benefits students [91] and by McLoughlin (1999) [11, 91] supporting that matching learning styles constitutes the means by which students learn best [11], many researchers uphold that teachers should endeavour to adapt their teaching strategies to accommodate the various learning styles of their students (Sarasin, 1998) [92]. However, the importance for teachers to understand the different learning styles of students can not be underestimated. A study by Griggs 1991 [55] emphasizes that the success of matching learning styles of individuals with the learning environment in a school requires the cooperation of teachers and school counsellors to diagnose and accommodate student learning preferences in classrooms. Both school teachers and counsellors should understand and be able to identify the different learning styles of students so that the most effective teaching style can be utilised.

This premise does not necessitate abandoning all traditional teaching styles. On the one hand, Montgomery (1995) [100] has demonstrated that learning styles typically neglected by traditional teaching styles, which typically do not incorporate such resources as movies, interactions, and demonstrations, are effectively addressed using computer and multimedia software and that the effectiveness of the software could be enhanced further by addressing the pedagogic needs of the various learning styles. It may appear obvious that one single teacher would find it more difficult to accommodate the learning styles of the entire class, whereas individual teaching on-line could address the disparate needs of learners due to the recent development of adaptive hypermedia systems. Martini (1985) [97] has stated that computer-assisted instruction was found to be very effective for all students irrespective of their learning styles. However, on the other hand, there is evidence that this may not always be the case and that not all learners benefit from computer-based learning. In their study of 60 accounting students, Butler & Mautz (1996) [101] found a statistically significant improvement in recall for visual learners when given media-enriched support materials. In contrast, the performance of verbal learners decreased when presented with the same materials. Likewise, in a study by [102] utilizing Kolb's learning styles, "divergers" (students who prefer to learn through reflective observation) performed best when imparted lessons

through the traditional classroom environment, at the same time as “accommodators” (students who prefer to learn through active experimentation) performed better with a computer-based interface.

A comprehensive review of articles published in the last decade investigating the application of learning styles in an online learning environment conducted by Funda & Aynur (2009) [99] would suggest the results of Butler & Mautz (1996) [101] and [102] may not be the norm. Analyzing a total of 54 articles, Funda & Aynur found that the research could be divided into two broad approaches: some researchers investigate the presentation of learning content and learning tools based on learning styles in an online environment and how this impacts upon academic achievements of the learner; whilst others use learning styles as a supportive factor to design the online environment for personalised online learning. Nonetheless, results consistently indicated that the use of learning styles with computer-aided study improved academic achievements.

Additionally, preferred learning style can be dependent on environment, or vary according to group composition in collaborative work. In a study conducted on 40 distance education students and 63 campus students, learning styles of students have been found to be dependent on the learning environment. Students within a campus environment have been found to have a more collaborative approach when deciding their preferences for a learning style (Diaz & Cartnal, 1999) [103]. Monaghan & Stenning (1998) [104] investigated using learning styles with problem solving method on 17 undergraduate students, and found a significant difference between the groups in interactions between learning styles and problem solving method in terms of modality and strategy, due to the complex nature of problem solving, which may entail different skills and problem solving strategies at different moments of the problem. These studies suggest that a preferred learning style may not always be static, but rather different learning styles may be required by the same student under different circumstances or to solve different tasks.

To address these complexities and the needs of multiple students with different styles within a single setting, a compromise may be necessitated. Riding & Douglas (1993) [105] observed that visual learners fared almost doubly better when subjected to a

combination of text and pictures than when they were taught with only text content, yet no such improvements were observed for verbal learners. These results suggest that the addition of a different learning style does not result in additional benefits when it is not the preferred learning style of the student. However, research by Simon (2000) [106] has found that while reflective observation learners performed best in a traditional teaching setting and active experimentation learners achieved best in a media-assisted environment, both sets of learners had increased success and satisfaction in a behavioural modelling method, which combines elements of both environments. Therefore, it seems that a media-assisted learning environment that does not neglect traditional teaching methods may be the best variant for teaching a group of disparate learners, even if not all individuals experience a benefit from all aspects of the environment.

Contrary to the matching concept, research has also found that a mismatch of teaching strategy to learning style can stimulate students learning abilities in what they term 'constructive friction' [107]. For instance, Kelly and Tagney (2004, 2005) [108, 109] found that students with a low activity preference exhibited a significantly higher relative learning gain when subjected to a mismatched learning environment. McKay (2000) [110] and Dekeyser (2001) [107] have found that mismatching is more beneficial than matching as mismatching causes 'constructive friction' which stimulates the creative learning processes in students. Thus, while a large number of studies support the effectiveness of matching learning styles in delivering an effective learning environment to students, many studies have also reported indifference to matching or the effectiveness of mismatching. Therefore it is clear that the current literature provides various stances and no clear conclusion on the effectiveness of matching or mismatching learning styles.

In an apparent compliment to the work of Monaghan & Stenning (1998) [104], some experiments show that for more able users, mismatching learning materials to learning styles may be advantageous as it encourages users to develop learning strategies that could cope with a wider range of materials and experiences in the future [26]. As a possible explanation, Vermunt (1992, as cited in Dekeyser, 2000) [107] proposed that the incongruence between learning style and instructional strategy, resulting in "constructive friction", can stimulate students' learning and thinking capabilities. Proponents of matching counter that matching of learning style and strategies leads to

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“cognitive comfort” (p. 77) for students (Roberts, 1999) [96]. A second meta-analysis conducted earlier by Hayes & Allinson (1993) [18] found that 10 out of 17 articles reviewed provided some support that instructional strategies would be differently effective for students with differing learning styles, yet four reported no support of inconclusive results, further demonstrating the discrepancies in the research.

Finally, there are some studies that reject the matching hypothesis outright. In a study investigating two different learning environments (text vs. media interaction-rich) conducted by Harris et al. (2003) [111], it was reported that there was no significant difference when students with a preference for one particular learning style were subjected to a different learning environment. This is supported by research conducted by Kavale and Forness (1987) [112]. Additionally, Harris, Dwyer, and Lemming (2003) [111] found no significant differences when they attempted to match two versions of an e-learning environment (text-only and media/interaction-rich) with active and reflective learners according to Kolb’s learning style model, again highlighting the ambiguity surrounding the research into learning style and student achievement

Therefore, whatever relationships there may be between learning styles and teaching styles or between individual learning styles, they are certainly complex. This has been stated by other researchers, such as Ford & Chen (2001) [90], who have also drawn attention to the possibility that other factors such as instructional method and gender may affect the interaction of learning styles. However, regardless of the obvious complications in its application, the theory of learning styles has nonetheless constantly drawn interest among researchers in the area of adaptive hypermedia. Per se, it has provided fascinating concepts for the existing research as the approaches that will be applied in the survey, learning styles combined with adaptive systems could certainly be applied by psychologists in the future to expand their theories regarding the use of learning styles in education.

It is the researcher’s view that learning styles can be considered as an inventory which provides many options to fit each learner’s style. Different models focus on various aspects of learner preferences, as can be seen from the range of different categories discussed in each section above. The more ways to show and present information through various styles, the more learning can be achieved. It becomes clear from this literature review that using a single learning style is not sufficient. As such, the

proposed system has taken this into consideration and aims to go further and bridge the gap in the literature by combining two learning style models to approach learning in a more appropriate manner. The following section discusses the models chosen.

2.1.9 The models used in the proposed system

It is possible to measure the various learning styles using any of the various instruments described above or indeed from a variety of other models not discussed in this thesis [54]. VARK was employed in our system due to its flexibility and the fact that it encompasses the perceptual dimension of learning. It was chosen as a learning style to be combined with Honey and Mumford. The Honey and Mumford approach was used mainly because it is based on a well-known theory (Kolb) and is used widely in the UK. It was also chosen because it is practical and, more importantly to the study, can be applied generically. The Coffield review of 71 models of learning styles developed over the past 50 years [13] shows that each model emphasises different aspects of learning from concrete and abstract perceivers to active and reflective processors. It is clear that in order to use two different models of learning styles for the system, there must not be any similarities between them or between the sub-styles within them; they must work together without overlapping.

The VARK method, described in section 2.1.3.1.2 above, was chosen as this model addresses a way for *perceiving* or taking in information. It contains the four sub-styles: visual, aural, write/read and kinaesthetic. In order to complement this method, the Honey and Mumford method, described in section 2.1.3.2.2 above, was chosen as this also contains four sub-styles which could complement the four from the VARK method; furthermore this model addresses the *processing* of information. By using these two models it would be possible to combine the style, for example, the activist, from the Honey and Mumford, could be combined with any of the styles from VARK, i.e. “activist/visual” or “activist/aural” etc. In this sense both classifications of learning style were integrated in the proposed system, combining the advantages of both. Furthermore, the Honey and Mumford approach encompasses the cognitive and affective dimension, (it describes the way in which learners receive, store, retrieve, transform and transmit information as well as relating to aspects of personality); while the VARK model encompasses the perceptual dimension. By combining these complementary styles, it is anticipated that learners will benefit from increased motivation and learning gains as found with previous studies using learning styles [43-45, 47-49].

The chosen learning styles were used by the researcher for integration in the current system developed for this research project.

The following sections discuss the concept of the Adaptive Hypermedia Systems (AHS), also referred to as Intelligent Tutoring Systems (ITS), followed by the merging of the two concepts: AHS and learning styles.

2.2 Intelligent Tutoring Systems

Intelligent Tutoring Systems (ITS) is an outgrowth of the earlier computer-aided instruction (CAI) models [113]. Computer-aided instruction systems (CAI) have been used in education and they succeeded in providing support and controlling different levels of difficulty, but they did not provide student-driven learning and knowledge acquisition [114]. Traditional computerised applications often provide the learner with facts followed by test questions. This method helps the learner to memorise and recall large amounts of information. By contrast, ITS are highly interactive. These systems help learners retain and apply knowledge and skills more effectively in operational settings. Intelligent tutoring systems have been shown to be highly effective at increasing student performance and motivation [28]. ITS techniques need more computational power to develop compared with the traditional computer-based instruction [115].

Gamboa defined intelligent tutoring systems as computer programs that support learning and can be used in a normal educational process or in distance education [116]. Ramachandran defined it as tutoring software that can tailor instruction to an individual student's requirements, and can provide intelligent instructional support similar to that of human instructors [117]. He also described it as a computer-based tutor that makes dynamic assessments of a student's unique skill levels and provides instruction that is adapted to individual skill levels [117]. Stottler said that it can best be defined as advanced training software that mimics a human tutor by adapting its instructional approach to each individual student [118]. - defined it as a computerised educational system that models some characteristics of the human learning, adapting its behaviour according to the mental state of users [119]. Sheng Hsieh defines intelligent tutoring systems as computer-based instructional systems that

utilise artificial intelligence techniques to represent the knowledge needed to teach about a subject [115].

It is also believed that intelligent tutoring systems can be used to enhance the teaching process. Students with ITS will be encouraged to be more responsible for their learning. ITS aids the assessment of learning more effectively and efficiently than by traditional means [120]. Research indicates that, when using intelligent tutoring systems, the role of the human tutor is changed [121]. The use of intelligent tutoring systems will enhance learning and make learning much effective [116, 122, 123]. The extent to which learning is effective, however, can be dependent on how well the system is designed.

Various studies have shown that one-to-one tutoring by skilled human tutors is considered the best mode and offers significant advantages over regular classroom work [118, 124]. As a result of these studies, ITS tend to produce one-to-one instructions automatically and cost effectively. ITS diagnose each learner and provide him or her with tailored instructions [117]. Monitoring and assessment of student's learning in ITS are continuous. The process is imitating the real human tutor's way of dealing with students, deciding his or her flow, and directing the learner to the best instructions that come after their current one [115]. ITSs enhance the whole learning experience [123, 125, 126]. Many existing intelligent tutoring systems have been designed for the needs of particular research purposes and were difficult to generalise to other domains. Moreover, they were developed for specific instructional purposes, and only those people who developed them can modify the system [115].

Intelligent tutoring systems help to improve knowledge acquisition and comprehension by diagnosing the difficulties in student's learning and immediately providing him or her with reports about their weakness [123]. A characteristic of many existing ITS is that they capture the student's current understanding and, based on that, they use a tailored model to adapt the instruction to the needs of the learner [114].

Yong [123] mentioned various properties of good teaching systems:

- the material should be stimulating and interesting;

- the system should present appropriate information for the learner's level of understanding;
- the system should make sure that the student understands clearly what has been taught;
- the system should also focus on the key concepts and deal with the misunderstood points;
- it should provide immediate feedback

To summarise, ITS follow the same line of reasoning as that of the student by implementing the one-to-one learning approach. ITS have succeeded despite the fact that human tutoring can look very different. The goal of such systems is to improve the usability of hypermedia applications by making them personalised. ITS are “intelligent” in the sense that they have the ability to “understand” the user and to adapt their behaviour to the user’s needs. ITS are able to diagnose the weakness of the student and improve his or her performance through placing emphasis on their strengths so that they can learn faster. Furthermore, ITS are able to deliver adapted and personalised content to suit different users understanding. Our research has made use of many of the concepts and results achieved by ITS and tried to make enhancements to the learning process experienced by the user. The proposed system has implemented the four components of ITS as described below.

2.2.1 Components of the ITS

An intelligent tutoring system has four major components: the student model, the tutoring model, the domain knowledge model, and the user interface model [28, 113, 127]. - also mentioned that ITS are composed of four similar models but uses other names: application domain, model of the student, tutor and user interface [119].

The model of the application domain is essentially the same as the **domain knowledge model**; it deals with the topic or course in which the user’s qualification is required. The **student model** determines, at any moment, the knowledge degree of the student for the subject he is learning. The **tutor model** determines who and what is taught or evaluated, as well as when and how. Finally, the **user interface model** is the interaction between

the student and the ITS, and is designed to be attractive and capable of keeping the user's attention [119].

2.2.1.1 Domain Knowledge Model

This model contains the topic information. It contains the material of the knowledge of the specific domain that is taught by the tutor [119]. This component contains the materials used to teach [28]. This knowledge is the backbone of the ITS. The knowledge here has to support reasoning and semantic networks similar to the process of a human tutor solving problems.

The domain knowledge model is sometimes referred to as the expert model because the knowledge conveyed to the student is derived from people who have gained years of experience in the field.

2.2.1.2 Student Model

The aim of ITS is to provide individualised instruction. To accomplish this, the system must create, develop, and maintain a model of the student [117]. The student model captures a student's understanding of the domain knowledge, records the progress and performance on the material being taught. It is used to predict the current state of knowledge of the student [28, 73].

The process of creating a student model is dynamic and usually occurs at 'runtime' (i.e. at the time when the student uses the system). The system creates the student model by logging his moves inside the system. The system registers both student progress and preferred learning styles. This process helps the system to adapt to the individual student [128]. This means that the student model is one of the most important components of an intelligent tutoring system. The system creates a student model for each individual student and maintains it as soon as the student logs into the system. ITS store different amounts of information about students; from that information the system may measure the mastery or the level of the required knowledge [118]. The aim is to get information about the user's knowledge with respect to the topic the user wants to learn [119].

The information stored in the student model varies according to the purpose of the ITS [129, 130]. Some models are built for capturing student plans; some are built for assessment purposes. The model should be built according to the aim of the ITS [131]: the domain of the knowledge, the type of the domain (for example - is the focus on reasoning or on pure facts?), the structure of the tutorial session, the interactivity with the user, the content presentation, the tutorial decisions, the feedback, and the evaluation. A student model is also built according to the planned adaptation of the system [114]. So, fundamentally, different ITS use different student models, depending on the aim of the ITS.

2.2.1.3 *Tutoring Model*

The tutoring model refers to the teaching strategy or pedagogical model. This model controls how material is presented, how the student interacts with the system, and decides which pedagogic activity will be presented [132]. Pedagogic activities can be explanations, advice, practice tasks, tests or any other activities that can be taken from the real tutoring activities. As mentioned in the student model, the tutoring model uses information about the student to control the system presentation. It should reflect the differing needs of each student [28].

The rules and the structure of didactic-pedagogical knowledge are stored in this model. The knowledge here is different from that described in the domain knowledge model. The knowledge in this model allows decisions to be made that are related to the tutor model [119].

2.2.1.4 *User Interface Model*

This model is in charge of making the internal representation understandable to the student. The screen layout is controlled by this component [28]. The user interface model, also known as the communication component, is in charge of the information flow between the user and the system [119]. It controls interaction between the ITS and the student. The user model is also responsible for text and information (e.g. sound, images) [128]. Usability and ease of use are crucial parts of this model because they are important to the student use of the application [73].

These four major components; the domain knowledge model, the student model, the tutoring model and the user interface model were implemented in the ITS system developed for this research work. It was very useful to organise the proposed system into these four components.

2.2.2 Some Existing ITSs

There are many intelligent tutoring systems that exist. Three real systems will be described to understand the concept of these examples.

2.2.2.1 Tactical Action Officer (TAO ITS)

The Tactical Action Officer is an intelligent tutoring system which has the advantage that it can be utilised both for individual students and for a class of students. The software's main aim is to extend active training of learners and to improve their knowledge of concepts and tactics.

There are three main difficulties usually related to intelligent tutoring systems: how to integrate subject expert knowledge in the system, how much the system would cost, and how long it would take to develop the system. In order to deal with these difficulties, case-based reasoning technique [133] was used in the Tactical Action Officer. This refers to the process of solving new problems based on the solutions of similar or past problems [133]. The software comprises of three components: scenario generator, intelligent tutoring and the instructor interface tool. The scenario generator allows the teacher, with minimal aid from a programmer, to develop various simulated scenarios. Scenarios are chosen by the software for the students to practice. The adaptivity of the system allows it to choose scenarios that the learner has not yet done or has performed poorly on in the past. It also allows the student to select any scenario. What is important about this software is that in addition to the intrinsic feedback that it gives, it also provides the learner with a detailed extrinsic feedback on his/her performance on the different parts of the scenario [118].

2.2.2.2 Intelligent Tutoring System for teaching 1st year engineering students

The intelligent tutoring system for teaching 1st year engineering students [134] is a software system that adapts teaching to each learner's individual learning speed.

Basically, the system observes the advancement of the learner and is able to select the next step in the teaching process.

This system was developed on the basis of fuzzy logic and fuzzy rule-based reasoning, presented by Lotfi Zadeh [135]. The composition of the system is a database with questions, a database with the learners in the course and their advancement, and an expert system with fuzzy-rule based decision-making that leads the behaviour of the intelligent tutoring system. Each question has three parameters assigned: concepts encompassed in the questions, difficulty level, and level of importance. The expert system extracts details about each student on the basis of their achievements and performance, as well as the concepts in each topic, the difficulty and the level of importance. After obtaining those new details, the system automatically selects the questions to be covered based on the achievement level of the learner. Since some topics are of higher importance than others, the system first selects questions from the most significant topics and after that, if the performance level of the student is satisfactory, proceeds to questions of topics with lower importance respectively. The learner's database keeps track of each learner's achievements. This database is updated automatically by the system and keeps record of how deep and how broad the student's knowledge acquisition is. Feedback is available for learners at all times during the learning session.

The reasons for the selection of fuzzy logic lie behind its similarity in decision-making to that of humans. It does not rely on complicated calculations. Instead, it bases its judgment on basic rules that a human instructor would base his/her judgment on. Another reason is that it is not difficult to use, and it can be adapted to everybody's needs and requirements. The assessment of the learner's advancement is also done in a flexible way, exactly as a human instructor would do, and not with the aid of complex formulas.

2.2.2.3 ELM-ART

The ELM Adaptive Remote Tutor [136] (abbreviated as ELM-ART) is a web-based intelligent text-book. It has two main characteristics. The first one is that it is familiar with the instruction material taught to the learners and offers help and support throughout the learning process. The second one is that none of the examples and problems in the system are merely text. They resemble more a 'live experience'. ELM-

ART helps students navigate through the lesson by utilising two hypermedia techniques: adaptive annotation and adaptive sorting of links. Adaptive annotation means that the software utilises visual cues to show the learning stage of each link. Adaptive sorting is utilised to show similar links between cases. After that links are shown in sorted order starting from the most relevant to the case ones. If the learner attempts to enter a page with material that was not yet covered, the system advises him/her that this material was not learned yet and guides him to the links in the textbook where the material can be found. The system also shows links with the pages in the textbook, if a student has trouble with the presented material or cannot understand a question, he/she can ask for assistance in such a case. The ELM Adaptive Remote Tutor can foresee the way in which students will solve a given problem and retrieve the most adequate example from the student's studying history. If a learner is incapable of finding the solutions to the problem and is unable to find the mistake reported by the system, he/she can ask for assistance and the system will provide him/her with a chain of help messages, which get progressively more and more in depth [136, 137].

It is clear that these systems offer students a chance to learn material in a way that best suits them. This approach is referred to as adaptivity and will be discussed in more detail below.

2.2.3 Adaptive Systems that uses learning styles

This section shows a brief overview of some of the systems that have been developed and summarise some studies which have attempted to incorporate learning styles into AEH systems. Each system caters for only one model of learning styles.

2.2.3.1 CS383

The CS383 [21] appears to be the first AEH system that incorporated learning styles. The learning style model used was the Felder & Silverman model [138] and the respective "index of learning styles questionnaire" [138]. Users learning style profile was assessed in an initial survey, then each resource type including movies, sound files and graphics was rated as to how suitable it was for a particular learning style out of 100%. An overlay model was then used to compare the user's learning style profile with the ratings of the resource types and from there the best matching resource was suggested.

The major drawback with this system was that it could only be adapted once – after the survey – users could not change their learner model thereafter. Users were essentially stereotyped at the beginning leaving no room for ongoing adaptation. In addition, the media resources were presented and then they were classified as to how suitable they were for specific learning styles. This meant that the users could not influence their learner model in the environment. With regard to an evaluation of this system, no formal evaluation was reported. The researchers collected casual learner feedback and described it as uniformly positive.

2.2.3.2 *CAMELEON*

CAMELEON [22] is an acronym for Computer Aided MEdium for LEarning On Network. This is a similar AEH system to the one described above in that it also used the Felder & Silverman learning style model [81] and the learning style profile was assessed by an initial survey. The available media types were also rated on a scale of 1 to 100 as to how suitable they were for particular learning styles. The difference from the previous model described was that, after assembling a set of sequence materials for individual learners based on their learning style, learners could choose to ignore their learning style and freely explore the environment. This allowed some flexibility in the learning process. The authors later conducted a short informal evaluation of the system [139] where users (10 students: 8 boys and 2 girls) were asked a set of five yes/no questions. The results showed that users enjoyed and appreciated the environment. The evaluation has been criticised however, as the questions appear to have been leading the users.

2.2.3.3 *Arthur*

This system is again similar to CS383 in that it was also a web-based environment. The difference with Arthur [23, 140, 141] was that the materials were specifically designed for learning styles. A metaphor of different virtual instructors was used to present the instructional materials in a different perceptual style. Four different presentation styles were used based on a perceptual model proposed by Sarasin (1998) [92] with auditory, visual and tactile elements; no psychometrical instrument was used. The styles were: visual-interactive (interactive Java applets), auditory-text (streaming audio), auditory-lecture (streaming audio and video) and a text-only presentation. This introduced an element of adaptation to the system.

A teaching style was allocated to the user at random. Performance in multiple choice exercises was measured after a lesson to determine whether the allocated style was a match or not. Case-based reasoning (collaborative matching) was used if less than 80% of the answers were correct, to compare the user with other users who had made similar mistakes. If a matching learner was found, the teaching style recommendations of the two learners were aligned. During phase one of the evaluation, Arthur was adaptable. If learners achieved less than 80% in a multiple choice test, they could freely choose their new learning style. In phase two, Arthur was adaptive: the system made the choice for the learners by using case-based reasoning, as described above. This method of allocating a style first then “correcting” is problematic, because its accuracy is questionable and it might frustrate users if they are initially mismatched. Another limitation was that although two evaluations were reported in relation to this system, neither of them used a control group, which means the results offered no insights about differences between adaptive, adaptable or static learning environments.

2.2.3.4 *SILPA*

SILPA [24, 142] is an acronym for “System for Intentional Learning and Performance Assessment”. It presents a unique approach to adapting hypermedia, because it includes cognitive factors such as emotions and intentions. The model used was Martinez’s own learning style model, the “learning orientation construct” (LOC), which included four orientations: transforming, performing, conforming, and resistant. These were assessed at the start of the course by a corresponding “learning orientation questionnaire”. 71 participants were tested for their learning orientations and then randomly allocated to one of the three versions of SILPA. Throughout the lesson, transforming and performing learners could self-elect to visit all other versions of the environment making the system adaptable; conforming learners were locked to their version resulting in an adaptive dimension. Four dependent variables were assessed: learner satisfaction, learning efficacy, intentional learning performance, and achievement. The results showed a statistically significant positive effect on satisfaction and learning efficacy, when the environment matched with the learning orientation. The fact that Martinez used her own model however, which was relatively new and consequently had a limited corroborating research base, meant that the system was lacking a degree of validity and reliability.

2.2.3.5 3DE

3DE [143, 144] is an acronym for “Design, Development and Delivery—Electronic Environment for Educational Multimedia”. The project was a European multi-national project, which included researchers, developers and participants from Italy, France, Spain and Finland. The Honey and Mumford learning style model was used dividing users into four styles: activists, reflectors, pragmatists and theorists. Prior to the lesson, the user completed a learning style questionnaire. The personal learning style, learning goals, previous knowledge and the preferences of a learner was considered by a custom course compiler which assembled “micromodules” to coherent courses for the course adaptation. 3DE suggested a customised learning path, but still allowed for limited learner control.

A cross-cultural experiment consisting of 40 participants in each of the four countries was conducted to investigate in what way a matched or mismatched style influences learning performance [145]. A statistically significant difference between best and worst matched learning style was found, which supports the matching hypothesis. Closer examination of the individual results, however, found that 3DE did not explicitly support ongoing assessment and adaptation. It was possible for learners to switch learning styles at boundary points between different themes, but this feature was not offered in the evaluation.

2.2.3.6 INSPIRE

INSPIRE [25] is an acronym for the term “INtelligent System for Personalised Instruction in a Remote Environment. The model that was used was Honey and Mumford’s learning style model dividing the users into four groups: activists, reflectors, pragmatists and theorists. Presentation, navigation and sequencing of the materials were dependent on the learning style – users could inspect the full model and adjust their learning style and level of knowledge. They could also switch the adaptation completely off. In this respect, the locus of control was shared between the learner and the system.

An experimental study involving 23 undergraduate students was carried out to evaluate INSPIRE. The problem however, was that the study was executed without a control group. Furthermore, only half of the users filled in the learning style questionnaire; the remainder self-assessed their learning style or ignored the feature, rendering the study unsound. Regarding the design, INSPIRE failed to provide different learners with different versions of educational material – it was merely a different *sequence* of

knowledge modules (e.g., activities, examples, hints from theory, exercises). This method is resource-efficient as it re-uses existing materials for the adaptation, however, it might not be sufficient to merely alter the sequence of knowledge modules to accommodate different learning styles.

2.2.3.7 *ILASH*

ILASH [146, 147] is an acronym constructed from the term “incorporating learning strategies in hypermedia”. The Felder & Silverman learning style model (Felder & Silverman, 1988) was used, but only the global/analytic elements were considered in the adaptation. The knowledge level of each user was also measured to adapt the navigation, but this feature was not used as an independent variable. Adaptive navigation techniques were used to highlight links to content that was ready/not ready to be learned, however, the system was essentially in full control of the learning style adaptation.

An experimental study involving 21 Year-10 students in a repeated measures design was carried out to evaluate the system. Users were first presented with a matched version of the environment followed by a mismatched version for the second course. Results found a statistically significant difference found between pre- and post-test with regard to student achievement: students achieved higher scores in matched courses than in mismatched courses. The limitation with the system however, was that the matching/mismatching approach was based on the information processing dimension, neglecting the perceptual dimension. Furthermore, the fact that the study focussed on the effects of matching and mismatching meant that learners could not switch between styles.

2.2.3.8 *EDUCE*

Educe [108, 109] comes from the Latin expression “educere”, which means “lead out, bring out or develop from latent or potential existence.” This system was built to examine the effects of adaptation to perceptual styles and the continual adaptation to learner behaviour. The model that was used to create different versions of the learning content was Gardner’s theory of multiple intelligences (1983/1993); however, only four out of the eight intelligences were used: logical/mathematical, verbal/linguistic, visual/spatial, musical/rhythmic. Prior to carrying out the lesson, users completed a

multiple intelligence inventory named MIDAS. The user's multiple intelligence profile was then matched and mismatched with different, custom-designed types of resources.

Two evaluation studies were carried out using a repeated measures design; the first involved 70 students with an average age of 14, and the second involved 47 boys with an average age of 13. There were four adaptation approaches: free choice (no adaptation), one single adaptation (static profile), adaptive plus choice (static profile), and adaptive plus choice (dynamic profile). Users were intentionally matched and mismatched with learning resources. Results of both studies revealed that the level of control had no conclusive effect on learning gain. A possible limitation of this approach was that the environment automatically pre-selected a matched or mismatched resource first and only thereafter learners were given a choice of other resources. Furthermore, EDUCE offered no clues for the learner as to how well suited the resources were.

2.2.3.9 Summary

The review of adaptive environments highlights the problem of lacking evaluations to some extent. Two of the environments (INSPIRE and Arthur) did not use an instrument to assess learning styles; instead they relied on self-assessment. This can be problematic as subjective self-assessment does not have the same reliability and validity as assessment instruments from established learning style models. On the other hand, two of the environments (CS383 and CAMELEON) which did use a learning styles model, used the Felder and Silverman model, which lacked reliability and validity studies at the time the project was commenced. Furthermore, four environments (INSPIRE, 3DE, SILPA and ILASH) did not include the perceptual dimension.

With regard to user control, three of the environments (CS383, CAMELEON and ILASH) based their adaptation solely on the initial assessment of the learning style profile, which was then taken to remain stable. Another three of the environments (Arthur, SILPA and 3DE) gave the users the opportunity to switch between learning styles, but only under certain conditions. EDUCE was the only environment which used learner behaviour and expressed media preferences to further fine-tune the learner model.

2.3 Adaptation

The terms Intelligent Tutoring Systems (ITS) and Adaptive Hypermedia Systems (AHS) both refer to systems which can be used in education to enhance the learning process and will be used interchangeably throughout this thesis as they are essentially referring to the same concept of providing learners with customised material. Kennedy [132] looked at adaptive education systems and intelligent tutoring systems (ITS) as if they are one. He illustrated four components of an Adaptive Educational System: (i) the domain knowledge base module. (ii) the tutoring module. (iii) the student interface module. (iv) the student module, just as was described for ITS.

Research into AHS began in the 1990s; it is a new generation of two combined areas of hypermedia and user modelling [148]. The concept of adaptation is the main goal of AHS where-by aiming to expand the personalisation to the users of the web-based systems [149, 150]. Bruen defined adaptive hypermedia as having "... the potential to break through traditional educational barriers by allowing tailoring applications to specific user needs and requirements by possessing a model of the user." [54, 151] .

Brusilovsky highlighted that adapting the content of a web page according to particular users is the aim of adaptive systems [7]. Adaptation makes websites a friendlier environment for its individual user [149]. To adapt the content to specific needs of a user, an adaptive system must store the relevant user information [152]. Adaptivity is one of the main characteristics that websites should offer to each individual student. [153]. Koch and Rossi [154] stated "The adaptation process may include changes such as the selection of pieces of information that are appropriate to the knowledge level of the user, or some guidance performed through the removal of links that the system considers not relevant to the user". Methods of adaptation differ from one another; there are no universal decisions and "best recipes" [151]. Adaptive systems can help the user to concentrate on specific content and save time by suggesting relevant content or showing helpful links [7].

Kinshuk and Hong [155] described the target of adaptation:

- a proper online method for interactivity
- initiate and evolve student models

- provide individual patterns for each student

Santally and Senteni [156] distinguished two forms of adaptation in web-based educational systems: adaptability and adaptivity. *Adaptability* is to give the user the ability to control and customise the system. While the other extreme is the *adaptivity* where the system decides everything based on system's assumptions about the user's needs.

Fully adaptable systems might not be the best choice especially when there are users who are not able to decide what choice is best for them to follow. On the other hand, the danger of fully adaptive systems is that the system cannot always be correct about user's preferences [156]. The spectrum of adaptation in computer systems is shown in Figure 2-6 below [157].

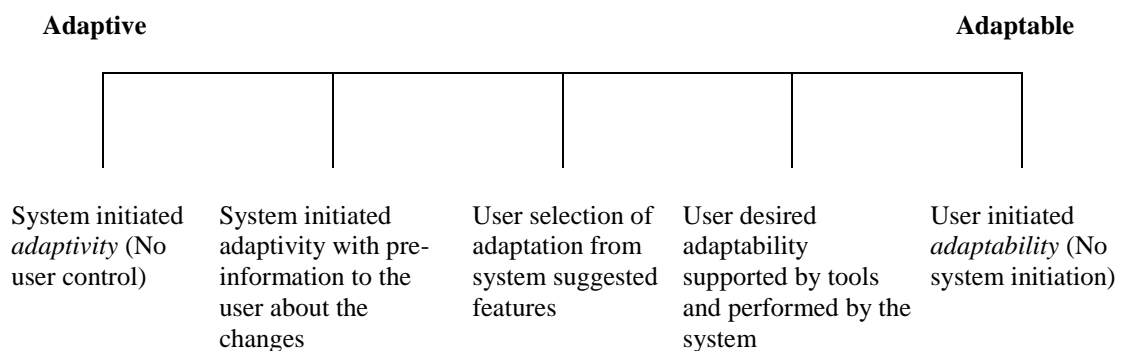


Figure 2-6: Spectrum of the concept of adaptation [157]

The perfect or the most efficient adaptation is difficult to achieve in web-based educational systems; the best situation to gain adaptation is from a real human teacher [156]. This in itself, however, also poses its difficulties in that one teacher is unable to provide a classroom full of students individual teaching styles to suit each individual learning styles. Based on this, the number of adaptive systems is increasing [149].

2.3.1 Adaptation in Educational Systems

It is claimed that using adaptive systems leads to successful learning [21, 127, 158]. Because most of the current educational systems are web-based systems and provide for a wider range of users, it is more helpful to personalise and customise information for

different users [39, 149, 159]. One of the major problems, however, of most educational systems is either stereotyping users or providing them “one-fits-all” instructions [160, 161]. Because the concept of adaptation is provided in the actual classroom, adaptivity is *essential* when designing systems, considering the fact that web-based educational systems are used by learners without the assistance of a physical tutor [51, 159]. It is, therefore, a *requirement* for instructional systems to offer adaptivity [151, 159].

There are two main interconnected processes that are done by adaptive educational systems: student modelling and adaptation decision making which is based on the information provided by the user model [48]. Brusilovsky [162] mentioned two types of adaptivity that can be offered to users: *content adaptation* and *navigational adaptation*. Content adaptation is the alteration of the presentation’s content to meet the needs of the user [163]. Navigational adaptation guides the user on available educational paths suitable for each individual learner [159]. Content adaptation is illustrated by Bruen [54] who stated that adaptive presentation has an effect on the selection of different media, based on user’s preference and adaptation of content based on user model.

Both adaptivity and adaptability are employed in the proposed system. Here, the meaning of adaptation refers to tailoring the presentation to individual student’s learning styles [44]. It allows the user to control and customise their preference, while at the same time allowing the system to compute some assumptions about the user’s needs offering an adaptive system to suit each user.

2.4 Integrating Learning Styles with adaptive applications

Web-based educational systems can adapt to many issues from user’s background and level of study to user’s preference. Learning styles are considered as a special case and impose new adaptation criterion on educational systems [48, 164]. They have an impact on users of learning systems; people with different learning styles prefer different media types while they are using learning systems [165]. Research has proven the importance of equipping educational systems with the ability to adapt according to users with different learning styles as discussed in section 2.2.3, especially when we know that adapting to learning styles improves the learning progress as discussed in section. Adaptation to different learning styles, however, is not a trivial task [161] as it involves selecting the appropriate learning styles, dealing with individual learners, and

determining the adaptation method, and implementing the relevant systems to address this.

Integrating learning styles with adaptive applications has been studied recently by a number of computer science researchers, but because of the difficulty of this integration, only a few studies have specifically studied the relationship between using learning styles and adaptive systems [20, 166] (AES-CS [167], APeLS [168], INSPIRE [25], iWeaver [169], MANIC [170], and Tangow [171, 172]). Upon closer inspection of these systems, it becomes clear that each researcher has selected one classification of learning styles, and presented the tutorial accordingly.

Adaptive educational systems try to accommodate a user according to his/her learning style based on their profile, i.e. the 'student model'; this stores all of the required information, to enable the system to adapt the presentation and navigation to each user [158, 161]. Rumetshofer [160] stated that the adaptive educational system to learning styles has to achieve four steps:

- 1- Recognise user's learning styles
- 2- Know the knowledge space
- 3- Know the organisation of the instructional material
- 4- Be able to dynamically adapt to its user

Hyun and Yong believe that the adaptation to learning styles can be achieved by diagnosing individual learning styles and then providing an adaptive interface to accommodate that learning style [129].

For the majority of existing adaptive systems, adaptation is provided to the learner in terms of content adaptation, navigational paths or the usage of multiple navigational tools. O'Keeffe showed several types of adaptation: direct guidance; link sorting; link hiding; link annotation and traditional conditional text [173]. ELM- ART is an example of direct guidance. It generates an additional dynamic link (called 'next') connected to the next most relevant mode to visit. Adaptive link sorting and hiding refers to when

links leading to irrelevant information are sorted or hidden respectively. The advantage of this is to reduce the complexity of the limitless hyperspace and lessen the cognitive load in navigation. Adaptive annotation technology adds links with a comment that provides information about the current state of the nodes. The most frequently used elements of instructional strategies found in the adaptive web-based education literature are as follows:

- Selection of items to accommodate different learner preferences or learning styles, e.g. the same information can be presented in variety of ways by using alternative media types: audio, video, image, text, etc.
- The order in which items are presented or providing different navigational paths, e.g. for active learners the information should be presented in the following order: activity-example-theory-exercise. This type of strategy can be realised through low-level adaptation techniques such as direct guidance, adaptive link sorting, adaptive link annotation and adaptive link hiding as mentioned above.
- Providing learners with navigational support tools, e.g. auditory learners can be provided with vocal instructions.
- Instructional strategies define how the adaptation is performed
- Instructional meta-strategies, also referred to as inference or monitoring strategies, are applied in order to infer the learners preferences during their interaction with the system. These strategies can not completely replace the existing psychological questionnaires for determining learning styles, however, they can be used as a simplified way to infer the learner preferences corresponding to these styles via their browsing behaviour.

These factors were taken into consideration when designing the current system. Instructional strategies were chosen carefully in correlation with the material in order to present the lesson in various different ways to suit each type of learner. Furthermore, the users were provided with navigational tools best suited to them. Instructional meta-strategies, as defined above, were also implemented; users were allowed to view the

lesson from other learning styles and change according to their preferences (Chapter 4 provides a full explanation of the system).

2.4.1 *Student Model*

Having discussed some of the most prominent learning styles (section 1.1) and components of ITS (section 1.2), it is important to address the implementation of these in the system. As discussed earlier, in order to individualise a tutoring system and monitor a student's progress in a subject domain, it is necessary to keep track of the student's work and assign him to the appropriate level. This information about the student creates a set of data which is called the student model, as discussed above in section 2.2.1.2.

A student model has been defined by Paiva as a representation of “some characteristics and attitudes of the learners, which are useful for achieving the adequate and individualised interaction established between the computational environments and students” [174]. McCalla (2000) defined student modelling as “the process of assembling and summarising fragmented learner information from potentially diverse sources” [175]. Ragnimalm (1995) stated that “*student diagnosis* is defined as the abstract process of gathering information about the student and turning that information into the basis for instructional decisions made in the ITS.” [176].

The aim of the student model, therefore, is to describe the student in some manner. It is a container for information about the student, including inferences made by the tutor module. This collection of information about the student is also used by the other components in intelligent tutoring [176]. Behaviour analysis and model management are two main activities in student modelling [177]. The whole process of examining the student is called behaviour analysis. It is part of the cognitive diagnosis which diagnoses the current state of the student's level or understanding [177].

The student model is essential to provide adaptivity to the intelligent tutoring system, providing tailored explanations to the student. A complete history of the student can provide information that might help in diagnosing his style [177]. The problem with this, however, is that it is difficult to model students because student reasoning is unpredictable [175, 177]. Students may learn new tutorials or forget known tutorials.

Knowledge of the student model can be divided into three levels: static, dynamic and reasoning. Static knowledge contains the facts and the basic concepts of the domain. Dynamic knowledge is concerned with the functional aspects of the domain. Reasoning knowledge is about the student's reasoning and can be obtained by tracking the student [177]. The information that the student model should contain depends on the instructional purposes and the type of the domain [176].

According to Anderson [178] there are two types of student models. The first, called "knowledge tracing", refers to tracking a student's problem solving as he/she works on a problem. The second type of student model is known as "model tracing". This model responds to specific questions asked by the user. "Knowledge tracing" is a much more complex model as it attempts to analyse and evaluate the reasoning behind a student's decision making process [179].

2.4.1.1 Initializing the Student model

The student model is able to initialise when a new student logs into the system and updates the student model according to his/her interaction with the system. Initialising the student model is very important when the educational system is supposed to provide tailored tutorials [180].

There are three approaches for initialising the student model [181]:

Explicit Questioning

Assuming that the new student is starting his knowledge from scratch, this approach is weak with a student whose knowledge is different from that of other students. It is used to collect general information and knowledge directly from the learner.

Initial Testing (pre-test)

The student's knowledge can be assessed by pre-testing. The test covers every aspect of the taught tutorials. This test is long but the number of questions can be reduced by using an adaptive pre-test. It is carried out by testing the learner, and hence analysing and examining the result, which in turn helps in identifying the goals and concepts for each learner.

Initial testing is different from explicit questioning; Explicit questioning is done by asking the user directly if he is a beginner or advance, or in system like the proposed one the user is asked what is your learning styles and the user select one of the available options, while initial testing is done by offering a test and the results of this test is calculated by the system which will later enable the system decide what to do.

Stereotyping

One of the methods for solving the problem of initialising the user model is to assign the new student to a certain group. It is used to gather information through the group of individuals who share the same interests according to certain criteria. The representation of the attributes of a certain group of people can be called stereotyping. Stereotype information is set as default initial parameters in the student models. The stereotypes were used in intelligent tutoring systems. It was first introduced by Rich in the system called GRUNDY [180]. The stereotype approach is a quick method to get started and customise the system according to the student. The problem with this approach, however, is that it does not focus on special individual characteristics. It is quite inflexible because it is constructed before real users have interacted with the system.

Alternatively, the approach of Tsiriga and Virvou of initialising the student model procedure is automatically updated at runtime while using the system, while the student interacts with the system. The stereotypes are used to make initial assumptions about the new student's knowledge level. The initialising of the model is based on recognising the similarities between the new student and the other students who have already interacted with the system [180].

The method used to initialise the student model in the current study was initial testing. The student's knowledge was assessed by pre-testing. The test covers every aspect of the taught tutorials, hence analysing and examining the result in turn helps in identifying the goals and concepts for each learner. The pre-test used measure the knowledge of the learner to be compared later with the post-test. Two tests of learning styles of VARK and Honey & Mumford also used to help the system decide the learning styles of the user.

2.4.1.2 *Methods Used for Updating Student Models*

Cognitive diagnosis is the analytic processing of the student's responses to the various questions and problem solving. This process produces the most important information for updating the student model.

- **Analysis of Student Responses [182]**

Analysis of student responses is also called performance measuring.

Tutoring system questions can be divided into two categories:

1. Simple questions for one curriculum element mastered by the student.
2. Complex questions for more than one curriculum to be mastered. Correct answers raise the measures while incorrect ones lower the trend.

Analysing complex questions needs more concentration and effort because if the answer is correct, it is enough to raise the trend for the entire curriculum. However, conversely, for an incorrect answer, a certain task, such as a test, is given to see which curriculum is used and which is not. If an inconvenient error model is presented, in case of incorrect answers the whole curriculum should be checked to identify the main reason for such errors.

- **Analysis of the Process of Problem Solving**

To analyse certain problem-solving episodes, the model tracing technology is applied. All possible correct rules that can be applied to help solve problems for the users are in the system with a guide to certain conceptions which guide him for types of errors that may occur. The system tracks the student rules and conceptions step by step along the process of solving the problem.

- **Analysis of Student Actions**

Coaching and analysing a student's actions is the most difficult way to go in the system. It is easy in certain domains to track and study every action of the learner, normally from gaining a set of curriculum elements or misconceptions. Solving a problem is very easy; it is done by tracking each student's actions and reactions.

In the proposed system, the method used for updating the student model is analysis of student actions. The system accomplishes this by supplying out of profile content for the user to review and then decide on how well this fits with their learning style. Weighting is then used by the system to add ‘scores’ to the relevant learning styles across the two models; Chapter 4 describes this in more detail.

2.5 Learning Object definitions

The term “Learning Object” is widely defined; there are many definitions. Each institute or organisation defines it according to its own methodology. Sosteric and Hesemeier [183] defined a Learning Object as “a digital file used in educational settings to support instruction”. The Learning Technology Standards Committee (LTSC) of the IEEE (Institute of Electrical and Electronics Engineers) defines it as:

“Any entity, digital or non-digital, that can be used, re-used or referenced during technology-supported learning. Examples of technology-supported learning applications include computer-based training systems, interactive learning environments, intelligent computer-aided instruction systems, distance learning systems, web-based learning systems and collaborative learning environments”[184]

Each Learning Object can be used and assessed independently. Each one can be used as a part of a complex learning system. A learning path can be composed by arranging Learning Objects together. An instructor can customise a learning path by collecting new Learning Objects, deleting unnecessary objects, and rearranging the sequence of the presentation.

2.5.1 The reason for Learning Objects

Any component that can be used to build a lesson is a Learning Object. Multimedia types can be Learning Objects, for example: text, graphics, animation, and audio, or they can be used to build various learning situations, such as questions, examples, seminars, discussions, workshops, exercises, and role play [185].

The idea of Learning Objects is to break down the lesson content into small chunks. Each one is independent and has its own duration of time, and can be used with other

chunks to build a learning system [186]. Learning Objects are self-contented, reusable, distinct pieces of material that satisfy a specific objective. They are an application of object-oriented basics that are used and re-used in different parts of technology all over the world, like Lego bricks, video presentations, stories, case studies, and many learning assessments. These re-usable objects can fit into many programmes [186, 187].

Learning Objects are used because of the following:

- Learning content is developed and deployed quickly and efficiently.
- It is easy to port Learning Objects between learning content management systems.
- The cost of development and delivery is reduced.
- Maintenance is easier.

Why use Learning Objects?

Bradley and Boyle [187] mentioned several reasons behind using Learning Objects:

- No need to design new objects
- Improving the tools already available
- Availability of materials with less thinking and effort
- Increasing the value of the re-used objects

Another reason for upgrading to Learning Objects is the usage of Rapid Application Design/Development (RAD) [188]. It is a process that permits software developers to develop and improve any piece of content more quickly, efficiently and of advanced quality. The main idea here is to re-use software components within another software application. The designer can choose and apply a group of pre-prepared and defined subroutines and use them in another program, called a template, in any programming

object-oriented based language. The major reason, however, for upgrading remains clear: it is to lower the expense.

2.5.2 Criteria of Learning Objects:

Studies [185, 189] have discussed the main features of Learning Objects:

- The material should be flexible to be used in multiple contexts.
- It should be easy to manage (searching, updating, filtered and selected).
- It should be customisable.
- The organisation should be allowed to set the specifications according to its needs.

Searching for Learning Objects is an essential issue. Many websites are meant to be for that purpose, and one of these search engines is the Campus Alberta Repository of Educational Objects CAREO [190] which has opened an ongoing research project for periodically updated and tested materials. Another guiding engine or library that gives a wide range of varieties is the Wisconsin Online Resource Centre,[191] which is a digital web-based resource that supplies most learners and developers with “Learning Objects”.

MERLOT is a project which contains sources and learning materials [192]. It is also an educational community. This community has contributed to the “growing up” of this project; many of the members make their professional materials available for MERLOT users.

These systems should be interoperable with other systems, as required by the Institute of Electrical and Electronics Engineers Learning Object Metadata standard (IEEE LOM) and the IMS Learning Design specifications (IMS LD) [193]. The ability to interact with different architectures as well as meta-data records should be possible. This allows re-using of Learning Objects as a template or plug-in component of another application.

Learning Object standards vary from learners to administrators and developers. As well as the financial affairs, each has their own vision [186, 194].

For learners: Courses must cope with every individual preference, presented in easily managed chunks and available at any time at one click.

For Administrators: Courses must fit all the learners' different motivations; variety lies in linking learning resources, and components of the course should be re-usable so that they can be applied in various fields other than the chosen one.

For developers: Objects created must be designed, used and re-used from various tools and can be employed on many platforms as in open standards. From the financial point of view, it saves a lot of money, depending on the study for the designing and developing of such ideas.

For Teacher: Teachers play the role of facilitator; they will switch from transmitters of knowledge to facilitators of learning so that learners can learn themselves [121, 195, 196].

2.5.3 *Taxonomy of Learning Objects*

According to Richey [197], the progress in models and items provides identification, description, relation and connection between variables used in creating Learning Objects. Object classification must be related to the instructional design, as both serve and are related to each other [186, 194] .

Wiley [186] listed five main types of Learning Objects:

Fundamental – a single resource unlinked to any other instructional theories. It is usually used in visual presentations.

Combined-closed – a small digital link designed by the Learning Object developers and creators to serve a certain purpose at design time. They are not cannot be decomposed to be used in any other application. These are most often fitted in video clip shows, as these involve sound, animation, and images, that are meant to show a certain idea but cannot be separated from each other.

Combined-open – a larger number of object learning items already made and put together at a requested time. They are reusable and can be combined and re-combined to serve in any other application, as in image, text, clips. They can be combined together to form a certain media file.

Generative-presentation – a combination of Learning Objects - whether to access the network or to generate Learning Objects - and link them to other applications to be used over and over. They can interact with several objects in the same context.

Generative-instructional – this is a combination between the fundamental, combined-closed, and generative-presentations. There are three types: the major difference here is that the learner can interact with such types to create and test in run time. This type has high reusability within the same program or with other software.

2.5.4 Connecting Learning Object to instructional design theory

Linking instructional theories to Learning Objects enhances the learning process [186]. Wiley [186] presented three major parts in enhancing such issues: an instructional design theory, a Learning Object taxonomy, and prescriptive linking material. These three relate the instructional theory to the Learning Object through Learning Object classification; these three in addition to the quality put Learning Objects to fit certain types of learning.

Before linking these three items, organisations and institutions faced a difficult obstacle, which was creating their own Learning Objects to be applied in their instructional design theory. After discovering prescriptive linking material, it becomes easy to link the required type of Learning Object through the taxonomy to the instructional design. It became clear that these links facilitate the development of Learning Object, as well as the instructional design when developing the current system.

The components or (Learning Objects) for this system were developed especially for this system; they were stored as links. The types of Learning Object used in the current system are Fundamental and Combined-closed. They are not to be used by other systems, and can be reached by putting the links together to compose a lesson, making

them combined closed. Some multimedia types were used such as sound files, pictures, texts which can be considered as Fundamental.

2.5.5 Learning Object Repositories

The centre of a Learning Object repository is the main database, containing hundreds of thousands of Learning Objects [194]. Such databases may be available online for any user; it can contain documents, media, websites, applications, and other knowledge resources [186]. These databases are saved and protected by legislation, policy, events, manuals and tables into a database. Access to these databases is restricted to end users only.

2.6 The proposed system

In the proposed system, Learning Objects are employed in order to break down each lesson content into small chunks; each one is independent, and can be used with other chunks. The proposed system was not tested for integration with other external Learning Objects as this was not part of the aims of the research. It considered and implemented the four components of ITS as discussed above:

- The system registers both student progress and preferred learning styles in order to develop the student model;
- The domain knowledge model contains the topic information, which in the proposed system was related to the group of users in order to keep them motivated;
- The tutoring model refers to the teaching strategy or pedagogical model, in this case the various categories of the VARK and Honey & Mumford learning styles;
- The user interface model is in charge of the information flow between the user and the system, and as such the usability and ease of use are crucial parts because they are important to the student use of the application. This is monitored by asking the users about the ease of use in a survey, which will be discussed in the following chapters.

Chapter 2 Literature Review

The aim of the proposed system is to develop a model using two different learning styles and consequently test it to identify whether or not the combination of learning styles aid the users. When learning is presented according to a learners' preferences, it has been shown to induce effective learning [11, 16, 47, 48, 88, 89, 91, 92]. The system will therefore be designed to be adaptive to the learning style of the particular individual using it. It is important that the learning system takes into account the appropriate details of the learning styles of the user. For this reason, it has to be determined whether the educational system that has been developed is able to adapt its presentation according to more than one learning styles model. The VARK and Honey & Mumford learning styles were chosen as they represent two prominent models in the literature. It is believed that intelligent tutoring systems enhance the teaching process, therefore it is hoped that the proposed system can offer this to its users.

The proposed system aims to be adaptive by offering the users the ability to control and customise the system (adaptability) whilst at the same time maintaining both content and navigational adaptation by computing some assumptions about the user's need. Adaptivity is a requirement for instructional systems as it has been suggested that it leads to successful learning [127, 158]. As such, adaptivity and adaptability are both employed in the proposed system. Everyone has a unique learning style and due to the differences that people have, designing a system to accommodate individual differences and learning styles will be a challenge. Here, the meaning of adaptation is tailoring the presentation to individual student's learning styles [44]. This will be of great importance in the design and application of the proposed system as it has been found that adapting to learning styles improves the learning progress [17, 198]. In this research, it is hypothesised that using two models of learning styles will give the learner a better chance to learn.

The research aims to examine whether or not there are differences between the users in terms of their learning gain and satisfaction. It is necessary that this is established as it will decide on the appropriateness of using two learning styles models as opposed to one. If there is no difference then it can be concluded that there is no additional benefit of using two models compared to one. If there is a difference then this will be the first system to incorporate two learning styles into an adaptive hypermedia system showing an increased awareness of users in relation to their learning styles. There are other systems but they use only one model of learning styles such as CS383 [21],

CAMELEON [22], Arthur [23, 140, 141], SILPA [24, 142], 3DE [143, 144], INSPIRE [25], ILASH [146, 147], and Educe [108, 109].. The research also examines whether or not users of the system can recognise that the system is producing tailored presentation using two of their learning styles.

It is hypothesised that users who are presented the lesson according to two of their learning styles will have a better learning gain and give higher ratings of satisfaction than those who are presented the lesson according to one or none of their preferred learning styles. It is also hypothesised that there will be a difference between user's recognition of a lesson that is presented according to two classifications of learning styles, one and none of the users' learning styles. Furthermore, it is believed that users who are presented with a lesson according to two models of their learning styles will have a more positive attitude towards the lesson than those presented with customisation to one or no learning styles.

The following chapter will outline the methodology used throughout the various stages in this study that will enable the researcher to address the main research question and in turn present the argument for developing an adaptive system that uses two learning styles model instead of one as has been developed thus far in the current literature.

Chapter 3

Methodology

3.1 Introduction

The primary purpose of this research was to design and evaluate a model that combines two classifications of learning styles. It was hypothesised that when presented with a lesson according to two of their learning styles, compared to with one or no personal customization, users will have a higher learning gains and express higher levels of satisfaction.

This chapter outlines the methodology used to design, develop and evaluate the proposed model for this thesis: “systems that adapt to learning styles”. Evaluation here is required to test hypotheses, and to evaluate the efficiency and usability of the system. Opinions and preferences of the users toward the model were collected. The evaluation provided information about the difference between using a model with two, one or no learning styles.

This chapter explores the research questions in more depth, and discusses what methods are the most appropriate, given the aims and nature of the research. Both the conceptual framework and the practical elements of the research will be discussed. It deals with data collection and covers how data is derived from participants. The chapter also details the approach used and conditions under which the various stages of investigations were carried out, development of initial contacts, pilot surveys, and the design of the main research instrument (survey), which was used to collect the primary data. This is followed by a discussion of the practicalities of how the data collection was conducted, and the approaches taken to data analysis. It further indicates how issues of validity and reliability were addressed and explores a few issues surrounding ethics.

3.2 The emergence of the research inquiries

Research should focus on solving specific topics rather than merely investigating generic subjects. Precise problems should be addressed, focusing on the key topics. A hypothesis should be elucidated to identify whether it is possible to research a certain

topic and establish the more insignificant issues [199]. This thesis proposes a system with more than one learning style will be built and evaluated.

As discussed in the previous chapter, using a single learning style is not sufficient. The conclusions reached by experts in the field may imply certain procedures are ineffectual. As such, an entrenched programme of research could rectify this discrepancy. Strauss and Corbin (1998) [200] have clarified research topics into four different categories which include proposed areas of study, or allocated assignments. Also categorised by Strauss and Corbin (1998) [200] are whether the data presented is of scientific origin or whether the data is simply nominal. Further categories include individual knowledge from personal experience as opposed to the opinions of experts, together with the topic under consideration. Personal knowledge and experience in this field was the foremost motivation for undertaking this enterprise, as explained in the following section.

The justification for undertaking this research is that at present no system exists that takes into account more than one learning style. The aim of this thesis therefore is to amalgamate two models of learning styles, then collect and collate the stance taken by the users who are to trial the prototype. Focused research in this area could supplement the existing knowledge in this field.

It is believed that one model of learning styles is not enough to cover all the processes of learning. In the case of this study, the model of Honey and Mumford learning styles looks at interaction with the learning, while VARK is from a different angle; it concerns how the learner perceives the information, or the dominant way to understanding and learning, by seeing, by hearing and discussion, by reading and writing, or by doing. In other words, the Honey and Mumford model is unable to describe everything about learning styles, and it looks at the learner from only one perspective. Both VARK and Honey and Mumford need each other to build a better way to look at the learner from more than one perspective.

3.2.1 How did the questions arise?

The research questions proposed in the current study evolved from a combination of personal vocational experiences combined with research into the field of education and technology. Many diverse incidents have been experienced during the researcher's career, which have been an asset in providing a platform on which to develop the arguments, and a sound hypothesis for the research, as described by King et al (1994)

[201]. Motivation such as this encouraged the researcher to consider carrying out the current study which, in turn, influenced specific queries, a factor noted by Strauss and Corbin (1998) [200] .

3.3 The current research

The principal aim of the research was to explore the ability to combine learning styles in an intelligent tutoring system. The relevance and appropriate timing of this investigation was enhanced by recent ambitions of two schools in Saudi Arabia to make changes to their education system in general.

3.3.1 *Progress stage*

To enable the research to be completed in an effective way, a primary image of the system was created, based on the existing literature and the proposed hypothesis, showing the work that needed to be done. The plan, as shown in Figure 3-1. below was divided into six main stages, three of which were completed in the first and second year of the PhD, and three of which were completed in the third and fourth year.

1. Carry out a literature search in order to build a bank of articles for the intended research.
2. Develop a first prototype of the system.
3. Carry out an evaluation of this system.
4. Modify and complete the rest of the system.
5. Conduct an overall evaluation.
6. Communicate results (including, papers, talks, and writing up the thesis)

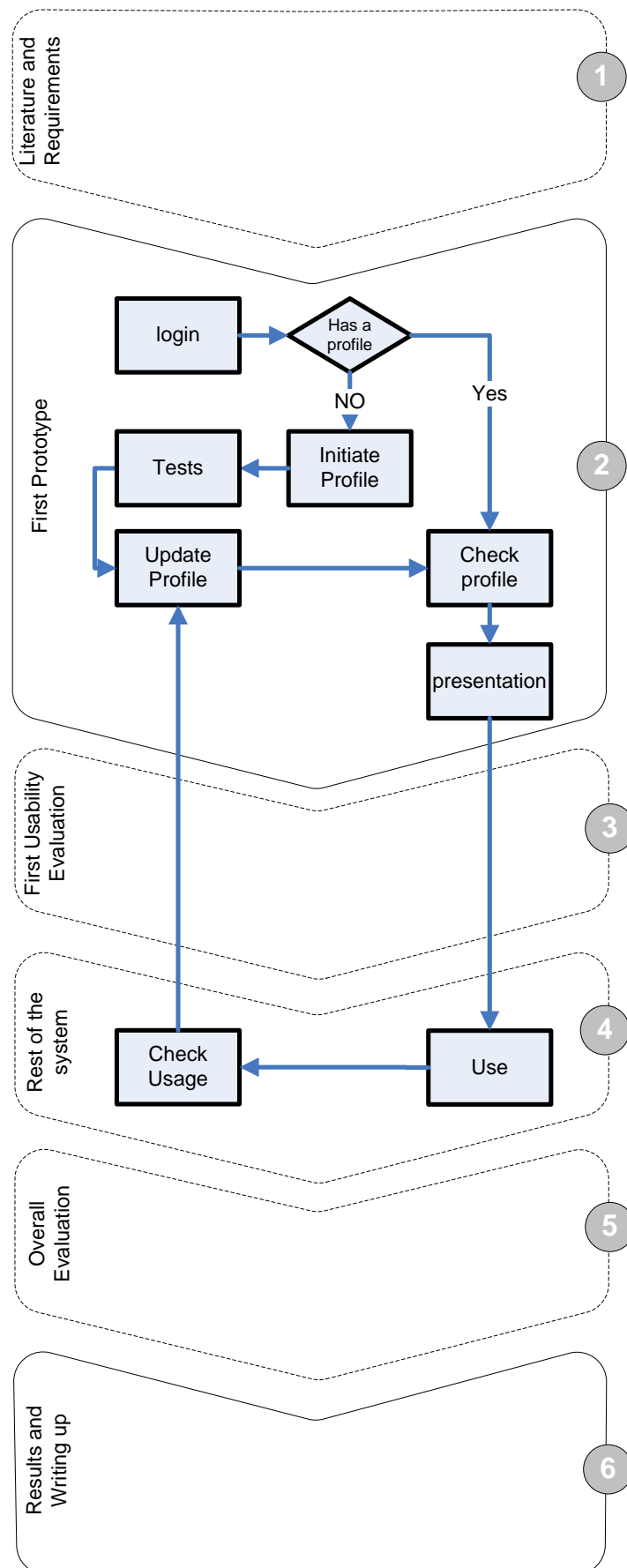


Figure 3-1: Progress stages in research and the system development

3.4 System Development Methodology

This section outlines the general approach taken to system design. Details of the system are discussed in more detail later on throughout this chapter. After carrying out the literature review, the next stage was to create a prototype of the system. The method used to develop the system was a common method presented by Avison, and Shah [202]. Figure 3-2 shows the followed method.

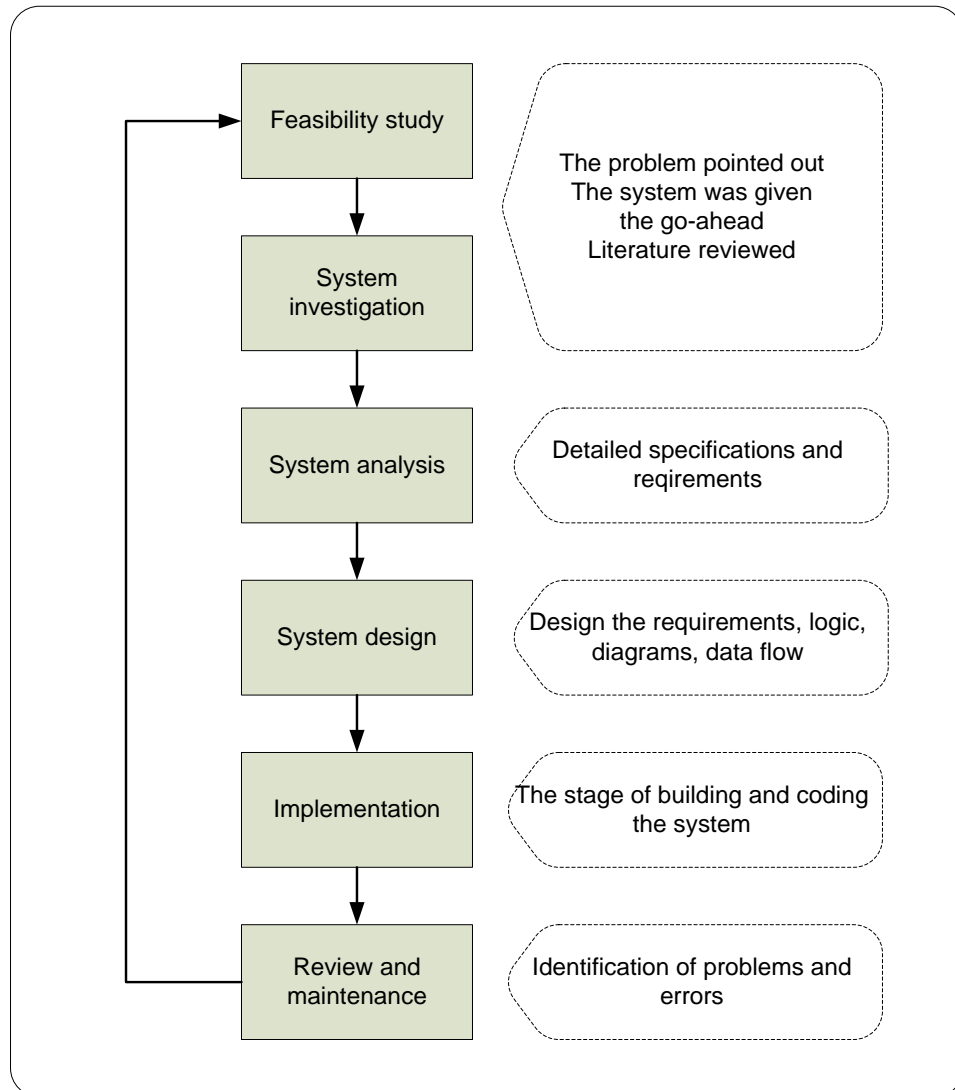


Figure 3-2: Methodology of the System Life Cycle

3.4.1 Feasibility study

The first issue that arises in the methodology of developing the system is to understand the problem and to investigate if the system is achievable. In other words in this

feasibility phase, the project as a whole is looked at including the estimated time it will take, and whether or not it can be done in the proposed time frame. Other factors such the availability of the technology that will be used to build the system and the possibility of learning within the time frame also need to be considered. The scope and objectives must be clearly stated prior to commencing the work.

3.4.2 System investigation

This phase looks at how other systems are built, the information needed, and the operation of the system. The needs of the user will also be investigated in this phase. No two systems are exactly alike in their requirements. However, there is a uniform and identifiable process for logically discovering the system requirements regardless of system purpose, size, or complexity [203]. Requirements are crucial to every project, without good requirements, projects fail, are late, come in over budget, or produce systems that are never used. Requirement issues should be fixed early, before committing to a design, because problems caused by poor requirements tend to be deeply embedded in the design and are difficult to remedy afterwards. Developers have a different perspective from users as they are looking at a requirement from the point of view of how to implement it rather than experiencing the problem that the users had in the first place. The safest way to ensure that the users' needs are met is to write down what the users need and what a system would have to do to meet that need. These are the user requirements and the system specifications respectively [204]

3.4.3 System analysis

The system requirement and the readings from the literature review need to be analysed. This phase combines the feasibility study and investigation study in order to assemble a detailed requirement and specification of the system being built. Flow charts and data flow diagrams were designed to aid the process. This stage is essentially preparation for the design phase which follows.

3.4.4 System design

There must be a step between the system investigation phase and the start of actual production. This intermediate stage is not redundant, and it is not unnecessary. Rather, it is an essential part of good software engineering. Design is an essential part of many activities, among them software engineering. It is a meaningful engineering representation of something that is to be built. It is also the blueprint for how that

system should be built. It can be traced to a set of requirements. Those requirements are then translated into a real educational web-based application through several stages. The design phase is the phase in which the system is broken down into smaller, less complex parts. These parts, when put together, need to be a solution to the problem under development.

3.4.5 Implementation

The challenge is to create a working web-based application to enable the educational system to cater for individuals' learning styles. When the design of the system is mostly completed, implementation begins. This means the design is translated into code. Implementation is the process of building the web according to its design [205]. This refers to the period of time in the software life cycle during which a software product is created from documentation and debugged. Implementation is included, as a phase, in the software development cycle in order to build and deliver a software system that has been engineered and designed in previous phases of the cycle.

3.4.6 Review and Maintenance

It is not likely to produce the perfect usable design; a designer can create a highly-usable interface only by stepping into a process that involves getting information from the system users. The system will therefore be tested to ensure that it is working well, to get rid of any errors, and to enhance it. In addition to testing there will be a usability evaluation and interviews with experts. The usability evaluation demonstrates the quality of a system that makes it easy to use and learn, and that is subjectively fulfilling.

The first few stages in the cycle involve the practical application of the theory in terms of how the system needs to be designed and built. Most of the researcher's time was devoted to this part of the study. The following sections in this chapter will cover the survey design and interview techniques used to evaluate the system. The next chapter will present a more detailed description of the final review stage, the part that involves the implementation of the system in the way of evaluation studies; there will also be some details of the code used to develop the system and how the system works.

3.5 Methodology stages

This section presents a brief outline of the various stages followed throughout the experimental stages of the thesis which are all discussed separately in more detail in the following sections.

1. The first prototype of the system was built: the starting point of the experimental stage.
2. Test phase: the system was tested solely to check if the system could store information and adapt.
3. Survey design: a survey was designed to collect the data and examine a range of issues related to learning styles.
4. Pilot study: the system was tested on normal users to check if the system was working well, and to receive any comments that could be implemented before carrying out the main experiment.
5. Interviews: these were carried out with a small group of educationalists in order to review and discuss the results of the survey and pilot study.
6. Testing feasibility of the system: this was carried out to test the first set of hypotheses and try to address some of the research questions
7. Testing learning gains and satisfaction: this was carried out to further investigate the aims related to learning gains and satisfaction of users.

The criteria for evaluation are rooted round the hypotheses:

1. The system which is tailored according to the user's styles is more effective than content which is not tailored.
2. Furthermore, the system which is tailored with two combined learning styles is more effective than simply using only one learning style.

The proposed research question in terms of methodology was:

- a. How can a model that presents tutorials using two combined classifications of learning styles be built?

The central research questions of the thesis are:

- a. Will the system be able to produce tailored presentation to two models of learning styles?
- b. Will users who are presented the lesson according to two of their learning styles have a better learning gain than those who are presented the lesson according to one or none of their preferred learning styles?
- c. Will users who are presented the lesson according to two of their learning styles give higher ratings of satisfaction than those who are presented the lesson according to one or none of their preferred learning styles?

3.6 Test phase

Before continuing to the evaluation stage, the system was tested in order to test if the system could store information and adapt, and to check if there was anything wrong with the system. This was to avoid reaching the pilot test with an incomplete system or one that had major faults, such as being unable to store data or adapt.

Eight PhD colleagues offered their assistance commenting on issues such as the length of the experiment and its comprehensiveness. They were observed while using the system, and think-aloud techniques were encouraged; participants were encouraged to speak, discuss and criticise the problems that they experienced. They were not only answering the questions, but essentially acting as evaluators.

The time taken to complete the experiment (pilot) was measured and an informal interview/chat took place to check if the language was understood and if there were any steps in the process which were not understood. They were given the opportunity to make any suggestions or inform of any mistakes and ambiguity with any parts of the system. They were asked to critically review the questions individually and assess them for clarity; they were also asked whether the group of questions accomplished the intended objectives. Upon completion of the task they were interviewed and asked to give their opinions and comments on the following:

1. Were any questions misunderstood?
2. Were the directions clear?
3. Was the survey too long or too difficult?

4. How long did it take to fill out?
5. Was there enough space for responses, etc.?

Feedback and comments were registered by the researcher. Their reviews helped to enhance the first draft of the survey. A few spelling errors were noticed and corrected. Another participant suggested that the users should be given more encouragement. The main finding was that the system worked well and saved information correctly. Once this was confirmed and the relevant changes made, a pilot study was carried out and experts were invited to provide their opinions more formally.

3.7 Survey Instruments Design

After careful consideration of the different evaluation tools that could be used from individual interviews to questionnaires, it was decided that a survey would be an efficient way to examine the users' opinions of the system and collect the data considering the time frame of the research. Several authors have documented the methods to design survey instruments [206-208] . This section discusses the methods used for the design of the survey used in the study.

Interview protocols or questionnaire forms can be verified using the application of cognitive interviews. Firstly, prior to the pilot study, the layout and survey statements were thoroughly discussed with the researcher's two supervisors. Secondly, after carrying out the pilot study, the survey was handed over to specialists at the Ministry of Education in Saudi Arabia for commenting. The procedure used for this part of the evaluation is discussed in more detail below in section 3.9.

This process of obtaining expert advice about the instrument has been coined as 'cognitive testing' by Fowler (2002) [206] . Four questions in particular require answers (P: 109):

- 1- Can the questions be understood in a consistent way?
- 2- Is the information necessary to answer the question available to the respondents?
- 3- Are the respondents views accurately described in the answers?
- 4- Are the measures, for which the question was designed to obtain,

appropriately supplied by the answers?

Questions arose from the reviewers as to the relevance of survey items, as well as its layout and clarity. They recommended that the survey be modified in some instances.

- 1- The reviewer appraised that sections with the same measurement level should be combined, i.e. sections requesting respondents to answer from an agreement scale (strongly agree – strongly disagree) ought to be put together in a single section, in order to avoid overly prolonging the questionnaire. They also concluded that sections requesting respondents to answer from a scale of their involvement frequency (always – never) ought to be put together in a single section
- 2- Some sections of the draft of the survey were based on a seven-point scale, e.g.:

Strongly disagree- disagree- mildly disagree- neutral- mildly agree- agree- strongly agree

It was recommended by the reviewers that the survey used a five-point scale:

Strongly disagree- disagree- neutral- agree- strongly agree

They also remarked that that some statements were repeated, making the questionnaire too long and in need of reduction by removing the repetition.

Certain considerations exist to select the best method to collect data, according to Fowler (2002):

- Sampling: if the sample is derived from a group of addresses, it is possible to use interviews and self-administered questionnaires
- Population type: when the subjects find the research problem interesting, they will generally respond
- Content and nature of question: if the research is designed with a self-administered questionnaire, the researcher should devise the majority of the questions to be closed, as opposed to open-ended, as closed questions can be

replied to easily by circling the answer or checking a box. Using this form of question ought to maximise the responses. Others consider personal interviews to be the most appropriate form to pose sensitive questions, as the interviewer can develop a rapport and gain the respondents' confidence, which is necessary for them to divulge personal information.

During the instrument design process, there are certain considerations to address, as identified by Fowler (2002) :

- The survey instrument should start with questions that are relatively simple and clear.
- It is best that sensitive or thought-provoking questions are set aside until the middle or concluding sections of the survey instrument.
- The survey instrument ought to have an effective layout, in order to best simplify the tasks of the interviewer (interview) and respondents (questionnaire).

The current research will attempt to address these matters, incorporating the above considerations into the design and methodology.

3.7.1 Testing components

Testing the appropriateness of selection and presentation will be looked at from two different angles:

- 1- Usage and preference from the user's perspective
- 2- Educational perspective

The aim is to test the hypotheses from the users' point of view, which in effect leads to the following questions:

- 1- Is the system usable?
- 2- Does the user notice a difference between lessons which are presented according to their learning styles?
- 3- Does the user prefer presentation styles which are consistent with those suggested by the learning style questionnaires and the student model in the system?

- 4- Does the user understand the content of the lesson?
- 5- Is the user satisfied with the system?

In addition to the above aims, achieving the above aim will enable the author proceed to the main and the general aim of the study “Testing learning gains and satisfaction” which aims to examine whether or not there are differences between the users in terms of their learning gains.

3.7.2 The experimental design

The experimental design used for the experiment was independent groups design [209]. This experimental design involves using different participants for each condition; in this case, there are four different conditions. It is sometimes called independent subjects design, independent samples design, or between groups design. Participants are allocated to each condition randomly.

The main difficulty with the independent groups design is that any differences in the dependent variable (DV) between two conditions may be attributable to differences between the two participant groups. This is known as the problem of participant variables. Humans are infinitely variable and there may well be differences between the participants chosen that could systematically affect one condition and spoil the results. For example, if one group is mostly young and the other group is mostly old, or one group mostly female and the other group mostly male, these differences will introduce a bias into the research findings. To avoid, or at least minimise this, the researcher must use random allocation in which each person has an equal chance of being assigned to any condition. This can be assigned by pulling names out of a hat or tossing a coin to decide who is in which group. In this way you can get a balanced mixture of all sorts of people in each group, and the bias should be eliminated. In the current study, the system randomly allocates each participant to one of the four conditions.

Repeated measures design [209] was not selected for the purpose of this study as this method involves using the same participants in all conditions. It is sometimes called related measures design or within subjects design. This would require the researcher to produce two, or four equal lessons which would consume a lot of unnecessary effort and time. Each participant would have to work through all lessons, meaning the results

might be affected by the participants' fatigue, refusal to do it again or sheer boredom. This method would also require the participant to devote more time to the session than if using the independent groups design. Participants may get bored or tired if they are performing the same task over and over again. Their responses may not be as speedy or as accurate as they were the first time. Their responses to the survey questions may also be affected by the previous task(s).

Matched pairs design [209] involves the creation of two different groups one of which will act as the control, the other as the experimental. This design was not selected as this type of sampling process has a major drawback. Using this design would require the researcher to create two groups that were matched on certain variables such as age, education and gender. This would require a large sample size and was not possible to create from the participating schools. Additionally, the current research does not really have a control group – the lessons are either tailored to the individual using two, one or none of their learning styles, therefore matched pairs design would not be suitable for this type of research.

3.8 Pilot study

To carry out the evaluation and test the system on normal users, it was necessary to carry out a pilot study. This is essentially to check if the system is working well, and to receive any comments that could be implemented before carrying out the final experiment.

3.8.1 *Purpose*

The pilot study is a smaller model of the final study. It tests how to gather information prior to a larger study and helps in validating the questions and the environment of the study. It is carried out to ensure that anything that may go wrong can be fixed before starting the final study. The pilot study will improve the latter's quality and efficiency.

There are four goals for the pilot study:

1. To identify problems with the proposed surveys.

2. To ensure that the questions are serving their purpose and determine their suitability and appropriateness, i.e. to test that each question measures what it is intended to measure.
3. To ensure that the system is categorising and dealing with the experiment correctly to prevent errors from happening in the main study.
4. To avoid wasting time and money on a system and survey that is inadequately designed, so that the main study will not have to be repeated.

3.8.2 *Evaluation tools*

3.8.2.1 *Survey*

The survey was used to collect both quantitative and qualitative data i.e. closed-ended questions and open-ended questions. The closed questions were suitable particularly to test and prove the hypotheses. Surveys were used as they are easier to distribute, easier to collect, and easier to analyse.

The survey is split into three sections:

1. Section one is dedicated to collecting information regarding the personal information of the participants (demographic data).
2. Section two is dedicated to collecting information regarding the learning styles. The researcher employed the Likert scale for this section: “one of the most widely used technique to measure attitudes”, according to Ary et al (2006) [208]. According to Bryman (2004) [207] , the Likert scale “is a multiple-indicator or item measure of a set of attitudes relating to a particular area”. The options available to answer a closed question ought to be balanced, for example, for question number one, a choice of three answers were given (I know it very well, I have heard about it and I have never heard about it). The answers to the remaining questions were given in the form of a five point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).
3. Section three is dedicated to collecting information regarding the usability of the system using open-ended questions. Schuman indicated that to get the participants’ true feelings on a topic open-ended questions are more effective than closed-ended ones [210].

The survey is web-based and was produced as part of the system (see chapter 5 section 5.4 for the full questionnaire). Questions one and three were employed to examine if the user had previous experience in learning styles. These relate to section 2 described above. The answers to these questions will help identify if there is a difference between those who do or do not have prior knowledge to recognise the lesson that was presented according to their learning styles; that will show whether the system is working properly or not. Question two is the central question used to test the hypothesis and research question to study the feasibility of the system. Questions four and five were used to examine the usability and the ease of use. These relate to section 3 above. Open-ended questions were included to allow participants to provide more information in their own words.

The fundamental goal of this survey was to obtain a general impression of the web-based system that adapted to two models of learning styles. Findings from this exploratory study and the interviews described below (section 3.9) were then used to derive the statements of the final survey.

3.8.3 Procedure

300 people ranging from high school pupils to undergraduate and post graduate students were emailed asking them to participate in the pilot study. 157 of them agreed to participate in the study. The data was gathered as follows:

- Users registered onto the system
- Demographic information was gathered
- Two learning styles tests were completed
- The results of these tests were used to build a profile for the user
- A lesson was presented according to the users profile
- Users completed the evaluation survey

3.9 Interviewing experts

Upon completing the pilot study, interviews with educationalists were conducted. Although the expected information from an interview is richer, there are two main

drawbacks to carrying out interviews; they are time consuming, and harder to conduct and analyse compared to a survey. Furthermore, they depend on the participants, if they are open minded, forthcoming the interview will be a discussion more than merely questions and answers. This is the main reason why interviews were only used for part of the study and with very few participants.

For the interviews, sampling was carried out with a purpose, as “the researcher samples on the basis of wanting to interview people who are relevant to the researchers questions” [207]. An argument from Silverman (2001) [211] is that “purposive sampling allows us to choose a case because it illustrates some features or process in which we are interested. It demands that we think critically about the parameters of the population we are interested in and choose our sample case carefully on this basis”. In the qualitative section of this research, the purposive sampling approach is based on choosing samples that achieve the researcher’s goal, resulting in "gaining deep understanding of some phenomenon experienced by a carefully selected group of people" [212].

3.9.1 Purpose

The interviews aimed to review and discuss results of the survey, pilot study, and provide the researcher with suggestions to assist the final study. Interviews with a small group were used to achieve two main goals:

1. To test, improve and enhance the final study following the pilot study.
2. To gain educationalists’ opinions, comments, and suggestions.

Four experts were involved in the evaluation of the various steps. They were asked several questions, which addressed the following points:

1. What is your opinion about the appropriateness of the presentation for individual users according to their learning styles?
2. How efficient is this method in terms of clarity and ability to test hypotheses?
3. Do you have any additional comments and suggestions?

The questions will be discussed in more detail in the following chapter in section 4.8.

Interviews were used as they enabled the researcher to go into more detail with the interviewees. The interviews were designed as semi structured to offer more flexibility allowing the researcher to explore issues as they were raised. Questions in the interviews can be explained more and if there are any ambiguities they can be resolved more easily. Participants in interviews can be encouraged to ‘tell the whole story’. This type of method offers the flexibility to gain as much information as possible from the interviewee who is expected to point out things not anticipated by the interviewer.

3.9.2 Procedure

After agreeing to participate, the survey was delivered to four Ministry of Education reviewers for their validation of the contents. One reviewer is a Director of Educational Development, and the other three are lecturers, two from the Department of Computer Science and one from the Department of Flexible Learning. As part of the interview, the interviewees were told how the experiment with users (participants) was to be conducted and the experimental steps that would be taken. The stages of the interview process are as follows:

1. Interviewees were emailed asking for permission to participate and to arrange an appointment, they were also given a sample of the questions
2. They were introduced to the selected learning styles
3. A demonstration of how the system presents tutorials was given
4. They were shown what learners did in usage
5. Before the conducting the interview, they were given a consent form to sign
6. They were given a short introduction about the research study, and the system
7. They were subsequently questioned:
 - Demographic information (age, gender, level of education)
 - Opinion about the evaluation method.
 - Opinion about the results of the pilot study.
 - Opinion about the main questionnaire.
 - Suggestion for the final study.

It was requested that all of the reviewers answer various questions as suggested by [213]. The questions were adjusted and asked accordingly in relation to the current study. Questions asked covered the interviewees opinions on the system and the evaluation methods, drawbacks related to the system or experiment, improvements that

could be made, the success of the research method in addressing the research questions and any final suggestions they would like to add. Overall, the Ministry of Education specialists responded with the appraisal that the questionnaire achieved its measurement goals.

3.10 Testing feasibility of the system Study

3.10.1 Sampling

It is not possible for any study to undertake research on the entire population, therefore the standard method is to choose a sample within the population under study and undertake the research in that sample. Due to certain factors such as quality, cost and feasibility, including all the components of a population in the research is rarely attempted, argues Lynn (1996) [214] : (a) Cost: of the materials, equipment and time. (b) Feasibility: if the results of the research are required by a certain date, there would not be sufficient time to include the whole population. (c) Quality: “Concentration of effort on a sample can increase the quality of the research which may then lead to more accurate results”.

According to Fowler (2005) [206] , making a sample involves selecting “a small subset of the population representative of the whole population. The sample procedure will give some members of the population a chance to be included in the sample while excluding others”. The sampling scope is coined by Lynn (1996) [214], as “The list of population members from which a sample is drawn”. This scope should be exhaustive over the entire population of interest.

Random sampling is where each member of the population has an equal chance of being selected for the sample. The method of selection should be independent of human judgement and is achieved by the lottery method, i.e. each member of the population is represented by a token which is placed in a container and mixed together. A sample of the required size is then selected. In this way it is simply by chance that someone is selected to take part. Alternatively, computers can be programmed to generate random numbers, which can be used to determine who (or what) is used in the sample. Opportunity sampling uses anyone who is available to take part in the research. For obvious reasons, this type of sampling is used in most student practicals. In the current study, convenience sampling was used as participants were chosen from a set of schools which responded to the initial invitation to participate in the study. Following on from there, the final data set was made up of only those who fully completed the survey.

Another issue is that of an appropriate response rate. Fowler (2002) [206] states that “There is no agreed-upon standard for a minimum acceptable response rate. The response rate depends on the nature of the sample, the nature of the study, how motivated people are, and how easy the task is for them.” Ary et al. (2006) [208] states that “Hegelson et al. found that an individual’s attitude toward research is an important factor in responding to a survey”. With regard to this study, therefore, selected participants should have some knowledge and experience of learning and learning styles theories or at the very least have some motivation to learn more about it.

Since the intended purpose of the study is to *use* the system, real learners are therefore the most appropriate participants. In the current study, the target users were computer students at higher education level. They were selected to participate in the study and allocated to each category randomly by the system. More than 120 students participated in the evaluation of the system, i.e. completed the survey. The evaluation exercise was carried out during one of their lectures as part of the module.

Although learners were informed about the evaluation in advance, participation was optional and some chose not to participate.

3.10.2 Purpose

The main purpose of this part of the study is to test the hypotheses and to answer the research questions, in an effort to help produce a model that presents tutorials according to learning styles that can be used in the current education system

3.10.3 Evaluation tools

Surveys were used because with large numbers of participants it is easier to use this method to obtain opinions about the system.

The final form of the survey was web-based and integrated with the proposed system. This type of survey design has a lot of advantages, such as free of cost, no unnecessary printing and the researcher avoids distribution and collection. It was short because most online participants have less time and patience to complete experiments and surveys.

3.10.4 Procedure

The experiment was intended to be conducted at Heriot-Watt University. Unfortunately the time chosen was not suitable for most of the students therefore alternative arrangements were made with schools in Saudi Arabia. The experiment took place in two different cities. Out of five schools contacted, only two participated: The College of Technology, in AlBaha and The Department of Education in Jeddah with additional collaboration from AlAlamyah Computer School.

The researcher gave a brief introductory presentation to the participants, before they began the experiment. During the presentation the following ideas were discussed:

- A brief description of what learning styles are
- The importance of learning styles
- Where to find more information about learning styles

The system was then introduced, which revealed the different learning styles, and the participants were required to carry out the experiment and fill out the survey.

The aim of this experiment was to examine whether the system was working properly in terms of whether or not it produced tutorials according to two combined learning styles for the participants' perspective. To examine if there were any differences between the learning styles, participants were divided into four groups:

Group A was given a lesson that was presented according to both of the participant's learning styles,

For Group B, the lesson was presented according to only one of the participants' learning styles (VARK).

For Group C, the lesson was presented according to only one of the participants' learning styles (Honey & Mumford).

For Group D the lesson was presented using none of participant's preferred learning styles,

By comparing the answers of these four groups, results will show if there is any difference between two, one or none learning styles.

3.10.5 Tasks

The participants had a range of tasks to complete:

Registering with the system

The first task was for users to register with the system. This allowed them to have their own login details and individual profile. They could register/sign up by clicking the “new user- sign up here” link which then navigated them to a form in which they entered their preferred username, password and other optional details. A consent form was also displayed on this page (users had to agree to participate in order to progress with the experiment).

Completing the two tests

The next task was to complete the VARK and the Honey & Mumford tests. To do this the user had to click on the links on the homepage after logging in with their unique username and password. To complete the tests they had to choose an answer from the options given to each question. Upon completion, the students profile was displayed in their profile and the system determined their learning style.

Studying the lessons/tutorials

Once the user completed the tests, they were presented a lesson which was tailored to their learning styles. They could, however, view the lesson content from other learning style perspectives by clicking on the links in the leftmost column. Overtime users’ learning styles could change via exploring the lesson content from other styles or retaking tests. Each time they login, their profile would be updated and lessons would be shown according to their new styles if they have changed. Lessons were presented according to the users own styles determined by the system by default.

Completing the survey

Users were then directed to complete an evaluation study consisting of a brief set of closed- and open-ended questions. The data was then used to investigate the research hypotheses in more detail.

3.11 Testing learning gains and satisfaction

The data collected in the main study was essentially used to identify if the system was working properly and presenting lessons according to individual learning styles. Data was analysed on the basis of this and are discussed in chapter 5. The learning gains and satisfaction of users were not specifically addressed therefore it was decided to further investigate this, hence leading to the additional study which is discussed in chapter 6. It was decided not to return to Saudi Arabia and use the same set of participants therefore Saudi Arabian Schools based in the UK were contacted to provide assistance in completing this final part of the study. This was necessary to avoid the risk of the data being influenced from any previous participation.

3.11.1 Procedure

Thirty two Saudi schools were contacted around the UK. Participants were invited by email; they were given the invitation in addition to an explanation of the project, and a hyper link to the website of the experiment. The language used in all of the contacts and the descriptions of the study was English.

234 people responded, however, only 149 of them fully completed the survey. For this study, learning gains was tested by posing a set of pre- and post test questions. Eight questions were asked before the lesson in relation to the content, i.e. they tested if the user had any previous knowledge or how much they knew about the topic “waterfall lifecycle” before using the system. After the lesson, the same eight questions were given. This was an important step in the analysis; the questions had to be the same in order to examine the learning that had taken place post-test. Learning gain was assessed by examining the difference between the results of the questions asked pre- and post-test. Further to the pre- and post-test questions, an additional confirmatory test was conducted to verify the difference between the groups in their learning gains. Nine different questions in relation to the content of the lesson that had not been tested before were asked in this test. These questions aimed to confirm the understanding of the content of the lesson.

Considering it had been established that the system could successfully cater for individual learning styles, from the results of Chapter 5, it was decided to evaluate the system and test the satisfaction of the users. This would essentially test the efficiency of

the proposed system of combining two learning styles to enhance the learning gains. The second aim of this study, therefore, was to test the satisfaction of the users from the four groups. There were 12 questions each with a 5-point Likert Scale to investigate satisfaction ranging from 1 (strongly disagree) to 5 (strongly agree). Questions measuring satisfaction were divided into three main concepts: Usability, Perception of learning, and Preference. If the system is not usable, any low learning gains might happen because of lack of usability. If perception of learning is low, that might also affect negatively the learning gains. And preference is one of the goals of using learning styles. The results of the study are discussed in chapter six.

3.12 Data analysis: Qualitative and quantitative research

The strategy associated with quantitative research tends to be more regulatory and doctrinaire than the flexibility associated with more qualitative methods, a feature noted by Wiersma and Jurs (2005) [215]. An ambiguous disparity appears to exist between qualitative and quantitative research, according to Bryman (2004) [207] ; despite the fact that they are at opposite ends of the spectrum, complementary factors exist between the realms of qualitative and quantitative research. Ideally, research methods should be varied according to the information that the researcher is attempting to establish (Silverman, 2001: 25) [211] . This is precisely what the researcher attempted to do when analysing the data in this thesis – the current study uses both qualitative and quantitative techniques to analyse the data.

People's language and behaviour are a prime feature of obtaining qualitative information, according to Maykut and Morehouse (1994) [212]. This comprises surveillance of participants' demeanour and activities, comprehensive colloquia, cohort interviews, and collating of germane records. The current study uses these 'tools' to carry out initial pilot studies, observing the participants and conducting interviews in order to finalise a survey that is relevant and structured and that measures what the researchers intends. Quantitative methods were then used to analyse various aspects of the qualitative data.

3.13 Validity and Reliability:

In experimental sciences, reliability is the extent to which the measurements of a test remain consistent over repeated tests of the same subject under identical conditions. An experiment is reliable if it yields consistent results of the same measure. It is unreliable if repeated measurements give different results. Reliability does not, however, imply

validity. That is, a reliable measure is measuring something consistently, but not necessarily what it is supposed to be measuring. According to Ary et al. (2006) [208] and Bryman (2004) [207], the key condition of research is validity. Validity, according to Bryman, is “concerned with the integrity of the conclusions that are generated from a piece of research” (28). For example, while there are many reliable tests of specific abilities, not all of them would be valid for predicting, intelligence per se. In terms of accuracy and precision, reliability is precision, while validity is accuracy.

The kind of validity evidence most apparent is that which is derived from content. Achieving this is possible through enlisting some colleagues "who are familiar with the purpose of the survey to examine the items to judge whether they are appropriate for measuring what they are supposed to measure" (P: 440), as well as whether “they are a representative sample of the behaviour domain under investigation” [208]. For this reason, four people who were familiar with the purpose of the survey were asked to give their professional opinions on the system in order that improvements may be made and the study be altered accordingly.

According to the definition of Krueger (1994) [216] & Fowler (2002:88) [206], validity is “The extent to which the answer given is a true measure and means what the researcher wants or expects it to mean”. In this respect, face validity can be accomplished providing an agreement exists between the researchers that a notion’s operational indicators are sound. Such elements as knowledge or ability tests; or questionnaire statements can be indicators (Bernard 2000) [217]. Therefore, building from Bernard’s argument, to verify and attain this validity, the survey was distributed to a number of researchers to verify and study its statements (as explained above). As argued by Davis (2002) [218], researchers and professionals exhibiting specialist judgment enables the attainment of validity throughout the course of devising a questionnaire. As such, specialist judgment in this study increased the face validity of the survey as issues with respect to format, language and comprehensibility of instructions were identified, enabling required improvement and minimising undesired mistakes in the fulfilment of the survey. In addition, a pilot study was conducted to further address these points supporting the validity of the final study.

According to Ary et al. (2006) [208], if the participants’ behaviour and responses are observed to correspond, the evidence for the research method’s validity is strengthened and reinforced. Participants were indeed observed during the pilot study in order to achieve this, further strengthening the validity.

There are two key variables that affect the validity, according to Ary et al.(2006) [208] :

- 1- The importance of the topic to the respondent: Participants that value the topic and are given information about it will provide more valid answers.
- 2- The level of anonymity for the respondent: Allowing the participants to maintain anonymity will achieve a higher level trust.

Both of these points were addressed in the current study in order to ensure the validity.

Among the strongest factors in the consideration of whether a measure is reliable is the internal reliability. According to Bryman (2004: 71) [207] , internal reliability is related to whether “the indicators that make up the scale or index are consistent; in other words, whether respondents’ scores on any indicator tend to be related to their scores on the other indicators”. This was addressed in the pilot study by asking certain questions throughout the survey and examining the consistency in the responses in order to assess the reliability of it.

For the semi-structured and focus group interviews, their reliability and validity were ensured through establishing an agreement with my supervisors on interview questions that were reliable, thus guaranteeing the credibility. Ensuring reliability was further supported by the iterative form of the interviews.

The risks to reliability and validity can be minimised by using certain approaches:

- A comprehensive array of research steps ought to be employed;
- Research questions should be chosen prudently;
- Considered sampling and choice of participants, events and schedule;
- The participants of interviews ought to be allowed to express themselves freely without inhibition of what they have in mind;
- An amicable and open atmosphere should be provided by each interview and case study;
- Anonymity and confidentiality should be guaranteed to the participants.

Each of these approaches were put into practice by the researcher in the current research methodology. Furthermore, a course of pilot studies assisted to verify and examine the reliability and validity of the survey, meaning that the survey statements ought to have achieved the intended measurements.

3.14 Ethical issues

In addition to validity and reliability issues, any social and scientific research project faces ethical issues. Bryman (2004) [207] claims that issues of ethics in social research are generally with respect to particular concerns, which have been conveniently decomposed by Diener and Cradnall (1978, in Bryman, 2004: 509) [207] , into four parts:

- If there is injury to participants;
- If there is knowledgeable agreement;
- If there is a violation of privacy;
- If there is any dishonesty.

It is vital that prospective respondents of the study are explained what participation will entail. Participants ought to be requested for their individual consent to participate by the researcher and be provided with adequate guaranteed confidentiality.

Identified by Fowler (2002) [206] , a number of ethical concerns are raised that potential participants ought to be informed about before being requested to respond:

- The organisation's name and the interviewer's name (of interview);
- A concise explanation of the research goals;
- A precise declaration of the degree of confidentiality protection offered for responses;
- Promises that participation is wilful.

This is further supported by several authors who explain the needs of a covering letter that ought to be distributed to respondents, Ary *et al.* (2006) [208] , highlighting the following features:

- The research's goal
- An appeal for participation

- The safeguards given to the participant
- The research's sponsorship
- Results guarantee
- Gratitude
- Appeal for prompt response.

The above ethical concerns were addressed in the current study with an appropriate cover letter designed to inform the participants of the researcher's goals and give them as much information as possible. To enlist participants for the interview, the researcher appended a note to the questionnaire requesting participants to willingly take part in subsequent planned interviews. The appended note detailed the ethical concerns that should be plainly declared in the consent form. A gatekeeper usually regulates the admittance to research participants; a researcher requires the assistance of the gatekeeper throughout sampling and the gathering of data. The head of the Technical Office for Studies and Development played this role in the current research.

In all forms of evaluation, it is important that evaluations are performed in an ethical manner and that all participants' (end users or expert evaluators) rights are protected [219].

The following guidelines ensured that this was done in the current study [219, 220]:

- Participants were informed of the goal of the study, how they would participate and what to expect. Issues like time to be taken, type of data to be collected and how it will be analysed were detailed.
- It was explained clearly that the information - be it demographic, opinions, or any other — disclosed or discovered during the evaluation would be confidential
- Participants were told that they had the right to stop during any stage of the evaluation if they felt like doing so.
- Participants were given an informed consent form to read and sign. The form explained the aim of the evaluation and any other relevant issues including the

fact that participants' personal details and gains will not be made public and will only be used for the stated purpose.

3.15 Summary

The current study took careful consideration of all of the factors discussed in this chapter in order to produce a fully functioning system and a sound and well structured survey. The methodology was robust with several pilot studies and interviews, with a focus to achieve reliable results. The system was constructed according to the researcher's goals and the survey was well designed and developed with careful wording. It was short to engage the participant's attention and avoid unnecessary blank responses. Data collection was secure and confidential. Careful thought was taken in relation to the analysis of the data – the researcher identified that both quantitative and qualitative methods were necessary and chose the appropriate statistics to evaluate the data.

The following chapter will continue to outline the system and discuss the results obtained from both the pilot study and interviews with experts.

Chapter 4

System

4.1 Introduction

The designed learning model employs two learning styles in order to determine the optimum presentation style of the tutoring material (lesson) for users. This chapter discusses the fundamental structural features and operational characteristics of the research model, followed by the results of the evaluation of the system in the form of the pilot study and interviews.

The concept of the system consists of four major components as discussed in Chapter 2: Domain Knowledge, Tutoring Model, Student Model and Communication Model. The high-level architecture for the system as shown in Figure 4-1 is based on the traditional Intelligent Tutoring System by Vasandani and Govindaraj [221]. Figure 4-1 below shows a high-level overview of the architecture of the system.

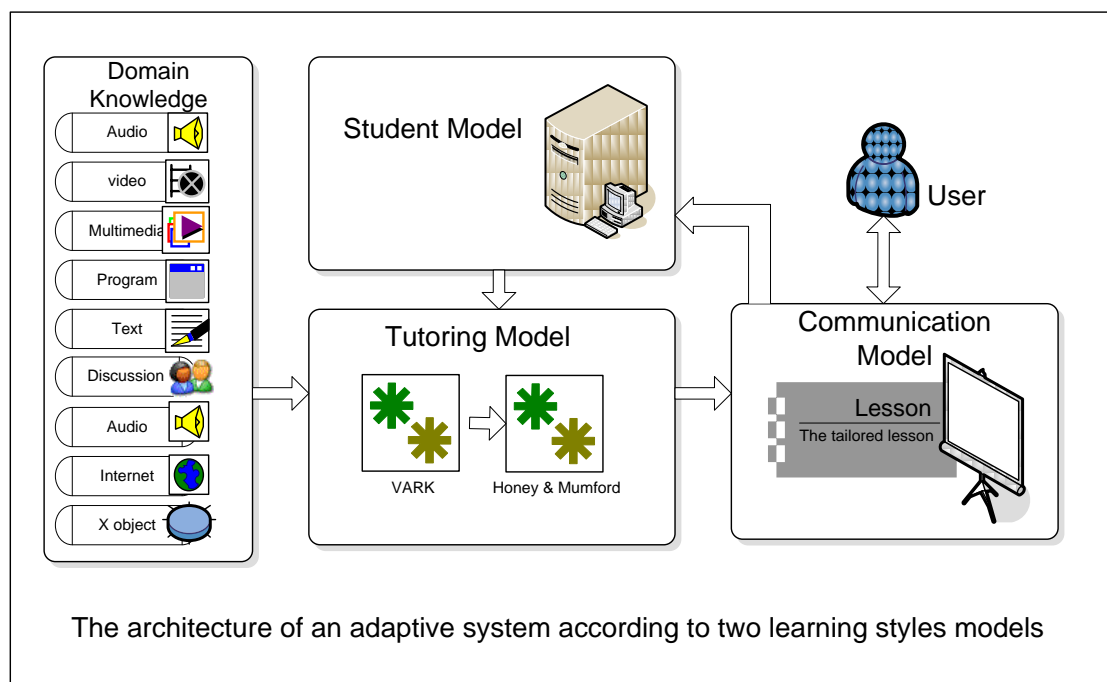


Figure 4-1: The architecture of the model

4.1.1 Revisited Aim and Hypothesis

The primary objective of the research model is to develop a system that presents tutorials to learners based on research conducted using ‘VARK’ (Visual, Aural, ReadWrite and Kinaesthetic), and ‘Honey and Mumford’ learning styles. The system is designed to be adaptive to the learning style of the particular individual using it. It helps identify the optimum learning style for a typical learner – whether a particular learning style, a combination of both, or a customised one would be appropriate.

It has been widely reported in the literature that learning styles help prepare better lessons. It was hypothesised that when presented with a lesson according to two of their learning styles, compared to with one or no personal customization, users will have a higher learning gains and express higher levels of satisfaction.

As outlined in the previous chapter, there are specific methodological steps of designing, developing and evaluating that the researcher followed in order to build the system that was used for the research studies. These will be described in further detail in the following sections.

4.1.2 The problem description or feasibility study

One of the most fundamental objectives of a teaching process is to effectively convey the subject or message to the learners. Traditionally it has been a face-to-face practice in which both the teacher and learner have an opportunity to go about the issue in a direct and flexible way. Amongst modern education techniques, however, e-learning is a rapidly growing trend. To enhance the e-learning process, learning models are being extensively used in e-learning systems. The practice across the board, however, is to rely on an individual learning model. This will almost certainly fail to address the needs of every individual. In order to ensure that an e-learning system takes into account as many details as possible in terms of the learning styles of the users, the current study aims to introduce more than one learning model. This research attempts to determine the added effectiveness of an e-learning system that is capable of adapting its presentation according to more than one learning model.

4.2 Requirements and specifications

The outcome of the requirement analysis is at the heart of this work. The success of any software development exercise greatly depends on it because it is the foundation of all other development activities such as design and implementation. Also, conducting good requirement analysis implies that users needs are properly identified and agreed, thus reducing possibilities for ambiguities that could lead to problems and failure of the project.

The aim of this section is to understand what the system needs in order to build the model and validate that the model will actually meet the both the system's requirements and the users' needs as identified by the researcher.

4.2.1 Functional requirements

The main function of this application is to deliver a customised lesson content based upon students' learning styles. Students are required to register to use the system. Once registered, students are then required to take two brief tests. These tests allow the system to decide upon the individual learning profile of each student. The tests taken are the VARK (Visual, Aural, Read, and Kinaesthetic) and Honey & Mumford. At the end of each test the system will quantify the student's response, however if the system is unable to quantify a student's profile more questions will be presented until a learning profile can be decided. Once a student has completed the tests the individual lessons will then be presented in an optimal fashion driven by the profile deduced during the tests.

During the lessons a student is free to take a lesson that has been judged as non-optimal for their particular learning style, they can then decide if the lesson was presented in a style that was compatible for them and their learning profile will be 'tweaked' accordingly.

The functional requirements of the system under discussion have been specified in Table 4-1 bellow. Each requirement is given a unique number F- # where F stands for functionality and "Use Case Label" column refers to the particular use case where the requirement is further analysed using use cases (see description below).

Table 4-1: Functional Requirement of the Adaptive System

F1	The ability to quickly register, log and take a test
F2	The ability to establish student model with results of VARK and H&M
F3	The ability to filter and order the content according to different Learning Styles (LS)
F4	The ability to use a needed CSS presentation according to different LS
F5	The ability to add scores to the student's profile. Depending upon student's selected preferences, respective scores are added to his profile by the admin.
F6	The ability to add scores to content's profile. In a fashion similar to the modifications in learning style, the system also allows modifications in lesson content through addition of scores.
F7	Administrator should be able to add, modify, and delete content
F8	The ability to retrieve student profile

Primary Use Case for the system

Use cases are descriptions of a systems behaviour, used to describe the functionalities of a system from the users' perspective; a use case describes “who” can do “what” within the system in question. In other words, it captures the relationship between the system and the user.

The use case diagram in Figure 4-2 displays the functionalities in the system based on Table 4-1.

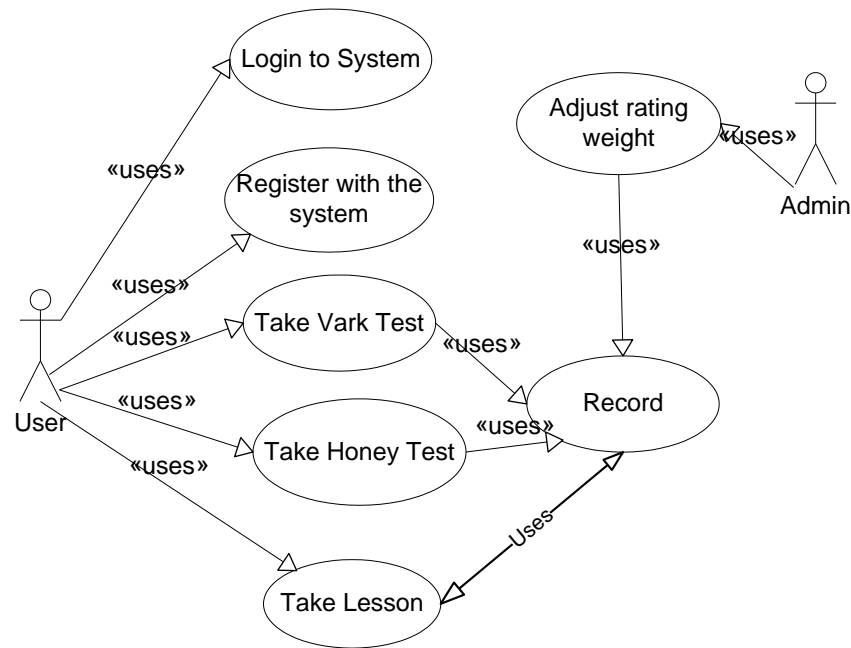


Figure 4-2: Use Case

4.2.2 Non-functional requirements

In addition to the functional requirements, there are non-functional requirements for the system as outlined in the following sections.

4.2.2.1 Portability

The adaptive system should be able to run on a PC browser because it is a web-based system.

4.2.2.2 Reliability

It is very important to handle errors properly so that the application does not freeze if anything goes wrong, e.g. when a user enters incorrect data, there should be a warning message, without freezing, allowing the user another chance to change the data.

4.2.2.3 Performance

It is widely perceived that users do not appreciate programmes that run slow even if they meet the desired requirements. In the designed program it has been ensured that the system exhibits a quick start-up - it takes less than six seconds to start up. This time is measured from the time the user starts the browser until the helpdesk is ready to be

used. Furthermore, a performance-quality-requirement has been put in place to ensure that users find it convenient to use the adaptive system.

4.2.2.4 Security

The system is capable of organising and protecting students' data. Students have to log in first to be able to use the system. Username and password management are built into the system.

4.3 Development tools

Database management systems are now a key part of daily life and they are increasingly contributing to the popularity of computers. A database is a set of associated data. According to [222], a Database Management System (DBMS) is a set of applications that provide facilities to make and manage a database. In this case, a number of technologies were employed to develop the dynamic web-based system. The system is web-based with a supporting database.

4.3.1 SQL and MySQL

MySQL is a high performing, reliable, multi-threaded and multiple user open source SQL DBMS. In November 1996 MySQL was made available for public use and ever since has been distributed with its source code. It has established itself as a super fast and trustable DBMS option for budding companies. The MySQL Manual states there are systems of production with more than 50,000,000 records. A transaction is defined as a group of coherent database modifications. An entire set of updates can be instructed to the database and then executed or undone as a unit, as specified by the SQL standard. MySQL only has partial compliance with foreign keys features. In the relational model, a foreign key is a valuable notion, being the way in which relationships are created in a relational database [223].

The system developed in this thesis is developed as a web-based application; therefore, it is not only a HTML and graphics application, it needs to be a website that is dynamic, enabled by integrating particular programming languages that control its flow. The use of a programming language provides handling of connections to the database and enables executing SQL queries for manipulating the database, as well as obtaining

results of certain queries that are then presented through a HTML page and transferred to the client.

4.3.2 *PHP*

Hypertext Pre-Processor (PHP) is a script language intended directly for web implementation. For implementation on Apache servers, it is the most widely used dynamic Web content technology. It enables the code to be embedded within HTML by writing certain tags. Its wide use also comes from its ease of use and the fact that it is free to obtain. PHP supports a vast amount of widely used databases as well [224].

PHP is the programming language that was selected for the current study due to its foundations as a server-side scripting language designed towards implementing dynamic web pages. The performance of PHP is very high, the development time is relatively short and so is the necessary learning curve. PHP is also compatible with the major platforms (Windows, UNIX and mainframes), and is interoperable with the majority of widely used DBMSs. The combination of all these features makes PHP a very good Web development option.

4.3.3 *Technologies*

In the current study, Apache was selected due to its flexibility as a web server. Owing partly to being free, Apache has the greatest share of the server market.

Gerken(2000) stated that “PHP was built with the needs of Web developers in mind [225]. Unlike other cumbersome, overhead-laden approaches, PHP is lightweight and focused on the Web - where it can solve complex problem scenarios quicker and more easily than comparable technologies.” My choice of DBMS is MySQL, the most popular Open Source DBMS. In October a Reasoning poll, carried out on the development community, showed that the company analysed the MySQL 4.0.16 production version more specifically. The quality of MySQL code was found to be six times better compared to the propriety code. It is apparent that there is a developing connection between the MySQL development team and that of PHP. All three of PHP, MySQL and Apache server can be used at the university and are free to download for PC home use.

AJAX

The acronym AJAX, meaning Asynchronous JavaScript and XML, is a collective term for a group of Web-based implementation languages for developing dynamic Web-based systems [226, 227], mainly in W3C standards (the specification XMLHttpRequest is created by WHATWG [228]): XHTML, which has more rules and smoother HTML rendering into XML.

CSS [229] is for markup and the addition of styles. JavaScript Document Object Model (DOM) enables the dynamic access and update of a document's structure, content and style.

XMLHttpRequest is an object that asynchronously sends and receives data to and from the Web server, minimising the necessity to constantly retrieve resources from the server. As data can be exchanged without demanding that the user reload the whole Web page, segments of data can be exchanged on demand. In addition, web page elements at any level of specificity can be updated to incorporate this. A system using AJAX works much like local applications running on the user's platform, which could lead to a distinctive user experience compared to traditional Web browsing.

The term AJAX represents a collection of steps for using certain available technologies, it does not refer to a particular technology. So far, no established standard for AJAX exists, however the introduction of the Open AJAX collective [5], backed by big establishments like Google and IBM, indicates that a standard using AJAX may be ratified shortly.

Both the user and developer can gain from the use of AJAX systems. Web-based systems have the ability to react to several user demands significantly faster and prevent the unnecessary exchange of unmodified data across the connection. In addition, as the technologies of AJAX are open, all JavaScript compatible web browsers support them, independently of Operating System platform; however, discrepancies in the implementation of the XMLHttpRequest amongst browser vendors leads to certain problems, where a number of vendors employ an Active X object whilst others implement a native solution.

In addition to choosing the specific technologies to assist with the development of the system, it was imperative that the researcher devoted time to choosing the appropriate set of learning models to incorporate into the system. Having carried out an in-depth literature review into the various types of learning styles, two learning styles that were deemed compatible were finally chosen, as discussed in Chapter 2. The following section will discuss these in greater detail.

4.4 Learning Styles Specifications

The system designed for the current thesis incorporates two models of learning styles: VARK [4, 65], and Honey and Mumford [5]. Each one of these learning models has four styles which were put into consideration when building the system.

4.4.1 VARK

As mentioned briefly in Chapter 2, there are four different subgroups within this learning style [4]. A more detailed description of these is given below:

Visual: These people prefer information presented in symbolic, written or numerical form. They prefer to draw this information from visual tools such as graphs and charts to support their learning process.

Aural: They prefer listening to information presented in forums such as lectures, tutorials, discussion groups, one to one conversations and tapes as their primary learning modality. Their learning comes predominantly from hearing information in the spoken word.

ReadWrite: They learn best through reading and writing. That is, they prefer to learn through words presented in the written form, either through reading written words or symbols for information input, or writing written words or symbols to present information as output.

Kinesthetic: They experience information in the manner it is presented, and then put the learning into practice. They will experience the learning whether the practice experience is real or simulated. They draw from a range of learning experiences, such as reading, writing or aural. The focus of learning comes from their connection to the

experience, irrespective of the type of experience. Hence they can learn through the direct experience, by example, or through putting the learned theory into a simulated experience or practice.

4.4.2 *Honey and Mumford*

In this learning style [5], there are also four different subgroups:

Activists: They are basically proactive people, who are not afraid of adventure and trying new things. They are creative in approach and like to face new challenges. They learn best in the midst of new and challenging experiences and when solving new problems.

Reflectors: They learn best in calm and controlled circumstances. They are a deep thinker, who observe, collect information and consider all possibilities, before reaching a final decision. Reflectors learn best when they have the time and space to observe, analyse and report back their observations

Theorists: They are an objective and focused problem solver. They use logic to think through problems in a step by step manner. Give them a complex problem and they will relish in the task. They will pull apart ideas and concepts to find the answer and solve the problem.

Pragmatists: They are always open for any new experience, so long as the commentary is short and to the point. They are a practical thinker and need time saving techniques to put into practice as well as clear instructions and feedback.

After carefully choosing these learning styles, it was time to implement them into the system and build the first prototype.

4.5 System Implementation

As mentioned briefly above, the designed system gathers information from participants of the study and builds a student profile by assigning one of the four styles from each model to the user based on two tests taken by the users. The user's learning style is determined as the style that possesses the highest score in each of the two tests. A lesson is then tailored according to the learning styles that best suit the user. The scores

can change through usage of the system through the option “click here if you like this” link which automatically adds points to the learning style at hand. The number of points is decided by the administrator of the system. These numbers are scores added to the profile of the user, and to the profile of the content. If a certain style surpasses the style with the top score then this style will become the user’s new learning style. Each lesson layout consists of three columns.

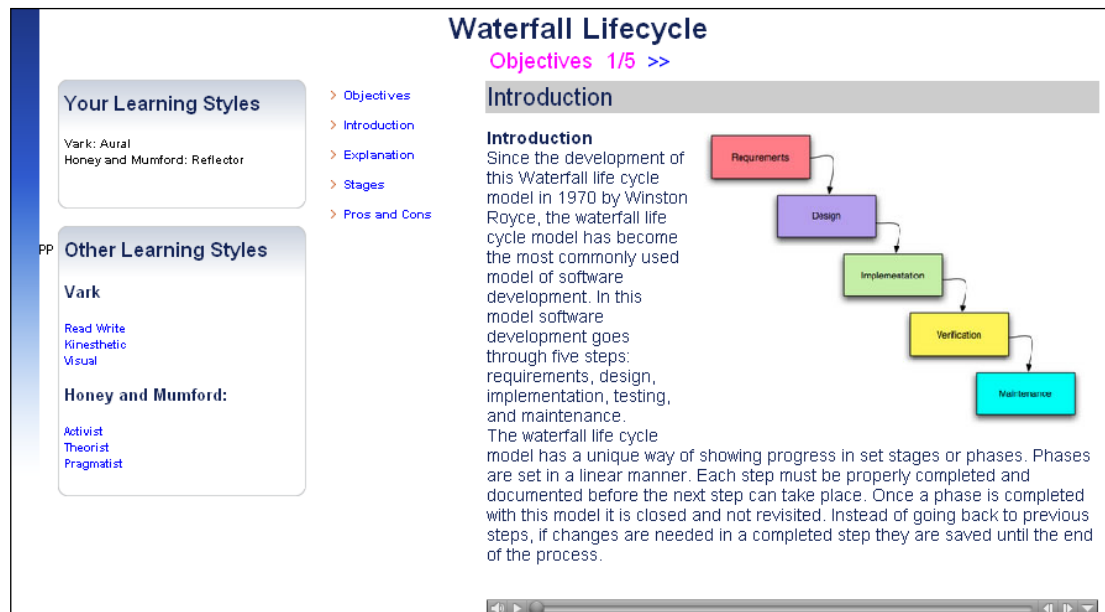


Figure 4-3: A lesson page

The section "your learning styles" in the first column in Figure 4-3 highlights the style chosen by the user for displaying the lesson; these are set to the user’s learning styles assigned by the system by default. Below it, the section "other learning styles" displays the remaining VARK and "Honey and Mumford" styles. The user can click on any of the alternative styles to view the lesson from a different style viewpoint. The user may revert back to their original styles by clicking the “my styles” link.

The second column shows the order in which the lesson content is displayed. This can change depending on the users learning styles – the order of presentation of lesson components is also changeable depending on the learning style of the student. The third column displays the content of the lesson which is displayed differently according to the particular VARK style. The lesson content also has a user profile and an ID which means that if the majority of users with a particular learning style say they like a certain content ID via the “click here if you like this”, then points are added to that content's

profile of the particular learning style and the system will mark it as being suitable for users. This practice not only allows the learning styles to be tailored but also the lesson content to meet students' requirements.

With respect to the lesson content, it is worth mentioning that initially the contents are selected by the administrator of the system. The administrator put the initial tagging for each content based on the literature review and the learning styles chosen. For example, audio files are suitable for aural students, pictures are suitable for visual, and diagrams are for kinaesthetic and so on. Any deficiencies with the initial tagging are then addressed in the light of the students' preferences.

4.6 Waterfall cycle

The waterfall lifecycle is one of the methodologies that is intended to assist the developer achieve their development projects starting from gathering the requirements until testing the system. It contains the following stages: Requirements, Design, Implementation, and Testing.

There are several reasons why waterfall cycle was selected as a lesson for the current research. Firstly, it is important for individuals who are in the field of computing. Secondly, it can be understood by non-computer field people and can be useful for them as well. Knowing waterfall lifecycle means knowing a method to plan projects, any project, even if not a programming one. Lastly, there are various ways to explain it - using words or illustrations as well as audio and visual aids. This is of key importance for the current research considering the fact that different types of learning styles are combined in the system. By using the waterfall cycle, different methods of presentation can be used whilst keeping the topic constant. This in effect will eliminate the effects of the 'topic' variable rather than having to use different topics for each learning style incorporated in the current system.

4.7 The first prototype

Having incorporated the two learning style into the system design, a prototype, which will examine the planning, requirements and show how the final system will look when completed, was built. The first prototype allows flexibility in reorganising the future work of the project. At this point, as discussed in the previous chapter, eight PhD colleagues were the evaluators, offering their assistance to act as users. They were

encouraged to speak out-loud while carrying out the test, discuss and criticise the problems that they experienced. The second stage involved developing the first prototype to get an initial image of what the structure would be, how it would be used, and to gain an idea of the work that would be required. As outlined above, the system offered two tests, both of which had to be completed. The computer then took the results of these two tests and built a profile for the user. After that, the system offered a lesson according to the user's profile.

Initialising Profile

The system creates a profile for the user. Information about the user is stored, including the results of the two learning styles tests presented at the initial login.

Checking the profile

The system loads information from the profile. Some of this information will instruct the system in the creation of the presentation.

Presentation

Based on the information stored in the profile and the content stored in the lesson, the system creates a customised presentation for the user. The presentation would be primarily of the preferred presentation style, or at least the explanation/support would be of the preferred style, based on the results of the initial tests.

4.7.1 Purpose

There were three goals behind developing the prototype. The primary goal was to examine the usability of the web-based system that will be used for the ongoing PhD project. The second goal is to obtain a general idea of the difficulties that might arise in the future for the main experiment. The third one is to gain and explore the opinions of the users. The importance of evaluation is a necessity at this stage of the research. It provides a lot of information that helps in measuring the progress and tests the expectations. It helps to enhance and improve the model. It reflects the true picture of the system from the user's point of view.

4.7.2 Evaluation tools

The instrument used for the evaluation study was a web-based questionnaire. Users interacted with the system and at the same time they filled in the survey. The survey questions were answered by utilising a five-point Likert scale, ranging from strongly agree to strongly disagree.

4.7.3 Data

The data was gathered in several ways. Following a registration screen where the demographic data was gathered, there were two learning styles tests to be completed. The results of these tests were stored in the database. The feedback of the tests and the feedback of using the system in general were also stored in the database of the system.

4.7.4 Participants

The target users were students at higher education level. Of the 300 people who were emailed, 157 responded. After reviewing the responses only 70 questionnaires were accepted due to partial or total incompleteness. A total of 70 participants engaged and accepted to complete the tests as part of this usability evaluation study. Table 4-2 below shows the demographic information collected from participants through the web-based system. 53 males (75.7%) and 17 females (24%) participated. 49% of the users' main work or area of study was computing (49%), compared to 51% who were not studying computing (51%).

Table 4-2: Summary of demographic information of the participants

		Total	%
Sex	Males	53	76
	Females	17	24
Discipline	Computer	34	49
	Non Computer	36	51
Educational Status	High school	3	4.3
	Undergraduate	25	36
	MSc	25	36
	PhD student	12	17
	Lecturer	2	2.9
Ages	<18	2	2.9
	18-24	19	27
	25-34	39	56
	35-44	6	8.6
	54-55	1	1.4
	>55	3	4.3

4.7.5 Results

Various aspects were addressed in the evaluation in order to gain as much information as possible to assist with developing and improving the prototype.

4.7.5.1 Learnability

Table 4-3 shows the questions that were asked to test learnability:

Table 4-3: Learnability

Questions	Agree	Neutral	Disagree	No answer
It was easy to learn to use the system and there was enough information to show how to use the system.	55.7	15.7	2.8	25.7
The information retrieved by the system was effective in helping me to complete the tasks.	44.2	25.7	2.8	27.1
Whenever I made a mistake using the system, I could recover easily and quickly.	35.7	18.6	7.2	38.6

The questions included in this section of the questionnaire, were designed to determine the opinions of the participants on the learnability of the website, i.e. if there was

enough information to show them how to use the system, if the information retrieved by the system was helpful to the participants completing the tasks, and whether it was easy and quick to recover when a mistake was made.

Table 4-3 shows that a over 55% responses agreed that the website was easy to learn from for new users. Positive feedback focused on many aspects of the learnability of the website such as good presentation, and clear and well set out objectives. Some problems were encountered, although they sometimes appeared to be to do with personal choice, as some users liked the layout of the website, whilst some thought it could be improved. In general, the results support that the website is learnable.

4.7.5.2 *Ease of use and usability*

This section of the questionnaire was included to obtain the opinions of the participants about ease of use of the website, the organisation and layout, and the navigation. It also allowed respondents to include suggestions for improvements or changes.

Navigation is one of the main elements in the success of a website. Users should be led easily to the required information and back to the homepage. Good navigation allows the user to see where they are located on the site. The layout and the organisation of a website are important features, which should be taken into consideration. A well designed website conveys a greater feeling of organisation for the user. The following questions were asked to test ease of use and usability.

Table 4-4: Ease of use and usability

Questions	Agree	Neutral	Disagree	No answer
The organisation of information presented by the system was clear and pleasant to use.	61.4	10	2.8	25.7
It was easy to navigate and to find the information I needed.	51.4	17.1	2.8	27.1
I was able to complete the Learning styles Tests easily.	81.4	17.1	0.0	01.4

A large percentage of responses were positive, as Table 4-4 shows. Users who did not find the site organised included helpful suggestions on technical issues (directions of use and instructional complications), the layout (the positioning of the options on the

page), and presentational issues (making the website more fun and enjoyable by using more colour or different fonts).

4.7.5.3 *Functionality*

This section of the questionnaire was useful in ascertaining the opinions of the participants about the functionality of the system. Opinions about these operational elements varied greatly. Positive feedback regarding the second lesson focused on it being easier to understand, less time-intensive, and that the content was often more suited to, and therefore preferred by, the user. Negative feedback was rare, but when provided was constructive, and tended to be from those participants whose two lessons had been similar or the same.

Table 4-5 below shows that a large percentage of responses shows that users who responded were able to discover their learning style from the website, and were convinced about the value, for them, of the information produced by the system.

Table 4-5: Functionality

Questions	Agree	Neutral	Disagree	No answer
The system was able to convince me that the recommendations and presentation are of value.	38.6	18.6	05.8	37.1
The lesson was presented according to my learning styles (when the lesson was according to their style)	35.8	20	04.3	40.0
The lesson was presented according to my learning styles (when the lesson was not according to their style)	32.9	20	11.4	35.7
I was able to discover my learning styles	64.2	27.1	07.1	01.4

Of the total number of participants who answered the questionnaire, a large percentage of responses noticed that an effort was made to differentiate between a lesson given in accordance with a users learning style and a lesson given against a users learning style. An unexpected finding was that users did not reject the lesson that went against their learning styles. This may indicate that the users did not have sufficient knowledge about learning styles and as such were unable to identify when the system did or did not present a lesson according to their learning style. Indeed, 40% of users gave no answer to the question that the lesson was presented according to their learning style even when the lesson *was* according to their learning style.

All of the feedback gathered from the survey was duly incorporated into the next model.

4.8 Interviewing Experts

The final stage in the development of the system was to seek expert opinion as this is very important, especially in the assessment phase of any study. It was necessary to be reviewed from different points of view if the study was to be successful. The opinions of the experts, based on their experience and knowledge, were very useful in determining if the study had reached its aim and objectives. The information gathered from the interviews was also significant for the part of the study where suggestions for further research were made.

4.8.1 Participants

The sample size was decided based on Nielsen's suggestion of 3 to 5 participants in each subgroup. As discussed previously in the methodology chapter (Chapter 3), the more users you add, the less you learn as ideas will be repeated over and over again. According to Neilson, "after the fifth user, you are wasting your time by observing the same findings repeatedly but not learning much new"[230]. As a result, four experts were involved in the analyses in the evaluation stage. Table 4-1 shows the participants in the interviews.

Table 4-6: Participants in the Interviews

Interviewee	Title	Field	Experience
Interviewee1	Lecturer	Computer Science	23 years, lecturing, programming, and psychology of programmers
Interviewee2	Lecturer	Computer Science	7 years, lecturing, web-based systems, Quality of service in Internet.
Interviewee3	Director of Educational Development	Education	30 years experience, has significant experience of curriculum design, and the development of teaching and learning. Has been external examiner for five universities.
Interviewee4	Lecturer	Flexible Learning	10 years, learning technologies, VLE, Flexible Learning, Designing Online Learning Environments, multimedia programming

4.8.2 Results

The purpose of the interviews was to review and discuss the results from the survey and the pilot study, as well as to prepare suggestions to be implemented into the final study. The following sections discuss the answers given to the different questions which address various aspects of the study.

4.8.2.1 The system and the evaluation methods

When asked about their opinion on the system and evaluation methods: What is your opinion on the system and the evaluation methods? All interviewees gave positive feedback. Interviewee 1 found the system very interesting, but showed concerns regarding the application of the system in education. He felt that the system could be potentially too costly to be implemented in education, but some larger corporations may find it a useful tool. Interviewee 3 also agreed that the study is very interesting and that it seems to address a significant learning challenge. He felt that the system could have good application in teaching programming code basics. The response of Interviewee 4 was that the evaluation method is quite good.

4.8.2.2 The Student Model

Participants were asked “What do you think of the idea of giving each user a specific tailored lesson, which is suitable for him, and over time his profile changes and the system adapts to this, what do you think of this idea?”. Interviewee 1 agreed that the idea was good, but was worried how the time-scale of the changing learning processes of individual participants would take effect and as such have any affect on the learning process. Interviewee 2 said that he liked the concept in principle. He was concerned about accommodating changes in learning styles not just over time, but perhaps from one subject to the next. Interviewee 3 felt that the idea was good. He suggested that the system can be used to identify a user’s learning style and based on that information, direct them towards a career that would accommodate that style, or even one that does not accommodate their learning style.

4.8.2.3 Evaluating the system

When they were asked “What do you think of my method to evaluate the system, the production of learning for the first time and getting them to complete the questionnaire this way?”, Interviewee 1 was concerned with asking respondents the question 'do you

like this?'. He thought that this should be more of a qualitative question, instead of a multiple choice response. Interviewee 2 was of the opinion that this appears to be a very good combination of learning processes and knowledge acquisition. Interviewee 4 agreed that the system appears to be very good.

4.8.2.4 Drawbacks

Interviewees were asked “What are the drawbacks you found in the system or experiment? What do you think should be done to reduce the drawbacks of the system?” Interviewee 1 considered asking those questions as a big first step of a step-by-step process that would develop. Interviewee 2 said that from what he had seen so far, he could not find any drawbacks, but he would have to look in further detail to be absolutely sure.

4.8.2.5 System Improvement

The interviewees were also asked about making improvements to the system: “What do you think can be done to improve the system?” Interviewee 1 felt that the approach of gathering information from an individual, giving them a learning experience that is tailored to their profile and re-testing them, was a sensible approach. Interviewee 2 had an idea of broadening the research by including a more diverse sample of people outside the computer field. He was unsure, however, of how necessary this was. Interviewee 3 thought that it would be very interesting to try the system using different lesson topics such as system theory or programming. He also felt that an experiment should be added which would test someone’s abilities to do something, rather than someone’s abilities to understand something. In this way, the ability to learn would be based on how well they completed the experiment at the end.

4.8.2.6 Improvement of system evaluation

A question was asked about the methodology: “The methodology of the evaluation system, what can be done to improve the method?” Interviewee 1 supported the opinion that professionals should be used as participants instead of undergraduates. This would be better because, in his opinion, the professionals would be more mature and more concerned about their own particular learning styles and therefore the results might be better. The researcher believes that this is the interviewee’s opinion and that is not necessarily true. Interviewee 3 felt that other topics and lessons should be experimented with.

4.8.2.7 Features of study to be acceptable

Participants were asked, “What features does this study lack to be acceptable”? Interviewee 1 felt that the questions asked were offering very little data, and that offering some qualitative responses to the results and asking more explicit-response questions would help. Interviewee 2 was of the view that the study did not lack anything. Interviewee 4 liked the study, especially if evidence that the system is actually adaptive to individual learning styles could be shown.

4.8.2.8 Research Method

They were further asked “Do you think this research method was successful in addressing the questions”? Interviewee 1 agreed it was, but was concerned that the amount of qualitative data that was retrieved from this study was limited based on the amount of effort the participants invested. He suggested that there might be a way of collecting better data without having to ask the participants to spend so much time. Interviewee 2 shared that he always had a problem with learning systems as they are always either too black or white, but it appeared to him that this system actually addressed that problem. Interviewee 4 liked the method, but recommended that the researcher should be thinking about his hypotheses and adjust the questionnaire in order to get the responses that he needs to get the questions answered.

4.8.2.9 Study improvement

When they were asked “Do you have any advice for me to improve anything in my study?” Interviewee 1 felt that more qualitative results would be more useful than getting a larger number of students participating. Interviewee 3 supported the opinion that even though looking at different age groups with different experience levels would be useful, the most important thing would be to try different topics.

Interviewee 1 liked the idea of the survey, but Interviewee 2 was not sure if all the questions were as useful as they could be. Interviewee 2 was so far impressed by the system and felt that what could improve it was to provide somewhere a definition of what each learning style means. Interviewee 4 was impressed by the concept, especially because it addressed two elements of learning style and not just one.

4.8.3 *Summary of responses to the interviews*

Once the interviews were conducted and the study was completed, a few interesting facts emerged.

A concern that arose was that of an interviewee who questioned the learning process in reference to the time-scale. A suggestion that was received was that the system could be used to pin point each participants learning style, which could mean that recommendations toward a career path could be more easily defined. Another idea that was made by Interviewee 2 was that it is useful to have the sample of participants wider and outside of the computer field even.

The interview allowed both weak and strong aspects of the study to be explored. When Interviewee 4 was asked for his opinion, he felt that the study needed to be adjusted, namely the research questions. He felt that the hypothesis needed to be studied more so that the questions would better elicit the responses needed for a definite answer. There was not enough space given for questions that needed complete answers and the researcher found that this area also needed to be expanded on. As such, the hypotheses were re-evaluated and re-defined in clearer terms. In this way, the research was given the advantage of being explored and the direction that should be taken both in terms of support of and, or following the research.

It was clear that the method to evaluate worked. Once the interviews were completed, most of the answers of the interviewees showed that they were pleased with both the system and the method. One felt there was nothing that was lacking in the study and another could not see any current drawbacks.

The system was found to adapt to each person or individual and their particular learning patterns and style; this was another plus noted by the interviewees. Another interviewee was impressed and especially taken with the fact that not one, but two learning styles were addressed through the research.

In principle, the system was approved by the interviewees and was confirmed to be working in the right direction to achieve its goals. At the same time, there were some minor improvements recommended by some of the interviewees – for example changes

in screen formatting and rephrasing of some of the instructions - which have been appropriately incorporated in the light of their feedback. Although there were many interesting points that came from the study, the fact is that time is limited. Some of the ideas suggested were incorporated into the study as best could be done within the available time frame; other factors that required more work could not be changed and as such could be addressed in future work.

4.9 Summary

This chapter described the fundamental structural features and operational characteristics of the designed learning system. The main function of this application is to deliver a customised lesson content based upon students' learning styles. The primary objective of the research model is to develop a system that presents tutorials to learners based on research conducted using 'VARK', and 'Honey and Mumford' learning styles. The system was designed to be adaptive to the learning style of the particular individual using it. Furthermore, the system helps identify the optimum learning style for a typical learner.

The system starts based on a student's learning profile and then continues to keep it relevant by dynamically changing the profile as the student's learning type changes over time. This is accomplished by supplying out of profile content for the student to review and then decide upon how well it fits with their learning style. The user's learning style is determined as the style that possesses the highest score in each of the two tests. A lesson is then tailored according to the learning styles that best suits the user.

A first prototype was built to examine the planning requirements and show how the final system would look when completed. A pilot study was carried out to provide a preliminary evaluation of the system. Interviews were also carried out with experts in the field as part of the evaluation to further provide valuable suggestions based on their experience and knowledge. From the comments made, it was found that most of the objectives of the study were met and that the survey fulfilled its purpose. It also acted as an assessment of the level of success in terms of both ideas and the application of those ideas. The results of both evaluation studies were used to improve certain features of the study – both the system and the survey.

The following chapter will unfold the results of the main study, focusing on whether the system is working properly and presenting lessons according to individual learning styles.

Chapter 5

Testing feasibility of the system

5.1 Introduction

Currently, in the existing literature on e-learning systems, there are several studies which have been developed to quantitatively evaluate adaptive educational hypermedia (AEH) systems; however, very few of these studies have carried out statistical analyses to test the effectiveness of adaptation mechanisms as already discussed in Chapter 2.

This apparent lack of quantitative studies in relation to adaptation mechanisms makes the justification of the research objectives of the current study even stronger. It is clear that a systematic experimental approach, utilising quantitative methods and statistical analysis of data, must be employed in order to find out objectively, whether using learning styles is an effective means of providing personalisation to users. This chapter will present the experimental data in relation to the system developed for users using two learning styles as discussed in the previous chapters.

There is no point in building a model for an educational system that adapts to learning styles, without testing the feasibility and accuracy of it. The aim of this thesis therefore, is to develop a model with two different models of learning styles and consequently it was hypothesised that when presented with a lesson according to two of their learning styles, compared to with one or no personal customization, users will have a higher learning gains and express higher levels of satisfaction. This hypothesis will be studied in chapter 6.

It is important to test if the system is showing the preferred learning styles. This chapter is to identify whether or not the learning styles are recognised by the users. It is important that the learning system takes into account the appropriate details of the learning styles of each user. For this reason, it has to be determined whether the educational system that has been developed is able to adapt its presentation according to more than one learning styles model.

The recognition of the learning style was necessary to do further steps toward the study. When learners recognise that lessons were according to their learning styles, the author

understood that the system was successfully working. Learning styles theory is based on the impression, preference and opinion of the learner, and how he feels. His point of view and his opinion about presentation are important.

The remainder of this chapter presents the methodology and results of the main evaluation study in relation to the current system.

The following sections will discuss how the experiment was conducted, including details on the participants and the variables used to answer the research question. It will give details of the analyses used and the results will be discussed further on in the chapter.

5.2 Testing for correlations between the two learning styles models

It is often interesting for researchers to know what relationship exists, if any, between two or more variables. Before commencing the study, it was necessary to check whether or not the two learning styles were in any way correlated. It is important at this point to examine whether the one model of learning styles is predicting the other. It has to be confirmed that the two learning styles being used in this study are completely unrelated, so that there is no overlapping of learning styles in order to give the user a wide range of learning styles to cater the learner from different perspectives. It is also worth investigating if any of the learning styles within each model have a relationship with other learning styles, i.e. any of the four sub-sections within VARK are related to any of the four sub-sections of the Honey & Mumford. In order to address these points, a Pearson's correlation test was used. The results of the test can be found in Table 5-1 below.

5.2.1 *Correlation between the VARK and Honey & Mumford Methods*

Each participant was given a survey about learning styles. The goal in this section was to find out if a correlation exists between the learning styles. The correlation is calculated by using the Pearson's Correlation test. The correlation values range from -1 to +1. The higher the values indicate the better fitting models to the data. For example, a correlation of +1 indicates a perfect positive linear relationship between variables, while a correlation of -1 indicates a perfect negative relationship between the variables. The

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correlation coefficient (r) is a commonly used measure of the size of an effect: ± 0.1 represents a small effect, ± 0.3 is a medium effect and ± 0.5 is a large effect.

From Table 5-1, it can be seen that none of the characteristics of the VARK method correlate with the characteristics of the Honey & Mumford method. This can be identified by looking at the first four columns in relation to the last four rows - all of the p values are greater than 0.05 indicating that there are no significant correlations between the different characteristics across the two different learning styles. It is therefore possible from the data to confirm that the study is utilising two unrelated models of learning styles. We cannot predict one model from the other. There is no correlation between the learning styles of VARK and Honey & Mumford.

Table 5-1: Correlations between VARK and Honey & Mumford learning styles

		Correlations							
		Activist_p	Reflector_p	Theorist_p	Pragmatist_p	Visual_p	Aural_p	ReadWrite_p	Kinesthetic_p
Activist_p	Pearson Correlation								
	Sig. (2-tailed)								
	N	129							
Reflector_p	Pearson Correlation	-.222*							
	Sig. (2-tailed)	.011							
	N	129	129						
Theorist_p	Pearson Correlation	-.368**	-.344**						
	Sig. (2-tailed)	.000	.000						
	N	129	129	129					
Pragmatist_p	Pearson Correlation	-.540**	-.279**	-.224*					
	Sig. (2-tailed)	.000	.001	.011					
	N	129	129	129	129				
Visual_p	Pearson Correlation	.006	.136	-.013	-.117				
	Sig. (2-tailed)	.948	.124	.883	.186				
	N	129	129	129	129	129			
Aural_p	Pearson Correlation	.075	-.114	-.104	.106	-.406**			
	Sig. (2-tailed)	.401	.198	.242	.232	.000			
	N	129	129	129	129	129	129		
ReadWrite_p	Pearson Correlation	-.008	-.062	.075	.011	-.512**	-.317**		
	Sig. (2-tailed)	.924	.483	.398	.901	.000	.000		
	N	129	129	129	129	129	129	129	
Kinesthetic_p	Pearson Correlation	-.101	.049	.059	.006	-.171	-.347**	-.210*	
	Sig. (2-tailed)	.253	.578	.505	.943	.053	.000	.017	
	N	129	129	129	129	129	129	129	129

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

The rest of the table shows the results of examining the four learning styles within each of the two models, i.e. the first row shows the correlations between activist from the Honey & Mumford with the other styles, and so forth down the rows and along the columns, until all of the styles are compared with each other.

5.2.2 *Correlations within learning styles:*

The following sections discuss the results of the correlations between the four sub-sections within each of the learning styles.

5.2.2.1 *Correlations within the VARK learning style*

It appears from Table 5-1 above that there is a relationship between the four characteristics within VARK. The relationship between the Visual learning style and the Aural, ReadWrite, and Kinesthetic styles is negative. Respectively the Pearson's correlation values are $r=-0.406$, $p<0.001$; $r=-0.512$, $p<0.001$; and $r=-0.171$, $p>0.05$. These results indicate that there is a significant negative correlation between the Visual learning style and the Aural style, and between Visual and the ReadWrite learning style as both of the p values are less than 0.05. There is no significant relationship, however, between the Visual and Kinesthetic styles, although the p value is approaching significance ($p=0.053$) and could perhaps differ with a larger sample size.

The same negative correlations were found between Aural and ReadWrite, $r=-0.317$, $p<0.001$ and between Aural and Kinesthetic style, $r=-0.347$, $p<0.001$. There was also a significant negative correlation between the ReadWrite style and Kinesthetic style, $r=-0.21$, $p<0.05$. The values obtained generally show a medium relationship between the variables, although the final correlation between the ReadWrite and Kinesthetic style shows a weak correlation, as the value is less than 0.3.

Each correlation described above has a negative value, so this indicates that as the score increases in one characteristic, the score decreases in the other. Although it can be concluded that they are negatively related, it cannot be said that a high score in one characteristic *causes* a low score in the other. Correlation does not indicate the direction of causality.

5.2.2.2 *Correlations within the Honey & Mumford learning style*

Looking at Table 5-1, it can be seen that there are significant correlations between the characteristics within the Honey & Mumford learning style. There is a significant

negative correlation between the Activists learning style and the Reflectors, Theorists, and Pragmatists styles. Respectively these correlation values are $r=-0.22$, $p<0.05$; $r=-0.368$, $p<0.001$ and $r=-0.54$, $p<0.001$. There is also a significant negative correlation between Reflectors and Theorists, $r=-0.344$, $p<0.001$; between Reflectors and Pragmatists, $r=-0.279$, $p<0.001$; and between Theorists and Pragmatists, $r=-0.224$, $p<0.05$. The values range between 0.2 and 0.5 which indicates that some of the correlations are weak while others are medium.

Based on the results obtained, it is valid to conclude that each learning style is unique, as the scores are negatively correlated between the four different characteristics. In other words, as the score in Activist increases, the score in the other characteristics decrease, inferring that the Activists learning style will not be a part of one of the other styles and vice versa. In general, therefore, it can be concluded that all the four learning styles have been grouped very well.

Having assessed the compatibility of the two learning styles models, the research could progress to the system development and evaluation stages respectively.

5.3 Method of Data Collection

After the development stage of the system, the opinion of real users was explored to make sure that the system was achieving its desired purpose, i.e. whether or not users recognised that the system was presenting the lesson according to two of their learning styles. Analyses were carried out in order to determine whether the users were able to differentiate between lessons that were presented to them according to a personalised learning style and those which were not.

5.3.1 Participants

Initially, the experiment was intended to be conducted at Heriot Watt University. Unfortunately the timing was not suitable for most of the students as it was set during the last two weeks of the term and all of the students were busy with project deadlines. Since students would be leaving after the end of term, another location was chosen. Five Saudi Arabian higher education schools were contacted, of which two responded: The College of Technology in AlBaha, and The Department of Education in Jeddah, with the added cooperation of its computer school.

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The initial number of students from one of the schools was 102, but only 91 fully completed the survey. More participants carried out the experiment from another city in Saudi Arabia bringing the total number of participants to 129.

As indicated in the Table 5-2 below, male respondents make up 67.4 percent of the total dataset, with 97.7 percent indicating that computer science was their chosen field of study. The majority of participants were undergraduate students, with the remainder of users making up only 14.7 percent of the total. From these results it becomes clear that the majority of respondents were male, computer science undergraduate students. This has both positive and negative implications. As a whole, analysing such a group means that the inferences can be kept narrowly defined. Given the small size of the dataset, this makes it easier to infer results. On the negative side, the system would benefit from an analysis of a broader range of individuals as a way of ensuring usability for the population at large. This may be something to consider for further research and investigation.

Table 5-2: Gender Frequencies

Gender	Frequency	Percent
Male	87	67.4
Female	42	32.6
Total	129	100.0

Table 5-3: Discipline Frequencies

Discipline	Frequency	Percent
Computer field	126	97.7
Non computer field	3	2.3
Total	129	100.0

Table 5-4: Status Frequencies

	Frequency	Percent
Undergraduate	110	85.3
Master	4	3.1
Diploma	9	7.0
Lecturer	6	4.7
Total	129	100.0

Table 5-5: Age Frequencies

Age	Frequency	Percent
18-24 years	110	85.3
25-34 years	13	10.1
35-44 years	4	3.1
44-55 years	2	1.6
Total	129	100.0

From Table 5-4 and Table 5-5, it can be seen that the status variable skewed to the undergraduate group, as is the age variable skewed toward the 18-24 age group. A bivariate correlation of the age and status variables indicated that the correlation is statistically significant with a Pearson correlation coefficient of $r=0.613$, which is significant at $p<0.01$. This positive correlation indicates that as the number of participants in age group 1 – 4 decreases (from 18-24 years in group 1 to 44-55 years in group 4), the number of participants in each status group from 1 - 4 also decreases (from undergraduates in group 1 to lecturers in group 4). As a result of the correlation analysis, status will be used exclusively, and age will be eliminated as the two variables appear to be measuring the same thing. This kind of correlation is not surprising, however, there would be no advantage in analysing them separately; the results would be the same.

5.3.1.1 Division of participants

The overall aim of this experiment is to test the hypotheses stated in the introduction of this study: **“There will be a difference between users’ recognition of a lesson that is presented according to two classifications of learning styles, one and none of the users’ learning styles”**. Participants were therefore, randomly assigned to one of four test groups (see Table 5-6 below):

Table 5-6: The groups that participants were randomly assigned to by the system

A	VARK
B	Honey & Mumford
C	VARK and Honey & Mumford
D	No tailoring

Group A was learning a lesson presented according to only one of the participant's learning styles (VARK); Group B was learning a lesson presented according to only one of the participant's learning styles (Honey & Mumford); Group C was learning a lesson which was presented according to both of the participant's learning styles (VARK and Honey & Mumford); Group D was learning a lesson presented with no personal customisation. The system considered the users as a queue of people. The first one would be in group A, the second would be placed in group B, third - C, fourth - D. This cycle would be repeated until the last user. Participants did not know which of the groups they were assigned to. The dependent variable, group, is central to this analysis. This variable indicates whether or not participants were given the system lesson in consideration of their learning styles and as a result of comparing the answers from each group, the research question will be discussed.

5.3.2 Procedure

The users were prepared for the experiment with a short fifteen-minute presentation on the importance of learning styles and the rest of the lecture time provided was used for utilisation of the system. During the presentation, the following ideas were discussed: overview of what learning styles are, why they are significant, and where more information on learning styles is available. After that the system was introduced and it was discussed how it could help them discover their own individual learning styles.

Two models of learning styles were considered. One was VARK, based on biological or physical learning considerations, and the other was Honey & Mumford, based on psychological learning considerations. The participants were presented with the two learning styles tests in order to determine their learning style, The system then used this information to generate a lesson based on the results of the learning styles test.

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During the experiment, some of the students were having problems with some difficult English words in the test and asked for assistance. The lecturer was eager to be of assistance; he encouraged and helped the students. Upon completion of the task, the participants completed a survey and expressed their opinion of the system and its functionality.

5.3.3 *Differences in methodology*

Due to different experimenters undertaking the studies, there were differences between the two cities in terms of how the studies were conducted:

In the first city (Albaha) the researcher himself gave the lecture and introduced the experiments, while in the second city (Jeddah), a local member of staff was in charge of the experiments. The researcher provided him with the details of the first experiment, and the questions he was asked by students during that session. Another difference was the time allocated to the session. In the first school, the time given was a full lecture; 50 minutes. While in the second school the given time was about twenty five minutes; which the person who was in charge believed was enough.

Despite these differences, the order in which the lecture, test and lesson were given was the same for both cities: students were introduced to learning styles and to the research experiment, they then used the system, and finally completed the session with the survey. The differences were minor, but to err on the side of caution, statistics were conducted to check if these differences caused any significant differences in the results related to the research questions and hypotheses. This was to rule out the possibility of the data having to be analysed separately. The results of the tests will be shown later in this chapter.

The following sections will present the survey questions and detail the variables and methods used for analysis.

5.4 Survey

As discussed in the previous chapters, the survey is web-based and was produced as part of the system. The survey is composed of three main sections:

- 1- Demographic data
- 2- Close-ended question

3- Open-ended questions

When a user registers on to use the system, he/she is asked for their demographic information:

GENDER (0 Male) (1 Female)

DISCIPLINE (1 Computer field) (2 Non computer field)

AGE (1 Age 18-24) (2 Age 25-34) (3 Age 35-44) (4 Age 45-55)

STATUS (1 Undergraduate) (2 Master) (3 Diploma) (4 Lecturer)

Upon completing the lesson they are asked to complete the following survey:

Close-ended questions and statements

- 1- How would you rate your knowledge of the concept of learning styles before you visited this website?
- 2- Was this lesson tailored to you? (According to your learning styles?)
- 3- It is easy to distinguish between a lesson that is presented for your learning styles and one that is not suitable for your learning styles?
- 4- This site is organised in a way that is easy for you to understand.
- 5- This site is easy to use.

For question number one, a choice of three answers were given (I know it very well, I have heard about it and I have never heard about it). The answers to the remaining questions were given in the form of a five point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

Schuman indicated that to get the participants' true feelings on a topic, open-ended questions are more effective than closed-ended ones [210], therefore the following open-ended questions were also included in the survey.

Open-ended questions

- 6- What did you like best about the site?
- 7- What did you like least about the site? How could it be improved?

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Questions one and three were employed to examine if the user had previous experience in learning styles. The answers to these questions will help identify if there is a difference between those with and without prior knowledge of learning styles. Question two is the central question used to test the hypothesis and research question. Questions four and five were used to examine the usability and the ease of use. Open-ended questions were included to allow participants to provide more information in their own words.

5.5 Variables examined and method of analysis

Below in Table 5-7 is a summary of the variables used to test the hypotheses and answer the research question proposed in this study.

Table 5-7: Summary of the variables used to test the hypotheses

Variable	Type	Description
Group	Pre-designated randomly by the system	A = VARK and Honey & Mumford; B = VARK; C = Honey & Mumford; D = No tailoring
Answer to Q2	Self defined	Was this lesson more tailored to you? (according to your learning styles?)
Honey & Mumford	System generated dependent upon user interaction	1=Activist; 2=Reflector; 3=Theorist; 4=Pragmatist
VARK	System generated dependent upon user interaction	1=Visual; 2=Aural; 3=ReadWrite; 4=Kinesthetic
Gender	Demographic	0=Male, 1=Female
Discipline	Demographic	University major or area of expertise
Status	Demographic	1=Undergraduate; 2=Master; 3=Diploma; 4=Lecturer

As discussed previously, question 2 addresses the research question and is therefore, the main variable that will be focussed on in the results section. Analyses will be carried out between the four groups to examine this. The other questions in the survey will also be analysed to establish other issues such as the user's knowledge of learning systems and the ease of use of the system. In addition to the descriptive statistics, analyses will be carried out on the demographic data in order to examine if gender, status or discipline have any effects on the users answers to question 2, i.e. if there are differences between males and females or between lecturers and undergraduates.

The variables are divided into six comparisons between four different groups

- 1- “VARK and Honey & Mumford Group” and VARK Group
- 2- “VARK and Honey & Mumford Group” and Honey & Mumford Group
- 3- “VARK and Honey & Mumford Group” and No tailoring Group
- 4- VARK Group and Honey & Mumford Group
- 5- VARK Group and No tailoring Group
- 6- Honey & Mumford Group and No tailoring Group

The tested hypothesis is “There will be a difference between users’ recognition of a lesson that is presented according to two classifications of learning styles, one and none of the users’ learning styles”. If the null hypothesis is approved, then it means that there is no difference between groups (those presented with one or two learning styles) in their recognition that the lesson given is tailored to their learning styles. If the null hypothesis is rejected, then it means that the conclusion for one group or more is different to the other group.

5.5.1 Data analysis

The stored data was coded and analysed using the statistical package SPSS [231]. Values for descriptive data such as means, standard deviations, frequencies and percentages were produced using SPSS. A Factorial Analysis of Variance (ANOVA) test [232] was used to determine whether there were statistically significant differences between the users of the four different groups (i.e. VARK, Honey & Mumford, VARK and Honey & Mumford, No tailoring). An ANOVA was also used to discover whether there were significant statistical differences between participants from the two cities (AlBaha and Jeddah – Saudi Arabia). A Pearson’s correlation test was used to examine the correlations both within and between the different learning styles.

5.5.2 Learning styles

As discussed previously, participants began by logging into the system and registering their demographic information. Following this they answered two sets of questions in order to determine their profile in each learning style – see Table 5-8 and Table 5-9 below. The tables below show the number of participants that scored highest in each sub-section of the two different learning styles.

Table 5-8: Frequency and Percentage of Honey & Mumford learning styles

		Frequency	Percent
Valid	Activist	38	29.5
	Reflector	33	25.6
	Theorist	28	21.7
	Pragmatist	30	23.3
	Total	129	100.0

Table 5-9: Frequency and Percentage of VARK learning styles

		Frequency	Percent
Valid	Visual	47	36.4
	Aural	45	34.9
	ReadWrite	31	24.0
	Kinaesthetic	6	4.7
	Total	129	100.0

For example, there were 38 participants who received their highest score in the activist section of the Honey & Mumford compared to 28 who received their highest score in the theorist section. Likewise with the VARK, 47 participants received their highest score in the visual section compared to only 6 participants who received their highest score in the kinaesthetic section.

Looking at the values in Table 5-9 it can be clearly seen that there are very few students (only 4.7 percent) who have a kinaesthetic learning style. An important point to raise here is that the last three questions in the VARK questionnaire do not contain a fourth option for the kinaesthetic in the original test of VARK. Up to question number eight, there were four answers, each of which belongs to one of the four learning styles. After question eight in the VARK test, there were only three answers and none belongs to the kinaesthetic learning style. This was beyond my control as it is how the questions are designed within the VARK questionnaire, but it could have contributed to the low number of participants who chose the kinaesthetic option as their preferred learning style.

It may also be that out of the sample (129 participants) there may simply be the possibility that only few of them were actually kinaesthetic learners. It is a human characteristic that people are different. In general, there is no control as to how many participants will fall into each sub-section. Individual differences are part of most experimental studies; a larger sample size may, or may not, have included more users with this type of learning style. In contrast, visual learning is dominant for the majority of participants. This seems to be in line with a previous study indicating that, although it has been found that kinaesthetic learners retain best, they make up only 5 percent of the population whereas visual learners make up 65 percent and auditory learners, 30 percent (Mind Tools 1998).

Another consideration might be the nature of the current study: in the online lessons a screen is used as the main communication medium. This perhaps lead more people to choose visual as their preferred method as the screen is a visual component in the lesson. It is therefore taken as normal that visual learners overwhelm all other learning styles. In Honey & Mumford, this problem does not occur. This could be due to the fact that the four sub-sections are not affected by the mode of presentation.

5.6 Results of the survey questions

There were seven questions in total in the survey, five close-ended and two open-ended. The following sections will discuss the results of the answers to these questions and address the issues of the differences between cities and the different demographic variables. As mentioned previously, question 2 is the main question which addresses the research question so will be the main focus of the results section.

5.6.1 Question 1

Q1. How would you rate your knowledge of the concept of learning styles before you visited this website?

This question allowed participants to rate their knowledge and experience of learning styles. The aim of this question was to find out whether there was a significant difference between those who had previous knowledge and those who did not. Table 5-10 below shows the number of participants falling into each category. In a later section (section 5.6.2.4), this data is used to ascertain whether a user's knowledge of the

learning styles has an impact on their answer to question 2, i.e. does knowledge, or lack of it, affect users recognition of whether or not the lesson is tailored to their learning style.

Table 5-10: Participants' knowledge of learning styles before visiting the website

	Frequency	Percent
I know it very well	30	23.3
I have heard about it	47	36.4
I have never heard about it	52	40.3
Total	129	100.0

The percentage of participants who indicated that they either knew it very well or had heard about it, was 59.7%, while those who indicated that they had no experience “I have never heard about it” were 40.3%. It should be noted at this point that the majority of participants were undergraduate students in the computing field, therefore this could explain the high percentage of participants who had never heard of learning styles. This issue will be addressed further on in this chapter (see section 5.6.2.4)

5.6.2 Question 2

Q2. Was this lesson tailored to you? (according to your learning styles)? (1 Strongly disagree, 2 Disagree, 3 Neutral, 4 Agree, 5 Strongly agree).

This question is the main question that addresses the question:

“Will this system produce tailored presentation to two models of learning styles for individuals?”

Its inclusion also tests the hypothesis

“There will be a difference between users’ recognition of a lesson that was presented according to two classifications of learning styles, one and none of users’ learning styles.”

In order to answer the hypothesis, an ANOVA was used to test the difference between the groups.

5.6.2.1 Can the collected data from two cities be analysed together?

As mentioned earlier (section 5.3.2 and section 5.6.2.1), the data was collected from two cities and the experimental conditions varied slightly. The main procedure was similar, however, there were slight timing differences between the experiments and as a result, it was necessary to explore any differences in the results from the two cities before describing and analysing the data as a whole. If there is a significant difference which could potentially affect the results, then the data from these two cities cannot be analysed together due to the differing experimental conditions.

An initial analysis for the data was carried out on each city before carrying out a statistical comparison.

Ninety-one of the participants were from Al Baha, and 38 were from Jeddah. Figure 5-1 and Figure 5-2 below show diagrammatically the results to the answers for question 2, this being the main question that addresses the research question.

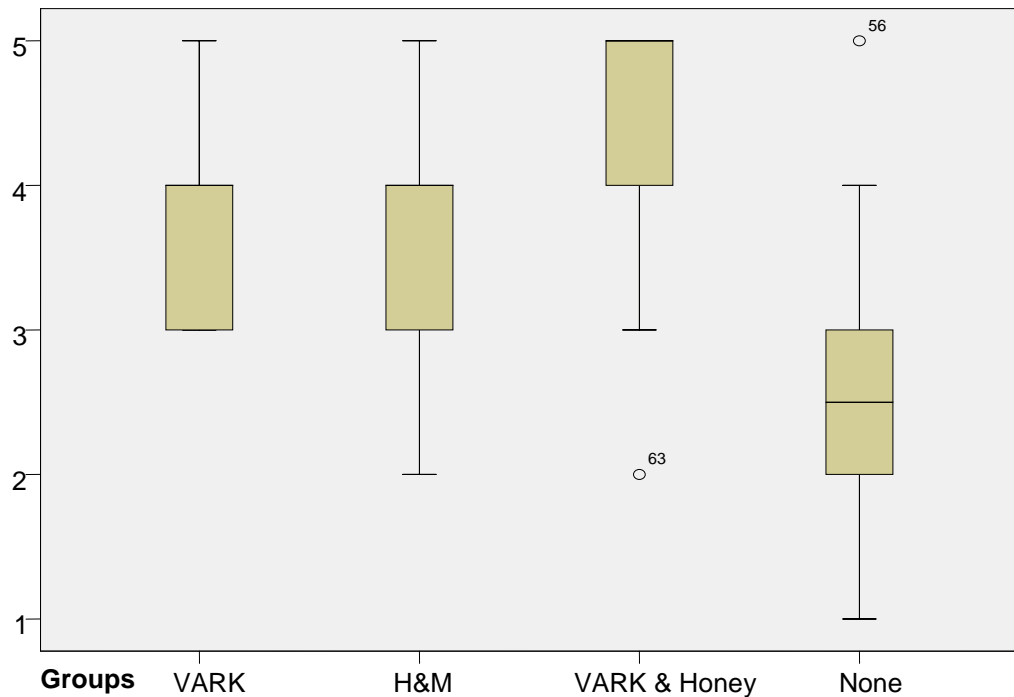


Figure 5-1: Answers to Question 2 from Al-Baha students

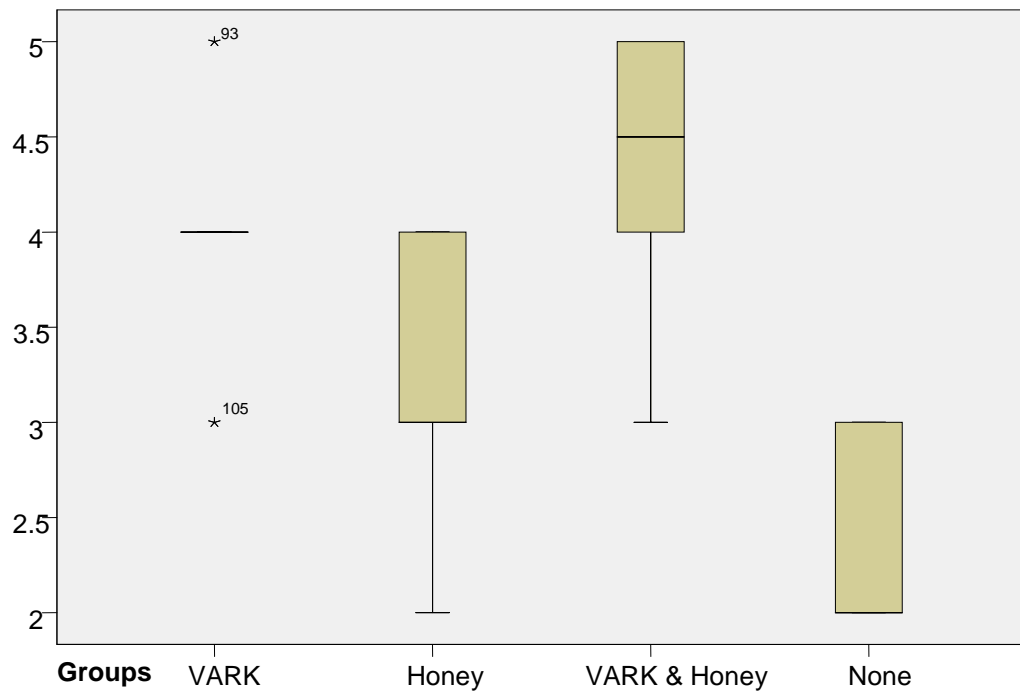


Figure 5-2: Answers to Question 2 from Jeddah students

The results from the box plot in Figure 5-1 indicate that all of the participants who were receiving learning styles managed to differentiate if the presentation of the lesson was tailored to one or two learning styles. The median scores given for question 2 were 4 (agree) for the groups presented with just one learning style, and 5 (strongly agree) for the group presented with two learning styles. Those who were not presented with any learning style showed the lowest score with a median ranging between 2 and 3 (disagree and neutral). Similar trend of scores were obtained from the second city as shown in the box plot in Figure 5-2, suggesting that there were no differences in the data between the two cities. A box plot is a quick way of examining one or more sets of data graphically therefore, it is necessary to test this significantly; an ANOVA was carried out.

Comparing the VARK group

The answers from Group A for question two were tested to see if there was a statistically significant difference between the two schools. Results from the ANOVA showed no difference between the scores, $F=0.252$, $p=0.619$.

Comparing the Honey & Mumford group

Similarly, the answers from Group B for question two were tested. Results showed no statistically significant difference between the scores from the two cities, $F=2.496$, $p=0.125$.

Comparing the VARK and Honey & Mumford group

The answers from Group C, for question two were also tested to see if there is any statistically significant difference between the two schools. Results showed no significant difference, $F= 0.100$, $p=0.754$.

Comparing the No Tailoring group

The answers from Group D for question two were tested to see if there was any statistically significant difference between the two schools. Results for this also showed no significant difference between the scores, $F=0.28$, $p=0.868$.

When the participants were divided into two groups depending on their school, it was found that there was no significant difference between the participants from the two schools in terms of recognising the lesson that was presented according to two, one or none learning styles. According to these results, therefore, the data can be used as one set of data and analysed together.

5.6.2.2 Comparisons between different groups

Having established that the data can be analysed together, the following six comparisons were carried out in order to examine the difference between the four groups (Figure 5-3):

1. “VARK and Honey & Mumford Group” and VARK group
2. “VARK and Honey & Mumford Group” and Honey & Mumford Group
3. “VARK and Honey & Mumford Group” and No tailoring Group
4. VARK Group and Honey & Mumford Group
5. VARK Group and No tailoring Group
6. Honey & Mumford Group and No tailoring Group

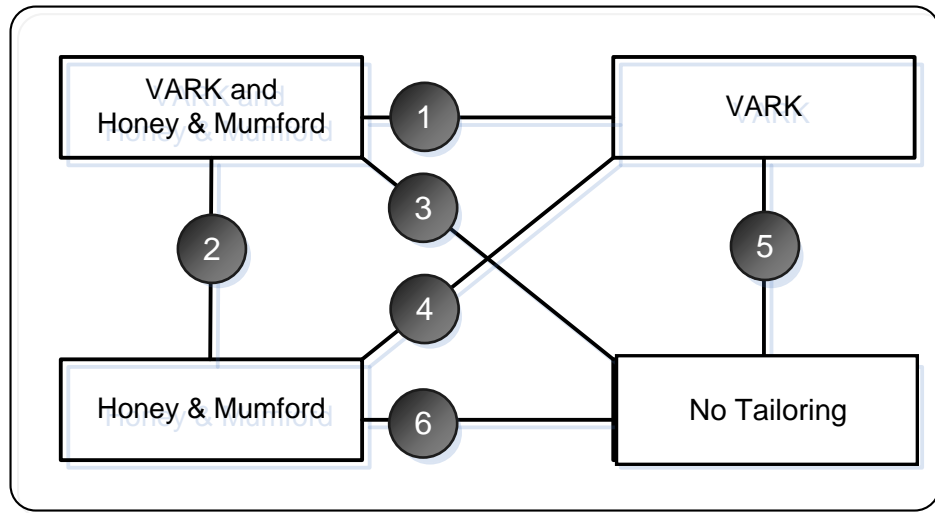


Figure 5-3: Comparisons between groups

1) Comparison between “VARK and Honey & Mumford Group” and VARK Group

The Table 5-11 below displays the means, standard deviations and standard errors for both groups A and C.

Table 5-11: Means, standard deviations and standard errors for both groups A and C

	N	Mean	Std. Deviation	Std. Error
VARK (A)	33	3.91	0.678	0.118
VARK and Honey&Mumford (C)	31	4.29	0.864	0.155
Total	64	4.09	0.791	0.099

The sample size (N) for the VARK group is 33 people. The mean of the data is 3.91. It can be concluded therefore, that the majority of the responders chose 3 (neutral) and 4 (agree) for their answers. Standard deviation of the data is 0.678, which is not a high value for the data range, indicates that most of the scores lie near to the mean. The standard error is 0.118, which is a low value for the data range, indicating that the variability is low and as such, that the sample used is likely to be representative of the population. The upper and lower limits are 4.15 and 3.67 respectively, indicating that the value of the population mean should fall within this range. The data did not need be

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normalised because there were no extreme values. The minimum choice of the respondents answers is 3 (neutral) and the maximum choice is 5 (strongly agree). No participant chose 1 (strongly disagree) and 2 (disagree). This indicates that most of the respondents in this group agree that the lesson given was tailored to their learning styles.

The sample size for the VARK and Honey & Mumford group is 31 people. The mean of the data is 4.29. It can be concluded that the majority of the respondents chose 4 (agree) or 5 (strongly agree) for their answers. The standard deviation in the VARK and Honey & Mumford group is 0.864 and the standard deviation is 0.155. Again, both of these values are low indicating low variability within the sample. The upper and lower limits are 4.61 and 3.97 respectively. There were no respondents who chose 1 (strongly disagree) for their answers. The answers ranged between 2 (disagree) and 5 (strongly agree). This description indicates that, on the whole, participants in the VARK and Honey & Mumford group tend to agree that the lesson given is tailored to their learning styles, with a few who seemed to disagree.

A 2 x 5 (group by Likert scale answers) ANOVA was carried out in order to test statistically whether there were any differences between the two groups. Results from the ANOVA revealed that there were no significant differences between the groups in how they recognised whether the lesson was tailored to one or two of their learning styles, $F(1,62)=3.881, p>0.05$. In other words, participants who were given just one learning style (VARK) recognised that the lesson was tailored to their learning style, in a similar way to those who were given two learning styles.

2) Comparison between VARK and Honey & Mumford Group and Honey & Mumford Group

Table 5-12 below displays the means, standard deviations and standard errors for both groups B and C.

Table 5-12: Means, standard deviations and standard errors for both groups B and C .

	N	Mean	Std. Deviation	Std. Error
Honey&Mumford (B)	32	3.47	0.761	0.135
VARK & Honey&Mumford (C)	31	4.29	0.864	0.155
Total	63	3.87	0.907	0.114

The sample size for the Honey & Mumford group was 32 people, and the mean value given was 3.47. It can be concluded that most of the respondents answers were between 3 (neutral) and 4 (agree). The standard deviation in the VARK and Honey & Mumford group is 0.761 and the standard deviation is 0.135. Again, both of these values are low indicating low variability within the sample. The upper and lower limits are 3.74 and 3.19 respectively. If there was any data beyond this limit, it would mean that the sample size was not enough or needed to be normalised. The data was not normalised because there were no extreme values. From the table it can be seen that nobody from this group selected 1 (strongly disagree) for the answer, indicating that none of the participants strongly disagreed that the lesson was tailored to their learning style.

The mean for the VARK and Honey & Mumford group (4.29) is higher than that for the Honey & Mumford group (3.47). Results from a 2 x 5 (group by Likert scale answers) ANOVA test revealed that the values are significantly different, $F(1,61)=16.065$, $p<0.001$. This suggests that when the system presents the lesson using two learning styles, participants recognise this fact better than when they are given only one learning style (Honey & Mumford).

3) Comparison between VARK and Honey & Mumford Group and No tailoring Group

Table 5-13 below displays the means, standard deviations and standard errors for both groups C and D.

Table 5-13: Means, standard deviations and standard errors for both groups C and D

	N	Mean	Std. Deviation	Std. Error
VARK & Honey&Mumford (C)	31	4.29	0.864	0.155
No tailoring (D)	33	2.48	0.834	0.145
Total	64	3.36	1.239	0.155

The sample size for the group who received no tailoring was 33 people. The mean data from the group is 2.48, which means that most of the respondents answers were 2 (disagree) or 3 (neutral). The standard deviation from the group's data is 0.834, which is

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appropriate for the data range. The standard error of this group is 0.145, indicating low variability within the sample. The upper and lower limits are 3.67 and 3.05 respectively. The data was not normalised because there were no extreme values. The minimum and maximum values that the answers in the No tailoring group vary from 1 (strongly disagree) to 5 (strongly agree). This indicates a large range for this data set ranging from strongly disagree to strongly agree, however, due to the low standard deviation and standard error values, it can be concluded that these values (1 and 5) have been given by very few participants with the majority answering 2 and 3.

The descriptive data shows that both groups have a slightly different range of values for the answers to question 2. The means are also very different with 4.29 for the VARK and Honey & Mumford group compared to only 2.48 for the group which received no tailoring. A 2 x 5 (group by Likert scale answers) ANOVA was carried out in order to test statistically whether these differences were significant. The results revealed that the means between the two groups are significantly different, $F(1,62)=72.385$, $p<0.001$. This illustrates that participants in the VARK and Honey & Mumford group recognise that the system produced tailored presentation to two of their learning styles better than those in the No tailoring group

4) Comparison between VARK Group and Honey & Mumford Group

Table 5-14 below displays the means, standard deviations and standard errors for both groups A and B.

Table 5-14: Means, standard deviations and standard errors for both groups A and B

	N	Mean	Std. Deviation	Std. Error
VAR K (A)	33	3.91	0.678	0.118
Honey&Mumford (B)	32	3.47	0.761	0.135
Total	65	3.69	0.748	0.093

The sample size used in VARK was 33 people and the mean of the data is 3.91. It can be concluded that the majority of the respondents' answer was an integer value between 3 (Neutral) and 4 (Agree). The sample size that was used in Honey & Mumford group

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was 32 people, and the mean value was 3.47. The standard deviation and standard error for both groups were low, indicating low variability within the sample.

A 2 x 5 (group by Likert scale answers) ANOVA test revealed that the values are significantly different from one another, $F(1,63)=6.07$, $p<0.05$. Looking at the means, it can be seen that they are slightly higher for the participants in the VARK group compared to the Honey & Mumford group. This suggests that when the system presents the lesson using learning styles from VARK, participants recognise this fact better than when they are given learning styles from Honey & Mumford.

5) Comparison between VARK Group and None Group

Table 5-15 below displays the means, standard deviations and standard errors for both groups A and D.

Table 5-15: Means, standard deviations and standard errors for both groups A and D

	N	Mean	Std. Deviation	Std. Error
VARK (A)	33	3.91	0.678	0.118
No tailoring (D)	33	2.48	0.834	0.145
Total	66	3.20	1.041	0.128

The sample size for the VARK group was 33 people and the mean of the data is 3.91. It can be concluded that the majority of the respondents chose 3 (neutral) and 4 (agree) for their answer. None of the participants chose 1 (strongly disagree) or 2 (disagree). This indicates that most of the respondents agreed that the lesson given was more tailored to their learning styles.

As regards to the group which received no tailoring, the sample size was 33 people. The mean data from the group was 2.48, which means that most of the respondents answers were 2 (disagree) or 3 (neutral). The answers participants gave ranged from 1 (strongly disagree) to 5 (strongly agree).

Both groups have low standard deviations and standard errors, indicating low variability, however the means appear to be different from one another. A 2 x 5 (group by Likert scale answers) ANOVA test was carried out and the results revealed that the

values are significantly different, $F(1,64)=57.941$, $p<0.001$. This suggests that when the system presents the lesson using one learning style (VARK), participants recognise this statement better than when they are given no learning styles within the lesson.

6) Comparison between Honey & Mumford Group and No tailoring Group

Table 5-16 below displays the means, standard deviations and standard errors for both groups B and D.

Table 5-16: Means, standard deviations and standard errors for both groups B and D

	N	Mean	Std. Deviation	Std. Error
Honey&Mumford (B)	32	3.47	0.761	0.135
No tailoring (D)	33	2.48	0.834	0.145
Total	65	2.97	0.935	0.116

The sample size for the Honey & Mumford group was 32 people, and the mean value was 3.47. It can be concluded that most of the respondents' answers were either 3 (neutral) or 4 (agree). As for the No tailoring Group, the sample size was 33 people. The mean data from the group was 2.48, which means that most of the respondent's answers were 2 (disagree) or 3 (neutral).

A 2 x 5 (group by Likert scale answers) ANOVA test revealed that the values are significantly different, $F(1,63)=24.64$, $p<0.001$. This suggests that when the system presents the lesson using learning styles from the Honey & Mumford, participants recognise this fact better than when they are given a lesson that does not incorporate any of their learning styles.

5.6.2.3 Discussion of comparison results

The overall results from question 2 have revealed the following:

Firstly, users are more likely to recognise that the system is producing tailored presentation to two of their learning styles than when only one learning style is used, i.e. when the lesson uses learning styles from both the VARK and Honey & Mumford, participants will recognise this better than if the system only presents the lesson using either the VARK or the Honey & Mumford learning style alone.

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Secondly, when comparing the VARK and Honey & Mumford as one learning style, the results revealed that participants recognise that the system is using the VARK more readily than when the system is using the Honey & Mumford learning style. This perhaps has something to do with the study using a visual based program which is incorporated into the VARK learning style more so than the Honey & Mumford.

Finally, when the system presents the lesson using either two or one learning style, participants recognised this better than when there was no learning style used at all.

The results have addressed the research question and shown that users of the system do indeed recognise that the system produces tailored presentation to two of their learning styles. The experimental hypothesis can also be accepted in that there was a difference between users' recognition of a lesson that was presented according to two classifications of learning styles, one and none of users' learning styles.

5.6.2.4 Does the demographic data have an effect on question 2?

It was hypothesised that participants who were presented with a lesson according to two of their learning styles (VARK and Honey & Mumford), will have agreed more strongly with the assertion in question 2 that the test accommodated their learning style. This was indeed the case, as the results from the ANOVAs in the previous sections indicated. Further analysis was carried out to examine if the demographic data has an effect on the results from question 2. In other words, we want to eliminate the possibility that question 2 was based on a person's gender, status, or discipline. To do that, several box plots were generated to ensure that these variables did not noticeably affect results from question 2.

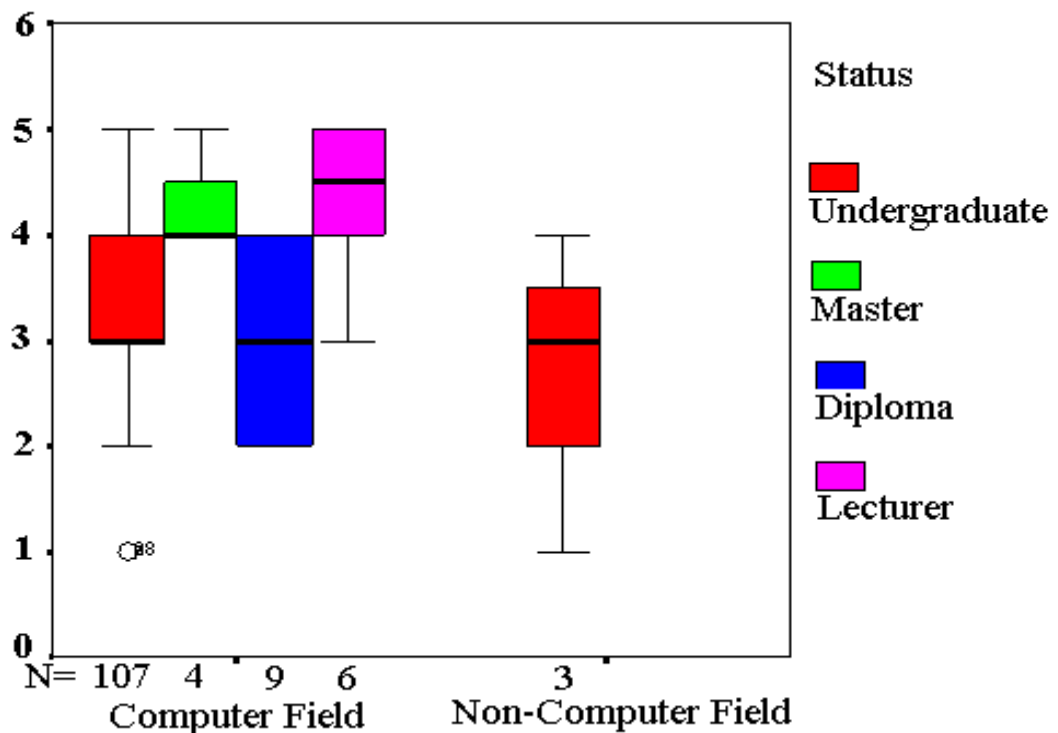


Figure 5-4: Clustered Boxplot: Question 2 * Discipline * Status

Developed first was a clustered box plot (Figure 5-4 above) to analyse the relationship between the responses for Question 2, and a respondent's status and discipline. This chart was chosen as a way of visually interpreting the results from three essential variables – Question 2, Discipline and Status. The box plot was able to show mean values for the variable discipline, which was divided by status, to give a picture of where the majority of the data results fit within the whole set.

The results indicate that overall the most common response was 3, indicating a neutral response to Question 2. The other responses were from respondents who were either Lecturers or Master degree students. The results for question two from both of these groups show that the middle 50% of scores are between 4 and 4.5, indicating that these groups more strongly agree that the test was tailored toward their learning style. It could be that these two groups have a better understanding of what these learning styles are like, therefore they were more confident about the meaning of the question and were more able to recognise the learning style and choose agree and strongly agree more so than the other participants. To analyse this further we can look at the answers to Question 1. Question 1 was a self determined rating of the participant's understanding of the term 'learning styles', which reads: How would you rate your knowledge of the concept of learning styles before you visited this website? Respondents answered by

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selecting one of the following options: 1) I know it very well; 2) I have heard about it; 3) I have never heard about it.

If our estimation of Master level students and lecturers is correct, then these two groups will have more often responded to this question with a 1, indicating that they know about learning styles very well. Table 5-17 below analyses this particular issue with a cross tabulation.

Table 5-17: Question 1 * Status (Percentage)

		Status				Total
		Undergraduate	Master	Diploma	Lecturer	
Q1 How would you rate your knowledge of the concept of Learning Styles before you visit this website?	I know it very well	20.0%	50.0%	55.6%	16.7%	23.3%
	I have heard about it	36.4%	50.0%	22.2%	50.0%	36.4%
	I have never heard about it	43.6%	0%	22.2%	33.3%	40.3%
Total		100 (N=110)	100 (N=4)	100 (N=9)	100 (N=6)	100 (N=129)

The Table 5-17 above indicates that our assumption was correct. Undergraduates were far less likely to believe that they knew a lot about learning styles; only 20.0% of undergraduates who participated believed they knew learning styles very well. Conversely, for Masters students, 50.0% believed that they knew the concept of learning styles very well, and the remaining 50.0% had at least heard about it. Surprisingly, with regard to the lecturers, only 16.7% felt they knew of the concept very well. 50% stated that they had heard of it before and the remaining 33.3% stated that they had never heard of it. The latter percentage is still fewer than the number of undergraduates who had never heard of it (33.3% versus 43.6%) which could explain why the lecturers recognised the learning styles in question 2 more so than the undergraduates

The last demographic variable to analyse is Gender (see Figure 5-5). Results indicate that responses were essentially the same regardless of what gender the respondent was.

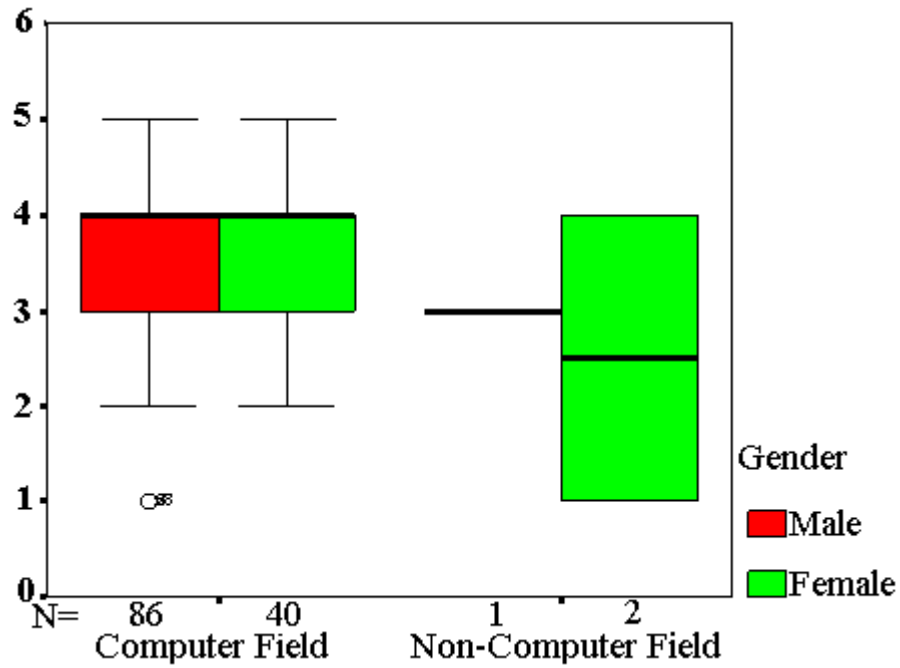


Figure 5-5: Clustered Boxplot: Q2 * Discipline * Gender

5.6.2.5 Success of the system

Now that the group variables have been analysed another point of enquiry can be addressed: did this computer system successfully administer a lesson that was conducive to the participant's learning styles? A cross tabulation was generated to analyse this question (Table 5-18 below).

Table 5-18: Cross Tabulation; Group inclusion * Q2 (percent)

		Q2 Was this lesson more tailored to you? (according to your learning styles?)					Total
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
Group inclusion	VARK	0	0	27.3	54.5	18.2	100 (N=33)
	Honey	0	9.4	40.6	43.8	6.3	100 (N=32)
	VARK & Honey	0	3.2	16.1	29.0	51.6	100 (N=31)
	No tailoring	9.1	42.4	42.4	3.0	3.0	100 (N=33)
Total		3	18	41	42	25	100 (N=129)

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Results from this analysis indicate that in fact, the system does appear to be tailoring the lesson to an individual's learning style. For those respondents who were included in the "VARK and Honey & Mumford" group (where the lesson included elements from both learning styles) 51.6% *strongly* agreed and 29.0% agreed that the lesson was tailored to their learning style. Those who were given only one learning style agreed that the lesson was tailored to their learning style, 54.5% for VARK and 43.8% for Honey & Mumford, indicating that there is a difference in response between those who were given two learning styles compared to those who were given only one (only 6.3% and 18.2% *strongly* agreed in the Honey and Mumford group and VARK group respectively). Furthermore, only 3% of those who were included in the "No tailoring" group (no customisation incorporated into the lesson) believed that the lesson was tailored to their style. Additionally, of the No tailoring group, 42.4% disagreed and 9.1% *strongly* disagreed that the lesson was tailored to their style, and 42.4% were neutral. (see Table 5-18).

These results show that the system that was developed managed to successfully incorporate the user's preferred learning style into the lesson. When two learning styles were used, the user was able to recognise this better than if only one learning style or no learning style was used. Incorporating one learning style was more effective than no learning style at all.

It can be concluded from the analyses carried out in this section that question 2 addresses the research question and hypotheses as intended. Users managed to recognise that the system produces tailored presentation to two of their learning styles. Furthermore, there was a difference between users' recognition of a lesson that was presented according to two classifications of learning styles, one and none of the users' learning styles. As hypothesised in the introduction, users who are presented with a lesson according to two models of their learning styles had a more positive attitude towards this presentation than those presented with customisation to one or no learning styles.

The following sections will proceed to analyse the remaining questions in the survey.

5.6.2.6 Questions 3 and 4

Question 3 and 4 related to functionality issues, as well as, for Question 3, how well the respondent felt they were able to distinguish learning styles.

Question 3: It is easy to distinguish between a lesson that is presented for my learning style and one that is not suitable for my learning style. (1 Strongly disagree, 2 Disagree, 3 neutral, 4 Agree, 5 Strongly agree).

If a respondent did not find it easy to distinguish whether or not the lesson was presented for their learning style, then it follows on that they would have had a difficult time offering a reliable response to question 2. With this in mind, it is expected that very few respondents will have a “disagree” or “strongly disagree” response to question3.

The crosstabs below were generated as a way to see if there were any negative patterns as expressed above that developed from the data.

Table 5-19: Q2 Was this lesson more tailored to you? (according to your learning styles?) * Q3 It is easy to distinguish between a lesson that is presented for my learning styles and one that is not suitable for my learning styles

		Q3 It is easy to distinguish between a lesson that is presented for my learning styles and one that is not suitable for my learning styles.				Total
		Disagree	Neutral	Agree	Strongly agree	
Q2 Was this lesson more tailored to you? (according to your learning styles?)	Strongly disagree	0	0	1	2	3
	Disagree	1	5	9	3	18
	Neutral	3	13	17	8	41
	Agree	1	16	21	4	42
	Strongly agree	2	7	13	3	25
Total		7	41	61	20	129

Table 5-19 above shows no unusual patterns from the data. Most respondents either agreed or strongly agreed that they were able to distinguish between learning styles. Those who were neutral (41 respondents), on the whole, still felt that the system had

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been tailored toward their learning style. Of the seven respondents who indicated that they were not able to distinguish between learning styles, three agreed that the lesson was tailored to their style, three provided a neutral response and one disagreed that the lesson was tailored to their style. It is difficult to determine why these three individuals could have given more than a neutral response to questions 2 given that it was not easy to distinguish the difference between styles.

Question 4 relates to the system: This site is organised in a way that is easy for me to understand (1 Strongly disagree, 2 Disagree, 3 Neutral, 4 Agree, 5 Strongly agree).

Table 5-20 below shows the results obtained. Only 1 out of the 129 respondents strongly felt that the site was not organised in a way that was easy to understand, and they provided a neutral response to question 2. The majority of respondents (56 out of 129 respondents) felt that the system was easy to understand, with a further 36 respondents who strongly agreed that the system was easy to understand. This shows that 71.3% of the participants felt that the site was organised in a way that was easy to understand. From these participants, only 12 disagreed that the lesson was tailored to their learning style. With regard to the 29 neutral responses to question 4, half of them still felt that the system provided a lesson that was tailored to their needs (16 of 29 respondents) and a further 8 respondents were neutral. These results indicate that the organisation of the site did not affect the way in which participants respond to question 2.

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Table 5-20: Q2 Was this lesson more tailored to you? (according to your learning styles?) * Q4 This site is organized in a way that is easy for me to understand

		Q4 This site is organized in a way that is easy for me to understand.					Total
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
Q2 Was this lesson more tailored to you? (according to your learning styles?)	Strongly disagree	0	1	1	0	1	3
	Disagree	0	3	4	9	2	18
	Neutral	1	1	8	21	10	41
	Agree	0	1	12	17	12	42
	Strongly agree	0	1	4	9	11	25
Total		1	7	29	56	36	129

5.6.2.7 Question 5

Question 5 relates to the ease of use of the site: This site is easy to use (1 Strongly disagree, 2 Disagree, 3 Neutral, 4 Agree, 5 Strongly agree).

From Table 5-21, it can be seen that only three respondents felt that the site was not easy to use. Despite feeling that the site was not easy to use, however, they still felt that it was tailored to their learning style, which means it is possible that if improvements were made to the functionality of the system, its value for these users may be enhanced as well.

Table 5-21: Q2 Was this lesson more tailored to you? (according to your learning styles?) * Q5 This site is easy to use.

		Q5 This site is easy to use.				Total
		Disagree	Neutral	Agree	Strongly agree	
Q2 Was this lesson more tailored to you? (according to your learning styles?)	Strongly disagree	0	1	1	1	3
	Disagree	0	4	8	6	18
	Neutral	0	9	18	14	41
	Agree	3	10	14	15	42
	Strongly agree	0	6	9	10	25
Total		3	30	50	46	129

5.6.2.8 Open-ended Questions

Question 6: What did you like best about the site?

From the feedback to this question, all respondents but one responded positively to the learning system. The one participant that responded negatively indicated that the lessons were not appropriate for their learning style; however they did not indicate what learning style they preferred.

Of the positive responses, most indicated that the idea was unique, they felt it was user-friendly and interesting. They seemed to enjoy finding out more about their own particular learning styles and based on responses from Question 7 below, they would have enjoyed finding out more details about each of the particular styles.

A few participants also indicated that this idea was something they had never seen before, and they appreciated how the system helped them with the lesson at hand. They felt that it helped them to understand the material in a personalised way. Overall, the participant responses were very positive based on this survey question.

Question 7: What did you like least about the site? How could it be improved?

After reading the answers to these questions it was clear that there were two distinct categories into which the answers could be divided: 1) Usability – how easy the system was to use, and how well they understood the system; and 2) Functionality – technically, what problems users may have encountered.

Concerning usability, several respondents felt that some of the questions in the Honey and Mumford survey were unclear, or difficult to understand. Additionally, two respondents felt that the questions were too narrow or “black and white” and did not provide enough response options. One respondent also indicated that the lesson did not accommodate his learning style because he prefers to move from one activity to the next.

As for functionality, two of the respondents indicated that they felt the system was not suitable for them because there was no audio in the lessons, which they indicated was one of their preferred learning styles. This was due to a technical problem with the computer they used. All of the other participants indicated that they encountered no major problems with the system.

5.7 Summary

The study concerned comparisons of learning styles, which was conducted by giving a survey about using two models of learning styles to present a lesson. The VARK and Honey & Mumford learning styles were used. The goal was to examine whether or not there were differences between users who were given two, one or no learning styles.

Before commencing the investigation, a correlation test was carried out in order to test whether or not any of the learning styles correlated with each other. This was to verify that the learning styles were measuring different attributes and did not overlap. The results showed that there were no significant correlations across categories from the VARK and Honey & Mumford. Furthermore, each category *within* the two learning styles used was negatively correlated to one another indicating that they were measuring different things.

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With regard to Question 1: “How would you rate your knowledge of the concept of Learning Styles before you visited this website?” A high number of participants indicated that they had never heard of them before, 40.3%. This was taken to be due to the fact that most of the participants were undergraduate students and from the computer science field.

Question 2 was the main question of this study and aimed to address the research question as to whether or not users of the system recognise that it produces tailored presentation using two of their learning styles: “Was this lesson more tailored to you? (according to your learning styles)”? Due to the fact that the data was collected from two different cities and that slight differences occurred during the procedure, a statistical analysis was carried out to identify whether or not there were any significant differences between the groups’ answers. Results from an ANOVA showed no significant difference between the participants from the two schools in terms of recognising the lesson that was presented according to two, one or none learning styles.

With the data from the two cities grouped together there was a total of 129 participants; 33 in the VARK group, 32 in the Honey & Mumford group, 31 in the VARK and Honey & Mumford group and 33 in the No tailoring group . Several ANOVAs were carried out in order to test the differences between these four groups resulting in six different comparisons in total. The results found that participants who were presented with two learning styles (VARK and Honey & Mumford group) agreed more that the system had produced a lesson tailored using their learning styles than those who were presented with only one learning style (either VARK only or Honey & Mumford only). When comparing the groups with a single learning style results showed that participants agreed more that the lesson was more tailored to them when the system used the VARK method compared to the Honey & Mumford method. As discussed previously, this could be due to the nature of the study in that the lesson was presented on screen using a visual- based program, which incorporates one of the VARK learning styles (Visual). Finally, when the system presented the lesson using either two or one learning style, participants agreed more that the lesson was tailored to their learning style than when there was no customisation used at all (No tailoring group). Taken together, these results indicate that there is a difference between users’ recognition of a lesson that was presented according to two classifications of learning styles, one and none of users’ learning styles, thus allowing us to accept the experimental hypothesis.

The question as to whether or not the system successfully administered a lesson that was conducive to the participant's learning styles was examined in order to assess the efficacy of the system developed. Results from this analysis indicated that the system does appear to be tailoring the lesson to an individual's learning style. When investigating whether or not the participant's discipline, gender or status affected the outcome of the answers, it was found that *on the whole* these demographic variables did not affect the answers given to the questions. For the variable of status, an interesting result was obtained with regard to the number of participants who had never heard of the concept of learning styles: 43% of undergraduate students, 22% of diploma students and 33% of lecturers. It was thought that these numbers may have affected the answer to question 2 but, from examination of the crosstabs, it seems that the mean response was between 3 and 4 for undergraduates, 2 and 4 for diploma students, and 4 and 5 for the lecturers. This highlights that their previous knowledge of learning styles did not have a negative impact on how strongly they agreed as to whether or not the system produced a lesson that was tailored to their learning style.

The remaining three questions in the close-ended set tried to examine how easy it was for the participants to distinguish between a lesson that is presented for their learning styles and one that is not suitable for their learning styles (question 3), whether or not the site was organised in a way that was easy to understand (question 4) and how easy they thought the site was to use (question 5). With regard to question 3, most of the respondents either agreed or strongly agreed that they were able to distinguish between compatible and incompatible lessons. In relation to question 4, only eight participants (6%) felt that the site was not organised in a way that was easy to understand. The majority of responses (71%) were 4 (agree) and 5 (strongly agree). As to question 5, only three participants felt that the site was not easy to use. Despite feeling this they still gave positive responses to question 2 stating that they thought that the lesson was tailored to their learning style. This implies that if improvements are made to the functionality of the system, its value for these users may be enhanced.

The open-ended questions were included to give the participants a chance to describe in more detail what they thought of the study. The first question was to investigate what they liked best about the site. Most of the participants felt that the idea was unique. It was stated that the system user-friendly as well as interesting, with a lot of the

participants expressing that they enjoyed finding out about their own particular learning styles. They felt that the system helped them with the lesson in that it presented the material in a personalised way to suit each individual's learning style enabling learning that particular lesson easier. Overall, the responses to this survey question were very positive. The second of the open-ended questions looked at the negative aspects of the system by asking what participants liked least about the site and asking how they thought it could be improved. Concerning usability, several respondents felt that some of the questions were unclear, or difficult to understand. As for functionality, two the respondents indicated that they felt the system was not suitable to them because there was no audio in the lessons, which they indicated was one of their preferred learning styles.

It is clear, from the analysis of the results to the questions, that the current system has achieved its purpose. This study shows that there is indeed a significant difference between users' recognition of a lesson presented according to two classifications of learning styles, one and none of users' learning styles as hypothesised. Furthermore, it is evident that the system is tailoring the lesson to each individual's learning style and that the participants enjoyed using the system. They found it useful and beneficial to their understanding of the lesson. The results from this study have shown that the current system is successful. It is the first attempt to combine two learning styles in the field of adaptive systems and as such it was anticipated that there would be some flaws as established from the responses provided to the open-ended questions. Positive comments and suggestions put forward by the participants could be used for future research to develop the system. As aimed, constructive feedback was obtained; the researcher, however, thought it would be a valuable opportunity to conduct an evaluation study to gain a more formal assessment/appraisal of the system. This would be advantageous both for the current research and to contribute to the general literature in the field, considering the current lack of evaluation studies on adaptive systems. From the systems described in the introduction to this chapter, only a few of them showed a positive effect of learning styles on satisfaction and learning efficacy when the learning styles were matched with the learning orientation (SILPA, ILASH and 3DE). Furthermore, it will strengthen the argument for the increased benefit of incorporating two compared to one learning styles model in the system. The following chapter discusses the evaluation study that was carried out.

Chapter 6

Testing learning gains and satisfaction

6.1 Introduction

The purpose of the experiment in the previous chapter was to test if the system was achieving the research goals, such as providing the user with a tailored presentation and to gain the opinions of the users as to whether or not they recognised that the lesson was indeed presented according to their individual learning styles. Once it was established that the system could successfully cater for individual learning styles, it was decided to evaluate the system's effectiveness in terms of learning gains, and test the satisfaction of the users. This in turn would test the efficiency of the proposed system of combining two learning styles in terms of enhancing student knowledge of the learning gains. This chapter will proceed to discuss the methodology and results for the evaluation study.

It is hoped that the system developed can be used to *enhance* the learning process and in the future be used as an aid to teaching by addressing the needs of each student individually. While few studies, as discussed in Chapter 2, have formally assessed the relationship between a student's learning style and satisfaction with a web-based learning environment, several studies have examined student performance in a course which was technologically based. These studies found a positive relationship between learning styles and learning gains, but one cannot assume student satisfaction merely on the basis of a certain level of performance. As such, an evaluation of the learning that takes place as well as user satisfaction is necessary in order to strengthen the credibility of the current research.

The main purpose of this evaluation therefore, is to test if there is a difference between presenting a lesson according to two models of learning styles, one model, or none, as outlined in the previous chapters. The difference with this experiment is that it will focus on two main concepts: learning gains and user satisfaction.

There is a lack of evaluation studies concerning the effectiveness of using two models of learning styles in adaptive systems. Of the studies which assess the benefits of learning styles, the majority found that there is an increase in students' motivation and learning gains when learning styles are matched to the students' preferences [43-45, 47-

49]. However none of these studies use two models of learning styles. As such it is hypothesised that users who are presented the lesson according to two of their learning styles will have a better learning gains and give higher ratings of satisfaction than those who are presented the lesson according to one or none of their preferred learning styles.

6.2 Learning gains

In this study, learning gain was tested by giving the participants a PRE-TEST, a POST-TEST, and a CONFIRMATORY TEST. The method of “pre-test / post-test” is widely popular in educational studies [233]. This is the classic controlled experimental design and is one of the best and most practical to assess the impact of an intervention or treatment on two or more randomized groups, one control and one treatment. The fact that the lesson itself was very short, however, meant that some of the participants may remember the questions from the pre-test which may bias the results somewhat. The author therefore proposed the idea of the ‘confirmatory test’ as coined by the researcher as a precaution. This involved implementing a different set of questions to measure learning gains in order to avoid any reservations surrounding the post-test results. The positive difference between the post-test and the pre-test will be considered as learning gains. The questions in the confirmatory test are new and will confirm if there is a real difference between the groups. The results of the learning gains will be discussed below.

6.3 Satisfaction

This is an important part of the evaluation as it examines the opinions of the users on several issues. The word to satisfy as defined in the Oxford English dictionary means 1) ‘to please (someone) by doing or giving them what they want or need’ 2) ‘to meet a demand, desire or need; therefore, the word satisfaction in itself can cover a wide range of needs’. Simmons (2006) looked at satisfaction as “a post-consumption feeling or attitude towards a product or service.” [234] In this study, the researcher wanted to establish what the participant’s attitudes were towards the system 1) to see if the site was organised and easy to use, 2) to see if they enjoyed using the site and would use it again, and 3) to see if they found the site useful for learning. For the purpose of this study and ease of analysis, the concept of satisfaction was divided into the following three main concepts respectively, as identified by the researcher:

- 1) Usability
- 2) Preference
- 3) Perception of learning

The opinions of the participants were measured on a five-point Likert scale to a range of questions divided into these three concepts. The results of the satisfaction questions will be discussed below in section 6.5.

6.4 Methodology

6.4.1 *The instrument*

The instrument used to collect the data in this study is the questionnaire. The questionnaire is web-based and integrated with the system. It is composed of four main sections:

- 1- Demographic information.
- 2- Pre-test, to measure the students' knowledge before using the system.
- 3- Post-test, to measure the students' learning gains after having the lesson.
- 4- Confirmatory test to further confirm the understanding of the content of the lesson.
- 5- Satisfaction section, to measure the three main concepts as divided above.

6.4.2 *Procedure of data collection*

The director general of Saudi schools in the UK and Ireland was contacted to seek the participation of the students and staff in the Saudi schools around the UK. After gaining permission, thirty two head teachers were contacted to encourage the staff of their schools to participate. Participants were invited by email; they were given the invitation in addition to an explanation of the project, and a hyper link to the website of the experiment. The language used in all of the contacts and the descriptions of the study was English.

6.4.3 Participants and demographics:

Of the total 544 people that were contacted from 32 schools, 234 provided some feedback while only 149 of them completed the questionnaires fully. The tables below show a breakdown of the participants according to different categories.

Table 6-1: Distribution of participants based on gender

	Frequency	Percent
Male	133	89.26
Female	16	10.74
Total	149	100

Table 6-1 provides the distribution of male and female participants. 89% of the participants are males.

Table 6-2: Distribution of participants based on discipline

	Frequency	Percent
Computer Field	59	39.60
Non Computer Field	90	60.40
Total	149	100

Table 6-2 shows the distribution of the participants based on their disciplines. For the purpose of this study, disciplines are broadly classified into ‘computer field’ and ‘non-computer field’. 6 out of 10 participants are from a ‘non-computer field’.

Table 6-3: Distribution of participants based on age

Age	Frequency	Percent
18-24	5	3.36
25-34	73	48.99
35-44	56	37.58
45-55	15	10.07
Total	149	100

Table 6-3 shows the number or frequency of participants in a given age group. There are four age groups as shown. The majority of the participants (86%) are aged between 25 and 44years.

Table 6-4: Distribution of participants based on educational status

	Frequency	Percent
Undergraduate	15	10.07
Diploma	7	4.70
Master	71	47.65
PhD	52	34.90
Lecturer	4	2.68
Total	149	100

Table 6-4 shows the distribution of the participants according to their education qualifications. Participants were divided into five categories. These categories are broadly classified as ‘Undergraduates’, ‘Diploma holders’, ‘Masters’, ‘PhD’ and ‘Lecturers’. Approximately, 48% of the participants are Master’s students, 35 % are PhD students and 17 % belong to the other three categories.

6.4.4 Groups

During the experiment participants were divided into four groups as in the previous study:

- 1- Group “VARK” were presented a lesson according to their VARK
- 2- Group “H&M” were presented a lesson according to their Honey and Mumford
- 3- Group “VARK and H&M” were presented a lesson according to their two models (VARK and Honey and Mumford)
- 4- Group “No tailoring”– were presented a lesson NOT according to their learning styles, i.e. no customisation

Table 6-5 below shows the number (frequency) of participants in each of the four groups of the experiment. Each of the groups VARK and H&M has 38 participants; while group “VARK and H&M” has 36 participants and the group No tailoring had 37 participants.

Table 6-5: Distribution of participants based on groups of the experiment

	Frequency	Percent
VARK	38	25.50
H&M	38	25.50
VARK and H&M	36	24.16
No tailoring	37	24.83
Total	149	100

As already mentioned, the degree of success will be classified according to two parameters: satisfaction and learning gains. For analysis, certain assumptions were made:

- The group “VARK and H&M” will have better learning gains and give higher ratings for satisfaction than the group VARK, the group H&M and the group No tailoring.
- The group VARK and the group H&M will have better learning gains and give higher ratings for satisfaction than the group No tailoring.

6.4.5 Testing learning gains

To test the learning gains there are eight questions asked before the lesson. The questions are multiple choice questions with 5 choices to reduce the chance of guessing. The questions are about the content of the lesson, i.e. they will test if the user has any previous knowledge or how much they know about the topic “waterfall lifecycle” [235] before using the system.

After the lesson, the participants are given a post test. The post test is composed of exactly the same eight questions in order to examine the learning that has taken place. The difference between the results of the questions asked on the above two occasions

represents the learning gain. The following tables show the results for the separate tests as well as the difference between the two tests.

6.3.1. Pre-test

Table 6-6: Mean scores of the pre-test

	N	Mean
VARK	38	%29.61
H&M	38	%31.58
VARK and H&M	36	%30.21
No tailoring	37	%37.16
Total	149	%32.13

As shown in Table 6-6, The highest mean score was obtained by the participants in the No tailoring Group (37.16%) showing that they understood the topic more than the participants in the other groups. An ANOVA was carried out in order to test statistically whether there were any differences between the groups. Results from the ANOVA revealed that there were no significant differences between the groups, $F(3,145) = 1.01$, $p=0.39$. This indicates that the difference in scores between the group means is not statistically significant, i.e. there is no significant difference between the groups in their knowledge before using the system.

6.3.2. Post-test

Table 6-7: Mean scores of post-test

	N	Mean score (%)
VARK	38	67.11
H&M	38	66.11
VARK and H&M	36	79.51
No tailoring	37	64.53
Total	149	69.21

From Table 6-7 it can be observed that overall all of the groups show significant learning gains. It can be seen that participants in the group “VARK and H&M” have the highest mean score (79.51) while the Group ‘No tailoring’ has the lowest mean score (64.53). By looking at the mean score of all the groups (69.21), it can be seen that the

group VARK and H&M is the only group with a score higher than this value. This indicates that the participants in the VARK and H&M GROUP achieved more learning gains than the other three groups.

An ANOVA was carried out to test this difference statistically. The results showed that the difference between the means of the results of the participants in the post-test was not statistically significant, $F(3,145) = 2.514$, $p = 0.061$. In other words, although from the means it appears that there is a difference in score between the groups, the difference is not statistically significant.

To further test the learning gains, the difference between the post-test and pre-test scores were calculated and entered into an ANOVA. Table 6-8 below displays a summary of the results.

6.3.3. Difference between pre- and post-test

Table 6-8: Mean difference between mean scores pre- and post-test

Groups	N	Pre Means	Post Means	Difference between means
VARK	38	29.61	67.11	37.50
H&M	38	31.58	66.11	34.53
VARK and H&M	36	30.21	79.51	49.31
No tailoring	37	37.16	64.53	27.36
Total	149	32.13	69.21	37.08

Table 6-8 above shows the difference between the pre- and post-test results i.e. how much the user knew before visiting the lesson and after visiting the lesson. It can be seen that the participants in the group VARK and H&M gained the highest learning gains, with a mean difference score of 49.31, while participants in the No tailoring group showed the lowest learning gains with a mean difference score of 27.36.

Results from the ANOVA showed that there is a significant difference between the groups scores, $F(3,145)=3.101$, $p<0.05$. Due to the fact that there are four groups in this analysis, six separate ANOVAs were carried out to examine where the differences were:

- 1- Comparing 'VARK and Honey & Mumford' with 'VARK'
- 2- Comparing 'VARK and Honey & Mumford' with 'Honey & Mumford'
- 3- Comparing 'VARK and Honey & Mumford' with 'No tailoring'

- 4- Comparing 'VARK' with 'No tailoring'
- 5- Comparing 'VARK' with 'Honey & Mumford'
- 6- Comparing 'Honey & Mumford' with 'No tailoring'

Of the above test only one revealed a significant difference between groups: the ANOVA between 'VARK and H&M' and 'No tailoring', $F(1,71)=10.29$, $p<0.01$. This result proves one part of the experimental hypothesis in that two learning styles are significantly better than none. The results did not support the second part of the hypothesis that two learning styles are better than one.

A confirmatory test was carried out in order to further test the learning gains, as the means in Table 6-8 above indicate that there is a trend supporting the difference in learning gains between two and one learning style.

6.5 Confirmatory test

An additional confirmatory test was conducted to verify the difference between the groups in their learning gains. Nine new questions we asked which related to content of the lesson. These questions aimed to confirm the understanding of the content of the lesson. The results from this test are shown in Table 6-9 below. Again all scores below are given as percentages.

Table 6-9: Mean scores on additional test

	N	Mean
VARK	38	66.37
H&M	38	64.91
VARK and H&M	36	78.40
No tailoring	37	60.96
Total	149	67.56
ANOVA	F-value	Sig
Between Groups	2.994	0.033

From Table 6-9, it can be seen that participants in the group 'VARK and H&M' have the highest mean of correct answers (78.40). Furthermore, they are the only group with

a mean score above the average score (67.56) across the four groups. Again, the group 'No Tailoring' has the lowest mean (60.56).

An ANOVA was carried out in order to test statistically whether the difference between the two groups was significant. Results showed that there is a significant difference, $F(1,145)=2.994$, $p<0.01$. Again, it was necessary to carry out six separate ANOVAs in order to reveal where the differences lie.

Results from these analyses revealed that there were significant differences between:

- 'VARK and H&M' and VARK, $F(1,72)=4.49$, $p<0.01$
- 'VARK and H&M' and H&M, $F(1,72)=5.09$, $p<0.01$
- 'VARK and H&M' and No tailoring $F(1,71)=9.14$, $p<0.01$

These results confirm the findings from the post-test with regard to participants using two learning styles gaining more from the lesson compared to those using no learning styles. In addition to this, the results further reveal that participants using two learning styles gain more than those using only one learning style, as first hypothesised in the introduction.

These findings indicate that the system indeed achieves the research goals where the learning process of users is enhanced by using two learning styles models. Participants who are presented with a lesson using two learning styles models have shown better learning gains than those presented with only one. It also supports the idea of using learning styles at all as even users who were presented the lesson using just one model compared to no tailoring showed significantly higher learning gains. This would seem to be in agreement with previous studies indicating better results using learning styles which match the user's preference [43-45, 47-49].

6.5.1 Satisfaction

As previously discussed, the second aim of this study was to test the satisfaction of the users from the four groups. There were 12 questions each with a 5-point Likert Scale to investigate satisfaction ranging from 1 (strongly disagree) to 5 (strongly agree). In this study the questions measuring satisfaction were divided into three main concepts for the purpose of analysis: Usability, Preference and Perception of learning.

Statements on Usability:

Q2 - The instructions and prompts are clear.

Q3 - Learning to operate this software is easy.

Q7 -The way that system information is presented is clear and understandable.

Q8 -The organisation of the system seems logical.

Q10 - It is easy to move from one part to another.

Statements on Preference:

Q1 - I would recommend this system to my colleagues.

Q4 - I enjoyed my session with this system.

Q6 - Working with this software is satisfying.

Q9 -The software has an attractive presentation.

Q12 - I would use this system again

Statements on Perception of learning:

Q5 - I find that the system is useful for learning.

Q11- I have a better understanding of the topic “waterfall lifecycle” by using this lesson.

6.5.2 Usability:

Table 6-10: Usability Summary

Group	N	Q2: The instructions and prompts are clear	Q3: Learning to operate this software is easy	Q7: The way that system information is presented is clear and understandable	Q8: The organisation of the system seems logical	Q10: It is easy to move from one part to another	Total mean score
		Mean score					
VARK	38	✓4.05	3.84	3.89	3.84	✓4.03	✓3.93
H&M	38	4.00	3.84	3.92	✓4.08	3.58	3.88
VARK and H&M	36	3.78	3.86	✓4.19	3.67	3.78	3.86
No tailoring	37	3.84	✓3.95	3.76	3.86	3.57	3.80
Total	149	3.92	3.87	3.94	3.87	3.74	3.87

Table 6-10 shows that none of the scores are below expectation with a minimum score of 3.57 and a maximum score of 4.19 out of 5.0 points. This indicates that the learning styles are adequate for usability. ANOVAs were carried out for each question in order to examine if there were any significant differences between the four groups.

Q2: The instructions and prompts are clear.

The results from Q2 suggest that all of the groups agreed that the instruction and prompts are clear with a minimum score of 4 out of 5. An ANOVA was carried out and found that there is no significant difference between the groups, $F(3,145)=0.483$, $p=0.695$.

Q3: Learning to operate this software is easy.

The results from Q3 show that the responses of all the participants range between neutral (3) and agree (4). It suggests that all the groups agree that learning to operate this software is easy. From the ANOVA, it can be concluded that there is no statistical significant difference between the groups, $F(3,145)=0.058$, $p=0.982$.

Q7: The way that system information is presented is clear and understandable.

With regard to Q7, it can be concluded that all of the groups agree that the information is presented in a clear and understandable way. An ANOVA confirmed that there is no statistical significant difference between the groups, $F(3,145)=1.062$, $p=0.367$.

Q8: The organisation of the system seems logical.

Similarly, from Table 6-10, we can observe that for Q8 all of the groups agree that the organisation of the system seems logical. Again, there is no statistically significant difference between the groups, $F(3,145)=0.833$, $p=0.478$ as confirmed by the ANOVA results.

Q10: It is easy to move from one part to another.

Finally, from the results for Q10, it can be concluded that all of the groups agree that it is easy to move from one part to another. Again, results from the ANOVA indicate that there is no statistical significant difference between the groups, $F(3,145)=1.125$, $p=0.341$.

6.5.3 Preference:

Table 6-11: Preference Summary

Group	N	Q1: I would recommend this system to my colleagues	Q4: I enjoyed my session with this system	Q6: Working with this software is satisfying	Q9: The software has an attractive presentation	Q12: I would use this system again	Total mean score
		Mean score					
VARK	38	3.63	3.55	3.74	3.37	3.47	3.55
H&M	38	3.71	3.55	3.61	3.63	3.27	3.55
VARK and H&M	36	✓4.19	✓4.06	✓4.00	✓3.81	✓3.86	✓3.98
No tailoring	37	3.49	3.08	3.54	2.81	3.05	3.19
Total	149	3.75	3.56	3.72	3.40	3.41	3.57

Table 6-11 shows that none of the scores considered for preference learning tools are below average with the exception of the No tailoring group for Q9 relating to attractive presentation of the software (2.81). Recommendation of the system to colleagues (Q1) and software satisfaction (Q6) received the highest overall mean scores among the participants, 3.75 and 3.72 out of 5.0 respectively. Looking closely at the individual group scores, the 'VARK and H&M' group give the highest scores in all the attributes considered. Overall, the results indicate that the preference attributes are well accepted across the groups (overall mean of 3.57) but mostly within the 'VARK and H&M' group (3.98).

Q1: I would recommend this system to my colleagues.

For Q1, it is interesting to note that a large number of the participants among the 'VARK and H&M' group agreed to introduce the system to their colleague and that those in the No tailoring group had the lowest score for this question. From the results of the ANOVA we can conclude that all of the groups agree that they would recommend this system to their colleagues; the difference in means is not statistically significant, $F(3,145)=2.392$, $p=0.07$.

Q4: I enjoyed my session with this system.

The above table shows that the response for Q4 is the highest for the 'VARK and H&M' group and the response for the No tailoring group is the lowest among the groups. Overall, however, the above table suggests that all of the groups agree that they enjoyed their session with the system. Results from the ANOVA for Q4 revealed that there is a significant difference between the groups, $F(3,145)=3.651$, $p<0.05$. Separate t-tests were carried out to examine between which groups the differences lie. Results found that there was a statistical difference between the 'VARK and H&M' group and the No tailoring group $t(71)=3.36$, $p<0.01$. None of the other t-tests comparing groups were significant. This indicates that the participants in the 'VARK and H&M' group enjoyed their session with this system significantly more than those in the No tailoring group.

Q6: Working with this software is satisfying.

Results for Q6 show that, once more, the response for the 'VARK and H&M' group is the highest and response for the No tailoring group is the least among the groups. From

the above table we can conclude that all the groups agree that they were satisfied on working with this software. The results from the ANOVA found that the difference is not statistically significant between the groups, $F(3,145)=1.141$, $p=0.335$.

Q9: The software has an attractive presentation

Again, results for Q9 show that the response for the 'VARK and H&M' group is the highest and response of the No tailoring group is the least among the groups. The above table suggests that, with the exception of the No tailoring group, all of the groups agree that the software has an attractive presentation. Results from the ANOVA revealed that the difference between the groups is statistically significant, $F(3,145)=4.215$, $p<0.01$. Separate t-tests were carried out to examine between which groups the differences lie. Results found that there was a statistical difference between the 'VARK and H&M' group and the No tailoring group $t(71)=3.42$, $p<0.01$; and between the H&M group and the No tailoring group $t(73)=2.97$, $p<0.01$. This indicates that the participants in the 'VARK and H&M' group and the H&M group agree that the software has an attractive presentation significantly more than those in the No tailoring group.

Q12: I would use this system again.

The response for the VARK and H&M group for Q12 is the highest and the response for the No tailoring group is the least among the groups. Table 11 above suggests that all of the groups agree that they would use the system again. Results from the ANOVA reveal that the difference between the groups is statistically significant, $F(3,145)=3.381$, $p<0.01$. Separate t-tests were carried out to examine between which groups the differences lie. Results found that there was a statistical difference between the 'VARK and H&M' group and the No tailoring group $t(71)=3.02$, $p<0.01$; and between the 'VARK and H&M' group and the H&M group, $t(71)=2.15$, $p<0.05$. This indicates that the participants in the 'VARK and H&M' group would use this system again significantly more than those in both the H&M and No tailoring group.

6.5.4 Perception of learning:

Table 6-12: Perception of learning Summary

Group	N	Q5: I find that the system is useful for learning	Q11: I have a better understanding of the topic “waterfall lifecycle” by using this lesson.	Total mean score
		Mean score		
VARK	38	3.89	3.13	3.51
H&M	38	3.42	✓4.03	3.73
VARK and H&M	36	✓4.00	3.94	✓3.97
No tailoring	37	3.49	3.22	3.36
Total	149	3.70	3.58	3.64

Table 6-12 shows that all the attributes scores are above average which indicates a positive perception towards the learning tools. In general, perception of learning has a good score (3.64), reflected mostly within the ‘VARK and H&M’ group (3.97) and H&M group (3.73).

Q5: I find that the system is useful for learning.

From the table above it can be seen that participants in the ‘VARK and H&M’ group give the highest response for Q5 (4.00). The lowest response was given from participants in the H&M group (3.42). An ANOVA was carried out in order to test if the difference was significant between the groups. Results found no significant difference, $F(3,145)=2.23$, $p=0.08$. This indicates that all of the groups found the system useful for learning to a similar extent.

Q11: I have a better understanding of the topic “waterfall lifecycle” by using this lesson. For Q11, the mean of all the participants from all four groups is above the average (3.58). The table above shows that in this case mean responses from the H&M group (4.03) are higher than those in the ‘VARK and H&M’ group (3.94). An ANOVA revealed that there is a significant difference between groups, $F(3,145)=6.282$, $p<0.01$. Separate t-tests were carried out to examine between which groups the differences lie. Results found that there was a statistical difference between the ‘VARK and H&M’ group and the VARK group $t(72)=3.02$, $p<0.01$; and between the ‘VARK and H&M’ group and the No tailoring group $t(71)=2.73$, $p<0.01$; and between the VARK group and

the H&M group $t(74)=3.54$, $p<0.01$; and between the H&M group and the No tailoring group $t(73)=3.24$, $p<0.01$. These sets of results indicate that participants using two learning styles rated that they had a better understanding of the topic “waterfall lifecycle” by using their lesson compared to those using the VARK style and those with no customisation. Furthermore, participants in the H&M group also rated that they had a better understanding of the topic “waterfall lifecycle” by using their lesson compared to those using the VARK style and those with no customisation.

6.5.5 *Summary and conclusion*

The main aim of this final evaluation study was to test the following two concepts:

- 1) Learning gains
- 2) Satisfaction

The results from the post-test showed a pattern for the learning gains: Learning gains were rated highest by participants using two learning styles (VARK and H&M group) compared to those using either one or no customised learning style. Following on, the results showed that those using only one learning style (either VARK or H&M) rated their learning gains as higher than those using no customised learning style. The only ANOVA, out of the six carried out for the pre- post-test difference, which revealed a significant difference between groups was the ANOVA between the VARK and H&M group and the No tailoring group. In order to confirm these results, an additional ‘confirmatory’ test was also carried out to examine the effectiveness of the learning styles on learning gains. These results confirmed the findings from the post-test. The results from the ANOVA were significant showing that participants using two learning styles gain more from the lesson compared to those using no learning styles. In addition to this, the results further indicated that participants using two learning styles gained more than those using only one learning style, as initially hypothesised.

These results appear to be in line with the results of many of the existing studies that highlight the positive effects of learning styles on student performance as discussed in the introduction to this chapter. This evaluation study has shown that learning gains are higher for those who were presented the lesson according to their preferred learning styles as tested from the difference between pre- and post-test scores. The current study goes even further and shows that by using two learning styles, the learning gains can be

significantly higher than when only one learning style is used. This could have major implications for teaching-learning practices showing that attention to a *range* of the preferred learning styles of students, not simply one preferred learning style, could improve their learning gains significantly more-so. A relationship between learning styles and learning gains in higher education can be problematic in that there are numerous variables which could influence student's achievement scores over the period of their studies through interacting with their learning style such as teaching styles and student motivation [236, 237]. This study investigates the learning gains of a pre- and post-test in relation to the lesson presented therefore few external variables (such as age, and subject) can impact upon the students.

The second aim of the study was to examine the satisfaction of the users from the four groups. Satisfaction was divided into three main concepts: usability, preference, and perception of learning.

The results from the usability section overall showed that the usability of the system was perceived to be positive by all of the participants with the mean score for each of the four groups higher than the overall mean score; which are positive responses and higher than 3. Results revealed that there were no significant differences between the groups for any of the five questions. This indicates that the perception of usability does not differ between groups, effectively showing that the system is organised and easy to use irrespective of the group in which participants were placed. It could be said the system is satisfactory in terms of functionality/usability for all users and does not 'favour' or 'benefit' any of the learning styles over the other.

In relation to the second concept of satisfaction, there were five questions that assessed preference. For all five questions, participants in the 'VARK and H&M' group gave the highest rating while participants in the No tailoring group gave the lowest ratings. Recommendation of the system to colleagues and software satisfaction received the highest scores among the participants. Three out of five questions revealed significant differences between groups. Firstly, it was found that participants in the 'VARK and H&M' group enjoyed their session with this system significantly more than those in the No tailoring group. Secondly, participants in both the 'VARK and H&M' group and the H&M group rated that the software has an attractive presentation significantly higher than those in the No tailoring group. Finally, participants in the 'VARK and H&M'

group rated that they would use this system again significantly higher than those in both the H&M and No tailoring group. These findings indicate that the learning styles had an effect on the participants in terms of their enjoyment of the system and whether or not they would use the system again. Those who were presented the lesson according to two of their learning styles gave higher ratings of satisfaction in these dimensions. This may be related to the fact that these participants felt that they learnt more and benefited from the system more. Indeed the results from the final concept (perception of learning) show just that. It becomes clear from these results, therefore, that the concept of satisfaction; in essence, satisfaction encompasses many aspects of how participants felt towards the system. Taken together, therefore, these results show that when users are presented a lesson according to their learning style, they are more likely to enjoy interacting with the system and are more likely to use the system again and this could in turn be influenced by the fact these users feel that they learn more when their learning styles are taken into consideration.

With regard to the last concept, only two questions were asked to address the perception of learning. The highest mean was gained by participants in the 'VARK and H&M' group for the first statement, "I find that the system is useful for learning". However there was no significant difference in the scores between the groups. For the second statement, "I have a better understanding of the topic "waterfall lifecycle" by using this lesson", participants in the H&M group had the highest rating. The ANOVA revealed that participants using two learning styles rated that they had a better understanding of the topic "waterfall lifecycle" by using their lesson compared to those using the VARK style and those using no customisation. Furthermore, participants in the H&M group also rated that they had a better understanding of the topic "waterfall lifecycle" by using their lesson compared to those using the VARK style and those using no customisation. These results of learning gains are in agreement with previous studies that show positive impacts on learning when learning styles are matched with teaching styles [43-45, 47-49, 90, 93, 99]. This study goes further by examining the attitudes of the users as well as the actual learning gains.

This study expands upon the previous work in the field and indicates the additional benefits of addressing more than one learning style. From the results overall, it appears that participants using two learning styles showed a higher learning gains, and had

higher levels of satisfaction across all three factors compared to those using only one or no customised learning style. Furthermore, those using only one learning style showed higher learning gains and had higher levels of satisfaction than those with no customised learning style. This confirms the experimental hypothesis put forward in the introduction highlighting the success of the system on learning and user satisfaction. These results provide support for the notion that matching instructional teaching styles to learning styles can have significant effects on student learning gains.

The evaluation study has provided an appraisal of the system in terms of learning gains and user satisfaction, which can be used to show the success of the system and more specifically in relation to learning styles, that two learning styles can offer users a higher level of satisfaction and learning gains compared to one or no customisation at all. Educators could build upon these results by incorporating the ideas surrounding the research into practice either by using various teaching strategies suited to individuals or by using adaptive systems to aid the teaching and learning process. Either way, this study has shown that the more learning styles taken into consideration, the better the learning gains and user satisfaction.

Chapter 7

Discussion

This chapter will provide the reader with a full summary of the design and results of the present research, as well as an analysis of those results. As an introduction, first a review of the literature deemed most relevant to the premises of the present research and upon which the design of the present research was based will be presented. The methodology and test results will be touched upon before a discussion of the implications, limitations, and possible future directions of the research.

As already have been seen from the literature review, the effectiveness of presenting information in accordance with the two preferred models of learning styles of students on their ultimate learning gain is a much debated phenomenon, and researchers like E. McKay, 2000 [110]; Dekeyser, 2000 [107]; Kelly & Tangney, 2004 [108] remain sceptical about the benefit of the application of learning styles. However, there are a great number of researchers who believe that the application of learning styles does have a positive influence, such as Hodges & Evans, 1983 [95]; Martini, 1985 [97]; Riding & Douglas, 1993 [105]; Butler & Mautz, 1996 [101], and they have produced work to support this hypothesis. On the whole, these researchers believe that there is a direct positive influence of learning styles specifically on learning practices, and it is this premise that is adopted in the research presented in this thesis.

Additional studies suggest that the application of learning styles is a popular method of instruction among students that also positively affects student satisfaction and attitudes to learning. A number of researchers including Dunn, Beadury, & Klavas, 1990 [238], Griggs, 1991 [55], and Simon (2000) [106] are of the view that as a result of adopting preferred learning styles, both the learning gains and satisfaction are improved.. Various other studies, such as Felder & Silverman, 1988 [81] go farther to suggest that application of learning styles in the classroom results not just in improvement of learning gain and the overall opinion of the course, but in the attitude of students to their studies as well. Similar are the findings from the work of (Bacon, 2004 [16]; Brudenell and Carpenter, 1990 [88]; Kramer-Koehler [91]; McLoughlin,

1999 [11]; Miller, 2001 [89]; and Sarasin, 1999 [92], who show that students taught according to their learning styles achieved higher test and attitude scores. Yet these authors go so far as to say their test subjects actively support learning styles. In general, Buch & Bartley (2002) [102] have found that preference and satisfaction have a significant relationship with the method of delivery of the tutorial. As a result, Felder & Silverman, 1988 have recommend teachers modify their teaching styles to suit the learning styles of their students in order to increase learning outcomes.

On the backdrop of the research cited above, the present research aims to develop a systematic application of two combined models of learning styles., VARK and Honey & Mumford, and to investigate its impact on the learning performance of students when presented as online tutorials to learners, based on the research conducted using the two models. The research aims to compare how application of the models may affect participants when implemented separately and in tandem.

The tests carried out in this thesis are aimed to design a system that is adaptive to the learning style of the individual using it. Furthermore, the researcher attempted to combine more than one learning style as such systems to date only use one learning styles model, which may not encompass enough styles for the users, given that VARK primarily refers to the medium of data input, whereas Honey & Mumford accounts for learning strategies. To adapt to an individual, learning systems must take into account as many details as possible in terms of the learning styles of the user, and thus it should be able to adapt its presentation according to more than one learning styles model. To ascertain whether the system works as intended to produce materials according to students' learning styles, it was first investigated whether learners could recognise when material had been tailored to two learning styles models, one model, or had no personal customisation.

The tests reported in this thesis represent one of the first attempts to develop a system that presents tutorials to learners based on research conducted using the two models VARK and Honey & Mumford. As a consequence, the research in this thesis has been relatively exploratory. The thesis started by considering the opinions and preferences of the users toward possible learning styles and recording this in a student profile which can be updated as the users' preference may change. Pilot surveys were designed and

tested in order to develop the main research instrument (as set of surveys), which was used to collect the primary data. The system was designed to determine the learning style of the user according to both the VARK and Honey & Mumford model and in turn present a lesson that was tailored according to the learning style(s) that best suit the user. From the results of the pilot studies, the system was amended accordingly and the main study and evaluation were carried out. Both experiments provided valuable information about the difference between using a model with two, one or no customised learning styles, first in terms of students' ability to recognize a tailored lesson, and then in terms of learning gains and satisfaction. The results of these assessments will be considered below.

7.1 Methodology

The methodology was developed to address points raised by detractors of learning styles theory. Firstly, Becta (2005) [239] states that although learning styles theory draws from pedagogy, psychology, and neuroscience, it does not fully engage in any one of these fields. Critics of learning styles theory contest that it lacks clear definitions and that learning style theorists have not distinguished learning style constructs from intelligence [19]. In short, there are too many different theories, and the confusion between terms and models result in the absence of a universally accepted model [20]. It was primarily for this reason that the researcher decided to use two learning models, VARK and Honey & Mumford. More about the rationale for selection of these learning models and their implementation will be presented in section 7.2,

Secondly, it has been claimed that the instruments used to determine a learning style preference lack of reliability and validity [240]. Another argument put forward is that the implementation of learning styles on a large scale is highly unreasonable in that matching teaching styles to each individual student style is unrealistic [13]. Teachers would face the problem of identifying each student's style then devising material to accommodate the various learning styles; this in itself is difficult to imagine, not to mention the lack of resources within the classroom and differing knowledge bases of teachers in learning styles theory. The methodology in this thesis has been developed expressly to address these concerns. The researcher has carried out the empirical tests necessary to provide results validating the application of learning styles theory as an educational aid. By developing a system that can automatically detect and adjust to a student's learning style, a powerful tool will be available to teachers or individuals in

self-study who may lack knowledge about learning style theory. The system will also provide a tool that can be employed by other researchers to address a final complaint against learning styles theory, that there is a lack of the longitudinal studies necessary to show how stable learning styles are over time.

To this end, a robust methodology was designed through the incorporation of two research tools, including two pilot studies and interviews with experts. These preliminary steps were employed to focus the revision of preliminary work and thus ultimately to achieve reliable results the final study regarding the use of two learning styles models, one model, or no learning styles. Firstly, a survey was used to collect both quantitative and qualitative data using closed-ended questions and open-ended questions. It was web-based and introduced as part of the system. The survey was designed and developed. It was short to engage the participant's attention and avoid unnecessary blank responses,

After developing the first prototype of the system, a small scale exploratory study using eight colleagues was carried out. The method of observation was a useful means of making sure that participants could understand the system and the survey well before a larger scale pilot study was begun, and the insights gained from this exploratory study were implemented within the larger scale pilot study. The main pilot study was carried out to safeguard against problems, such as respondents misunderstanding instructions, and to ensure that anything else that could go wrong was be fixed before attempting the final study.

Finally, interviews with educationalists were also used to review and discuss results of the main survey and pilot study, and to provide the researcher with suggestions to assist creation of the final study. Four experts were involved in the evaluation of these various steps, and interviews were conducted after the pilot study in order to enable the researcher to go into more detail with the interviewees about preliminary results and setbacks. The interviews were designed as semi-structured to offer more flexibility, allowing the researcher to explore issues as they were raised.

7.2 The System

The designed learning system employed two models of learning styles in order to determine the optimum presentation style of the tutoring material (lesson) for users. The two models, VARK (Visual, Aural, Read, and Kinaesthetic) and Honey & Mumford, differ in terms of how learning styles are categorized. VARK is based upon biological or physical learning considerations, whereas Honey & Mumford is based upon psychological learning considerations. Therefore, when the combination of two learning styles is referred to in this thesis, what is meant is the combination of the student's preferred learning style from a biological/physical and psychological perspective, rather than any combination of learning styles from within any one model.

Before commencing the investigation, a correlation test was carried out in order to test whether or not any of the learning styles specific to the VARK and Honey & Mumford models correlated with each other. This was to verify that the learning styles from each model measured different attributes and did not overlap, as well as to determine if a learning style from one model could predict the learning style in the other model. The results showed that there were no significant correlations across categories from the VARK and Honey & Mumford learning styles models, and therefore it was valid to test for the effect of combining a student's preferred learning styles from each model.

The concept of the system consisted of four major components: Domain Knowledge, Tutoring Model, Student Model and Communication Model. The high-level architecture for the system was based on the traditional Intelligent Tutoring System by Vasandani and Govindaraj [221].

To initiate the process of creating an ideal system, a prototype was developed and then modified slightly to get an initial image of what the structure would be, how it would be used, and to gain an idea of the work that would be required. The first task of the system was to decide upon the individual learning profile of each student. Students were initially required to register to use the system, during which they provided basic demographic information later used for statistical analysis. Once registered, students then completed two brief tests that serve as diagnostic tools for the VARK and Honey & Mumford models). At the end of each test, the system quantified the student's response. If the system was unable to quantify a student's profile, additional questions

were presented until a learning profile could be decided upon. The system classified the user's learning style for each model as the style that possessed the highest score in each of the two tests. By assigning one of the four styles from each model to the user, the system was able to gather information from participants of the study and build a student profile. Once the tests were completed and a student profile built, a lesson was then tailored according to the learning styles that best suited the user and presented to the user for evaluation.

Student profiles were not assumed to be static, and the possibility that students' learning styles may change over time was catered to by the system in two ways. Firstly, it allowed students to 'step out' of their current learning style and take lesson content designed to be optimal for a different style. Once content was provided to the student, the system questioned the student about the suitability of the content. If a student decided that it did indeed fit with his/her way of learning, the previous learning style profile was updated. In this manner, the researcher followed meticulous methodological steps to ensure that the system designed would deliver the lesson according to the perceived learning style(s) of the users, regardless of the effectiveness of the original diagnostic tests.

7.3 Testing feasibility of the system

The first test addressing feasibility of the system was intended to ascertain if the users could reliably identify when a lesson was presented according to their preferred learning styles from each model, and to determine if the presence of two, one, or no preferred learning styles affected users' ability to perceive whether a lesson was tailored to them. The target users were students (graduate and postgraduate) and lecturers in higher education. Of the 300 people who were emailed, 157 people responded. After reviewing these responses, only 70 questionnaires were accepted due to partial or total incompleteness of the questionnaire. A total of 70 participants were engaged in usability tests as part of this usability evaluation study.

To examine if the number of the models of learning styles utilized in a lesson resulted in a difference in the ability to recognize individually tailored lessons, participants were divided into four groups: Group A was given a lesson presented according to the participant's learning style from both models; for Group B, the lesson was presented

only according to the participant's VARK learning style; for Group C, the lesson was presented only according to the participant's Honey & Mumford learning style; for Group D, the lesson was presented using neither of the participant's preferred learning styles from either model. The system considered the users as a queue of people, and thus every first of four was placed in group A, the second in group B, the third in C, and the fourth in D. This cycle was repeated until the last user. Participants did not know to which of the groups they were assigned. A total of 129 participants completed the study.

To assess users' perceptions of the lesson, a survey with open (Q 1-5) and closed (Q 6-7) questions was administered upon its completion. With regard to Question 1: "How would you rate your knowledge of the concept of Learning Styles before you visited this website?" A high number of participants (40.3%) indicated that they had never heard of the concept before. This was taken to be due to the fact that most of the participants were undergraduate students in the field of computer science. The question of users' previous experience with learning styles theory was commented on by users as a potential limitation of the current system, and this question is addressed in section 7.11 on future directions of research.

Question 2 was the most important question of this study because it aimed to address the research question of whether or not users of the system recognised when it produced a lesson tailored to their learning styles: "Was this lesson tailored to you? (according to your learning styles)"? This question's inclusion in the survey also aimed to test the hypothesis that there will be a difference in users' ability to recognize a lesson presented according to two classifications of learning styles, only one classification, or neither of the users' learning styles. The results found that participants who completed a lesson presented according to two learning styles models (the VARK and Honey & Mumford group) agreed more often that the system had produced a lesson tailored to their learning styles than those who were presented with only one learning style (either VARK only or Honey & Mumford only). When comparing the VARK only group with the Honey & Mumford only group, results showed that participants agreed that the lesson was tailored to them more often when the system used the VARK method compared to when the system used the Honey & Mumford method. As discussed previously, this could be due to the nature of the study in that the lesson was presented on screen using a visual-based program, which incorporates one of the VARK learning

styles (Visual). Finally, when the system presented the lesson using either two or one learning style model, participants agreed more often that the lesson was tailored to their learning style than when there was no customisation (No tailoring group). Taken together, these results indicate that there is a difference between users' recognition of a lesson presented according to two classifications of learning styles, one classification, and neither of the users' learning styles, thus allowing the experimental hypothesis to be accepted.

The remaining three closed questions (Q 3-5) were intended to examine how easy it was for the participants to distinguish between a lesson adapted to their individual learning style(s) and one not suitable for their learning style(s) (Question 3), whether or not the site was organised in a way that was easy to understand (Question 4), and how easy they thought the site was to use (Question 5). With regard to Question 3, most of the respondents either agreed or strongly agreed that they were able to distinguish between learning styles, which also reflects on the validity of results obtained in Question 2. In relation to Question 4, only eight participants (6%) felt that the site was not organised in a way that was easy to understand. The majority of responses (71%) on a scale of 1-5 were 4 (agree) and 5 (strongly agree). As for Question 5, only three participants felt that the site was not easy to use. Despite this feeling, s they still indicated in Question 2 that they could determine whether a lesson was tailored to their learning style. However, the presence of these responses implies that if improvements are made to the functionality of the system, its value for certain users may be enhanced as well.

The final 2 open-ended questions were provided to assess the users' evaluation of the site in terms of usability. Question 6 investigated what they liked best about the site. Most of the participants felt that the idea was unique, stating that that the system is user-friendly as well as interesting. A lot of the participants expressed that they enjoyed finding out about their own particular learning styles and that they felt the system helped them with the lesson in that it presented the material in a personalised way, enabling that particular lesson to be learned more easily. Overall, the responses to this survey question were very positive. Question 7 looked at the negative aspects of the system by asking what participants liked least about the site and how they thought it could be improved. Concerning usability, several respondents felt that some of the questions were unclear or difficult to understand. As for functionality, two of the

respondents indicated that they felt the system was not suitable to them because there was no audio in the lessons, which they indicated was one of their preferred learning styles. Suggestions were made with regard to clarity in that there could be slight improvements to the site by making some of the questions clearer and providing more information on the concept of learning styles prior to the lesson to help users to identify which learning style best suits them, and thus enabling them to take full advantage of the system. The key findings showed that there was a significant difference between how often users could recognize whether a lesson had been tailored to their learning styles when it was presented according to two classifications of learning styles, only one classification, or neither of the users' learning styles. By implication, those who were presented with the lesson according to two of their learning styles may have had more opportunity for them to recognise that the lesson was presented to their learning styles compared to those with one or no customisation. With regard to users' evaluation of the system, open-ended questions allowed participants to describe in more detail what they thought of the study. Overall, it was found that participants enjoyed using the system, finding it useful and beneficial to their understanding of the lesson. Therefore, the system was found to be a realistic option for delivering lesson content that was recognizable to students as tailored to their learning styles.

7.4 Testing learning gains and satisfaction

An important reason for the application of learning styles theory is to improve student performance and satisfaction. Therefore, the main purpose of the final evaluation was to test if there was a difference between presenting a lesson according to two models of learning styles, one model, or none, focussing on two main concepts: learning gains and users' satisfaction. Learning gain was tested by giving the participants a pre-test, a post-test, and a confirmatory test. User satisfaction with their learning experience was addressed by means of three main concepts: usability, perception of learning, and preference. To test the learning gains, eight questions about the content of the lesson were asked before and after the test; i.e. they tested if and how much previous knowledge the user had of the topic before using the system (pre-test) and how much they learnt during the lesson (post-test). Participants were divided into four groups as done in the previous study (VARK and Honey & Mumford, VARK only, Honey & Mumford only, and No tailoring). A total of 149 participants completed the study.

Results from both the pre- and post-tests showed that there were no significant differences between the groups with regard to learning gains, indicating that there is no significant difference between the groups in their knowledge. The difference between the pre- and post-test scores were then analysed in order to assess if there was a difference in the amount of learning that had taken place throughout the lesson. Results revealed that there was a significant difference between the groups. Further ANOVAs revealed that the significant difference was between the VARK and Honey & Mumford group and the No tailoring group, indicating that two learning styles are significantly better than none.

An additional test was conducted to verify the difference between the groups in their learning gains. Nine different questions in relation to the content of the lesson that had not been tested before were asked. These questions aimed to confirm the extent of the participants' understanding of the lesson. The results confirmed the findings from the post-test that participants using two learning styles models gained more from the lesson compared to those using no learning styles. Additionally, the results also indicated that participants using two learning styles gained more knowledge than those using only one learning style, as first hypothesised in the introduction. These results appear to be in line with the results of many of the existing studies that highlight the positive effects of learning styles on student performance [90, 93, 99].

With regard to user satisfaction, the results from the usability section overall showed that the usability of the system was perceived to be positive by all of the participants with no significant differences between the groups for any of the five questions. This indicates that the perception of usability does not differ between groups, effectively showing that the system is organised and easy to use irrespective of the group in which participants were placed. In relation to the second concept of satisfaction, perception of learning, from the means for all five questions, participants in the VARK and Honey & Mumford group gave the highest rating, while participants in the No tailoring group gave the lowest ratings. Three out of five questions revealed significant differences between groups. Firstly, participants in the VARK and Honey & Mumford group enjoyed their session with this system significantly more than those in the No tailoring group. Secondly, participants in both the VARK and Honey & Mumford group and the Honey & Mumford group rated the attractiveness of the software presentation

significantly higher than those in the No tailoring group. Lastly, participants in the VARK and Honey & Mumford group rated that they would use this system again significantly higher than those in both the Honey & Mumford and No tailoring group. It was proposed that the results to the questions in this set may be related to the final concept of perception of learning, in that those who were in the group with two learning styles may have given higher ratings for enjoyment of their session because they perceived themselves to have learnt more than those in the other groups. With regard to the last concept, perception of learning, results revealed that participants using two learning styles rated that they had a better understanding of the topic after their lesson compared to those using the VARK style and those using no style. Furthermore, participants in the Honey & Mumford group also rated that their lesson had given them a better understanding of the topic compared to those using the VARK style and those using no style. These findings indicate that in addition to finding significant gains in learning outcome when using two learning styles, users rate themselves as having a better understanding of the topic, showing that attitudes towards the system are also affected by the different learning styles models used.

From the overall results, it appears that participants using two learning styles showed higher learning gains, and had higher levels of satisfaction across all three factors compared to those using only one or no learning style. Furthermore, those using only one learning style showed higher learning gains and had higher levels of satisfaction than those with no learning style. This confirms the experimental hypothesis put forward by the researcher, highlighting the success of the system for learning gains and user satisfaction. This finding adds weight to the argument that matching learning styles with teaching practices is more effective for student learning gains [43-45, 47-49, 90, 93, 99]. Furthermore, as a practical implication, the results from this study have shown that it seems beneficial to use two learning styles to improve both learning gains and user satisfaction. Therefore, based on the results of this study, it is recommended that teachers should use learning styles. Studies [241-243] have shown that learning styles are applicable to success in a traditional education setting as well. The researcher can therefore suggest that teachers use learning styles both when they teach in a traditional classroom or in online learning.

7.5 Other factors that may influence learning

The findings of this research suggest that learning styles do have a positive impact on the performance of learner. However, there are a few other factors that should be considered here as well.

- Learning style is not the only technique to improve learning skills, as argued by Mupinga *et al.* [244].
- Learning may also be influenced by social and cultural practices as suggested by [245-247].
- Factors like an individual's ability, willingness, motivation, prior knowledge, and learning environment as highlighted by Jonassen & Grabowski, 1993 [248] also play an important role towards the learning gains.
- Gender may also dictate the learning performance. Researchers like Philbin, Meier, Huffman, and Boverie (1995) [249] are of the same view, but have not been able to determine any correlation in this respect. The influence of gender remains a potential area of research.

Despite these factors, the positive influence of implementing a preferred learning style, either on its own or in conjunction with other factors, has been shown in many different studies, and the current research provides further evidence of the benefits of utilizing learning styles in the presentation of educational materials.

7.6 Limitations

Some of the major limitations of the studies carried out in this thesis are related to the sample population. Most of the participants are Arab, because the educational institutions that participated in the study were Arab. Previous studies have shown that there can be cultural differences in learning styles. A study carried out by Zhenhui (2001) [250] found that the traditional study patterns of a group of East Asian students affected the way they learnt material from an American teacher who used a more global, kinaesthetic approach to teaching. It was found that the students were inherently introverted, analytical, and reflective learners, indicating the negative impact was due to a mismatch in learning styles. It would be better in the future, therefore, if the study was carried out using people from different parts of the world, or a cultural study examining the differences in learning styles between different cultures could be attempted.

Secondly, in relation to the current study, the majority of the participants were male; it would be beneficial to have a more equal ratio of male and female participants as there have been some indications of gender differences in learning gains when using learning styles. The study carried out by Ford and Chen (2001) [90] described in Chapter 6 found that matching learning styles mainly affected male students. The findings in the current study, therefore, may not apply to the female population; more female participants would be advisable in any future follow up study. A further issue surrounding the participants is the fact that the majority of them were computer science undergraduate students. This may have influenced the results in that they may have had previous knowledge of adaptive systems and therefore performed in a way they think the researcher wants them to behave. This is known as participant bias or demand characteristics. In addition, the data were collected from a convenience sample of computer science undergraduate students from intact classes. As [251] noted, convenience samples can introduce a bias into sample estimates of population parameters. Thus the ability of the results obtained by this study to be generalised may be limited.

Taking these factors into account collectively, they have both positive and negative implications. On the other hand, the system would benefit from an analysis of a broader range of individuals as a way of ensuring usability for the population at large. The sample used for this study does not appear to be representative of the current online population of users.

Therefore, something to consider for further research in order to provide more robust findings might be to include students from various types of schools and levels of education and students from various cultures. Although the study was carried out on participants in higher education, at the university and above levels, the theory of learning styles is useful for all learners, from elementary to high schools. Future studies, therefore, should try to include analyses of different age groups; this would involve developing the system to incorporate different topics and questions suitable for each age group. This area of research would also benefit from longitudinal studies, to ascertain the stability of learning styles over longer periods of time [239].

With regard to the system, when scoring the users' performance, only the highest scores from each model were taken into account in order to develop the users' learning styles profile. When using the VARK learning styles, for example, sometimes the highest score is not very far from next highest score (often only a few points different). In the system, only the highest scores are considered, while in real life a person can be a mixture of more than one style from the same model. In the future, it would be worth looking at addressing a main style combined with one or two other styles from the VARK model if the scores are not very different from the highest scoring style.

With regard to comments made from the interviewees, there were many suggestions proposed as discussed in Chapter 4. The researcher attempted to incorporate as many of the comments as possible within the time frame available, however, there are certain factors that remain for future studies, such as using different lesson topics. Additionally, a final experiment could be added to test the participants' abilities to do something rather than understand something. In this sense, the ability to learn would be based on how well participants completed the experiment at the end. One of the interviewees felt that the system could potentially be too costly for implementation in educational institutions; this is a concern that requires additional research before introduction of the system into the market.

7.7 Future Directions

Of the potential areas for development mentioned above, a few are quite promising areas for further research. For example, it has been mentioned that learning begins from a very young age and continues throughout a person's lifetime. Developmental studies could be carried out to investigate developmental trends in learning. This would be a large scale study and would require a large amount of resources, but it would be very worthwhile and could ultimately advance the methods of learning as we currently know them. This would also address the issue of investigating the stability of learning styles as criticised by Becta [239], who highlighted the lack of longitudinal studies.

Secondly, it is possible to refine the system in terms of the number of learning styles addressed within the same model or different models and other techniques for adaptive learning. The current system uses two learning styles out of a possible 71 modes [19]. Different styles and various combinations could be incorporated into a system with the

aim of devising the ‘perfect’ learning style for each individual. We are a long way away from achieving this goal, but continued investigations combined with innovations within the field of computing may enable us to arrive at this stage in adaptive learning sooner than expected.. The study and the system might be also improved by utilising one of the Machine Learning techniques such as a Bayesian Network. Further information is available in chapter eight.

Improvements in the experimental design could corroborate the findings reported in this study and increase their external validity. Similar comparative studies could be carried out with a larger or different population, other types of learning content and learning styles, or a random sample of participants rather than a convenience sample. Future studies could focus to a greater degree on assessing the influence of prior knowledge on learning styles and interest (in the knowledge domain) on the effect of recognising whether or not the lesson was presented accordingly. Some of the participants in the current study suggested that giving more information on the concept of learning styles prior to the lesson would be useful so that more users will be able to identify which learning style best suits them in order that they may take full advantage of the system.

Additionally, future studies could investigate what other factors may have an influence on learning gains and user satisfaction. As [90] noted, it appears that “the effects of matching and mismatching information presentation strategy with cognitive style may not be simple, and may entail complex interactions with other factors such as gender, and different forms of learning”. Previous studies have shown that other factors such as motivation of the learner, demographic factors, teaching strategies and teaching methods may have an impact on bettering academic achievement [99]. Perhaps future evaluation studies could include questions to assess these factors to provide a more rounded assessment of learning gains.

I strongly believe that the field of adaptive hypermedia would benefit greatly from collaborative work with psychologists specialising in learning styles theory. The aim of the current research was to build and evaluate a system using two learning styles models. Creating an adaptive application with support for learning styles requires a lot of psychological knowledge: how to structure the application and how to provide content alternatives to present equivalent information for users with different learning

styles. Perhaps developers of adaptive systems could provide an authoring background, i.e. create an adaptive application with support for learning styles so that those with more knowledge in learning styles could design the application for the learning content. This way the choice of learning styles and definition of the strategy is performed by authors rather than the developers; in this case, the psychologists. This would require the developers to provide enough flexibility for the authors to apply different strategies for a particular application. In this way, the authors would be free to experiment with their strategies and see which of the variations represent particular learning styles in the best way. This collaborative approach would have the benefit of combining the knowledge base of two specialist groups (computer science and educational psychology) in order to develop an adaptive system to meet the needs of learners.

7.8 Conclusions

In summary, this thesis has illustrated that the devised approach of combining two models of learning styles achieved better results compared to one model of learning styles or none in terms of both learning gains and user satisfaction (most notably preference). The study confirmed previous findings that matching learning styles (two and/or one learning style) is better than mismatching (No tailoring group). The results have expanded our knowledge of how learning styles can be used to enhance learning gains. The research introduced a novel approach to combining two models of learning styles (VARK, Honey & Mumford); previous research in the field of adaptive hypermedia has only addressed one model of learning styles. This thesis has broadened the knowledge surrounding the VARK and Honey & Mumford methods of learning and has further highlighted the importance of using more than one model of learning style within a system to enhance learning. Further research should be aimed at investigating different types and models of learning styles and various combinations of these in order to present a more complete picture of learning styles within adaptive systems.

It is the combination of more than one learning style to suit each individual that makes the system proposed in this research so powerful, as well as the fact that the system adapts to each individual automatically. Thus it helps students to understand their learning style and how to make use of it. This is not a trivial task because the system has to consider different inputs. Not only is the system useful for students, but it is potentially useful as well for educational psychologists, teachers, and academic staff, in

that they are able to capture a pattern for each individual student's preferred style of learning and use this information to guide students accordingly. Alternatively, students can use the system as an aid to supplement face-to-face teaching. Research indicates that, when using intelligent tutoring systems, the role of the human tutor is changed and students generally learn faster and their performance is better than that of traditional classroom participants [116]. The current study provides one more addition to the growing body of literature that asserts the benefits of using learning styles to enhance learning gains and that adaptive systems provide an effective method of learning.

Understanding and exploring learner types makes it easier for someone to choose their own learning style as well as gain a better understanding of themselves, which can lead to a highly beneficial learning experience. Furthermore, a student will have the confidence to change their learning process to get the best out of it. The method by which one learns may not be fully captured by a single measure. The research carried out in this thesis has shown the added benefits of incorporating two learning styles models. Several other models of learning style could have been used, each of which addresses the dimensions of learning in a slightly different manner. Future studies build upon this study by investigating the differences in learning gains when using two other models and by comparing which combination of models produces the best outcome both in terms of user satisfaction and learnability. To date, there has been limited research which examines the role of learning styles in e-learning environments. It is hoped that the issues discussed in this thesis will serve as heuristics to guide future research. The results of this future research can provide participants of adaptive e-learning environments with a more enjoyable, satisfying and effective learning experience.

Chapter 8

Future Directions

8.1 Introduction

The primary aim of this chapter is to provide guidelines for future work. The research presented herein has developed a learning system that presents lessons to users according to two different models of learning styles (VARK, and Honey and Mumford) based upon their specific learning preferences. The feasibility of the system was tested in chapter 5 that indicated that the system had the ability to adapt to the user's learning styles by providing a lesson based on individual user's learning styles. The learning gains and the user satisfaction were also tested in chapter 6.

This chapter reflects upon some of the adaptive measures that are recommended for future work. The proposed system would provide a two way process of interaction to judge the influence of both the learning item and the user on each other. In this case, the possible application of machine learning techniques such as Bayesian Networks is also reflected upon. In case of repeated interaction between a learning item and multiple users it is possible that the learning styles of users or the learning item itself experience changes.

The aim of this chapter is to open new doors for future researchers by exploring the adaptation of the proposed system in case of such variations, and the impact of the interactions between the user and the learning items. It also aims to suggest a method to enhance the adaptation.

8.2 Second Version of the system

Following the preliminary investigation on the prototype, a second version of the system was developed.

8.2.1 *System Structure*

Figure 8-1 shows the structure of the system.

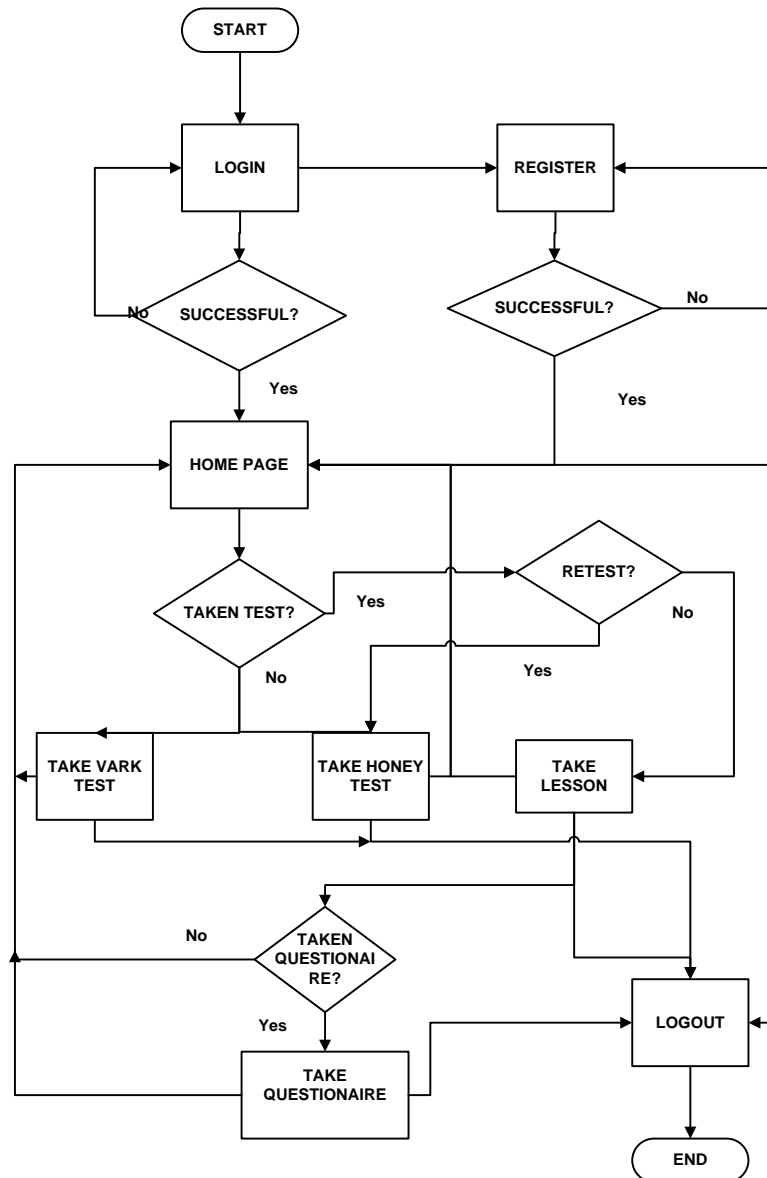


Figure 8-1: System Structure

8.2.2 Student Model

All first-time users are asked to register their basic information to start building their student model. They are required to register/log on before using the system, therefore, the first information about the user is entered as soon as the user begins to use the system and continues as the user continues to use the system. See Figure 8-2 below.

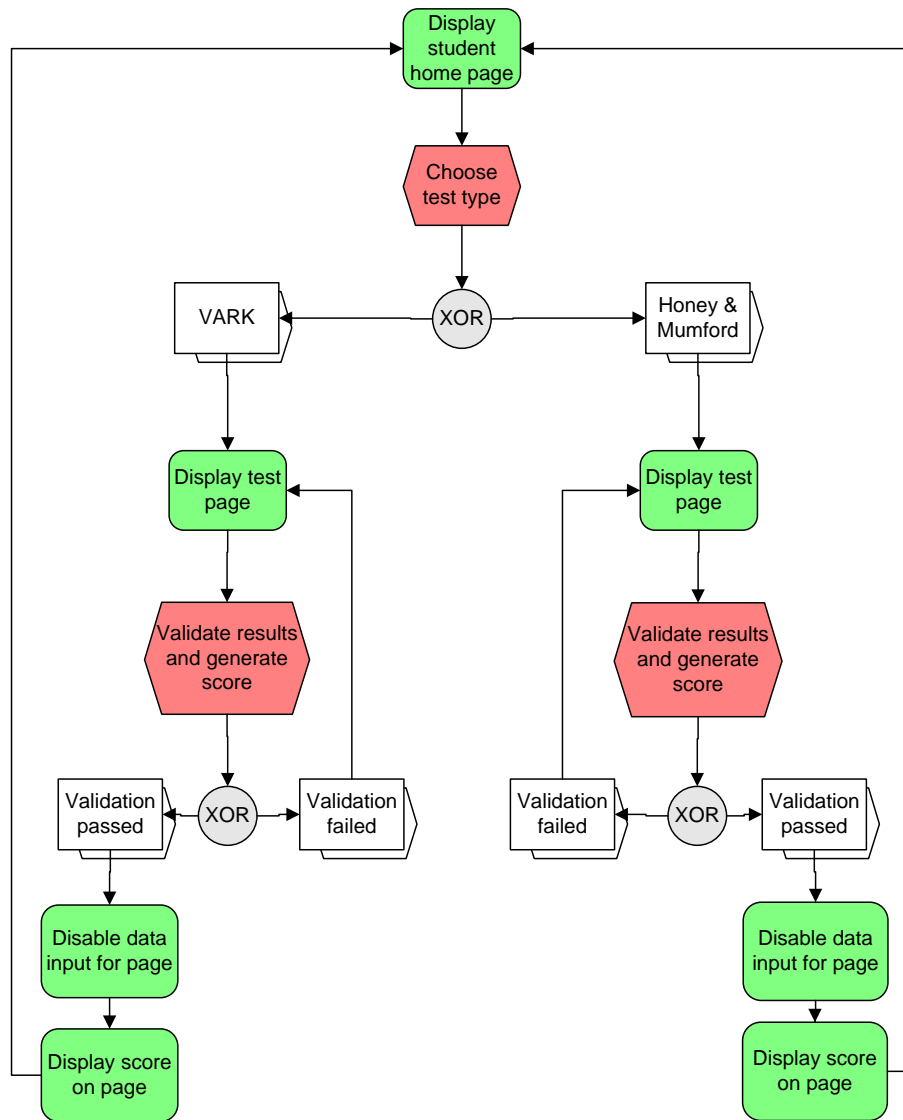


Figure 8-2: Initialising Student Model

8.2.3 VARK test page

Validation overhaul, including displaying the error message on same page instead of a separate page.

```

on_page_load_event: hide_error_message_control = true
perform_validation
  if the_following_list_is_true then validation = passed
    each question has 1 radio button selected
  endif
if validation <> passed
  error_message_control_content = error_message
  hide_error_message_controls = false
endif

```

Display test results in same page

```

on_page_load_event: hide_test_result_control = true
on_submit_form_event:
  if validation = passed
    disable_form_input = true
    hide_test_result_control = false
  endif

```

8.2.4 *Honey & Mumford test page*

Validation overhaul, including displaying the error message on same page instead of a separate page.

```

on_page_load_event: hide_error_message_control = true
perform_validation
    if the_following_list_is_true then validation = passed
        each question has 1 radio button selected
    endif
if validation <> passed
    error_message_control_content = error_message
    hide_error_message_controls = false
endif
Display test results in same page
on_page_load_event: hide_test_result_control = true
on_submit_form_event:
    if validation = passed
        disable_form_input = true
        hide_test_result_control = false
    endif

```

8.2.5 *Content Model*

Contents represent the information that is presented to the learner, which is considered as the component of a lesson. A group of components will compose a lesson. Each component has a specification; to achieve the goal of this research, each component has eight main specifications as described below.

Each piece of content has eight main fields; which are the files of the two models of learning styles VARK (Visual, Aural, ReadWrite, Kinaesthetic) Honey and Mumford (Activist, Reflector, Theorist, Pragmatist). In each field the Administrator of the system (instructor or the teacher) initiates weights for each piece of information based on their experience. If for example the estimated weight is wrong, it will be corrected by the users when they use the system.

Suppose that we have three Introductions, introduction 1 is more suitable for activists because it is written in bullet point format, introduction 2 is more suitable for theorists because it has more lengthy information with more references and more discussion, and introduction 3 is more suitable for reflectors because it contains more opinions of others and examples. The administrator will give a higher score to the activist for introduction 1 compared to introduction 2 and 3. The same applies for the other styles. These weights or scores will be used by the system to check which component is suitable for certain users according to their learning styles.

Each component can be of a different media type such as text, image, video, audio and animation. The contents are stored in a database. There is a mediator table in the middle between the system and the wanted content. The system will detect its type and produce it in the appropriate presentation; the system will detect the extension of the file of the link, if it is (.swf) the system will add the required tags to enable the browser to show it. If it is a (.jpg) the system will produce the suitable html tag to display the picture. The same idea applies for all the other multimedia types.

8.2.6 Presentation

The contents of the lesson for a specific user ID are displayed according to the following two parameters.

- 1- Within each group of components, select the one that has the highest score for the user. For example, if the student is visual, and there are more than three introductions for a lesson, the system will select the introduction that has the highest score in visual.
- 2- Display the components in an order determined by the administrator. For example reflector would like to see the explanation before questions, while activists would like to see the questions or exercises before explanations.

Note the addition of a check, in the flowchart below shown in Figure 8-3 , to discover if the student has taken the profiling tests yet.

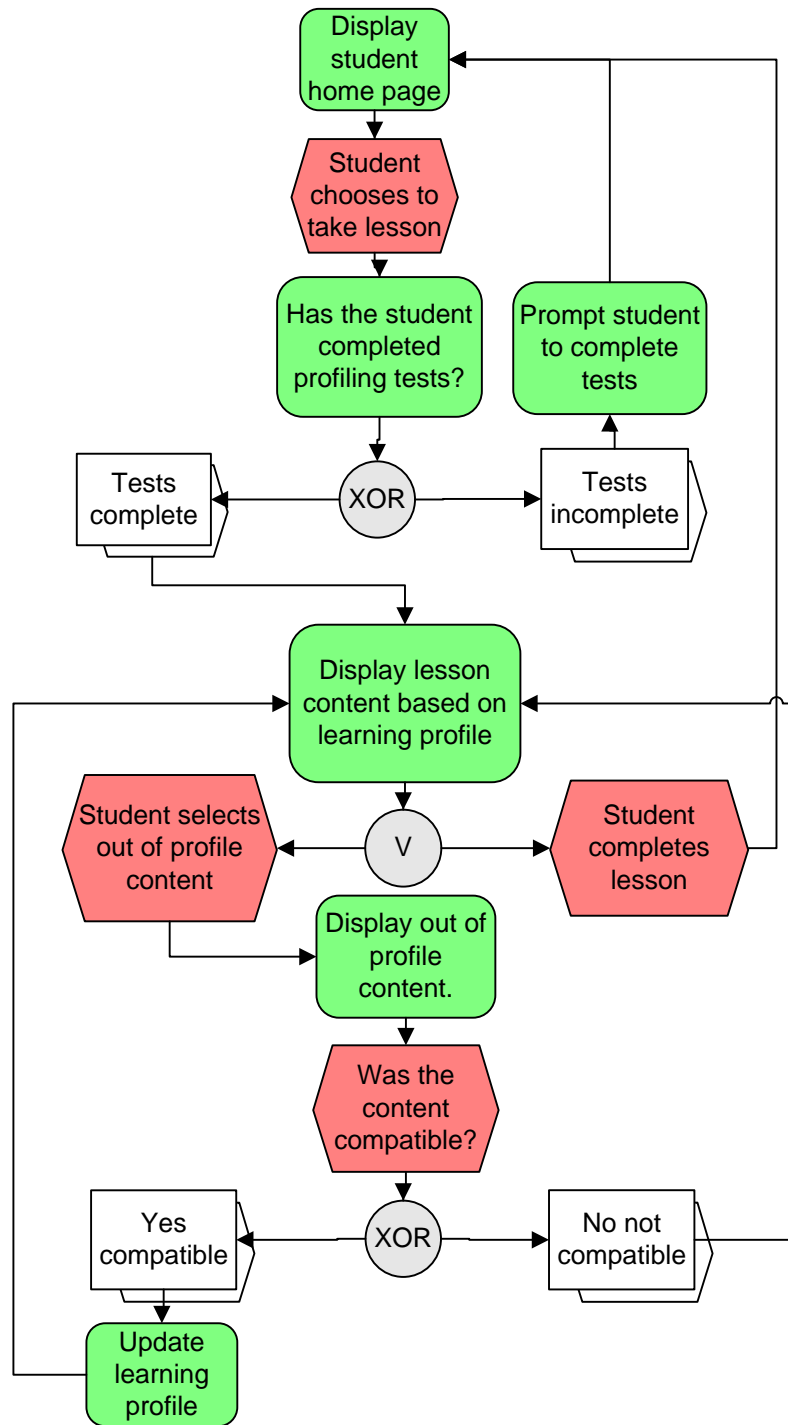


Figure 8-3: lesson delivery process

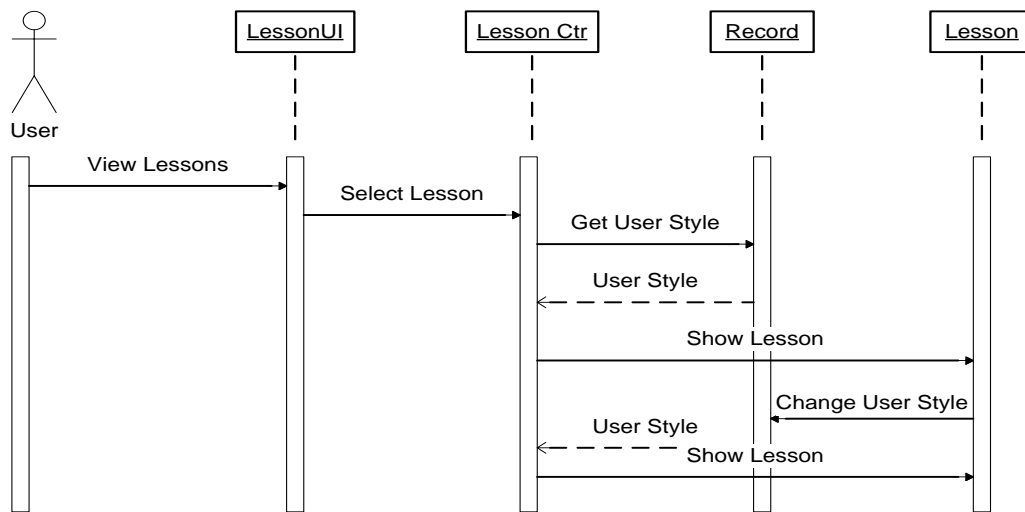


Figure 8-4: Lesson Sequence Explanation

In the sequence shown in Figure 8-4 the user views the list of lessons. He then selects a lesson. The system retrieves the user style and displays the lesson. The user may then change the user style and view the lesson accordingly. The system also updates the profile of the user according to the new profile selected by the user and then calculates the overall profile of the user and stores it.

8.2.7 Adaptation

Forming the backbone of the entire system, this process aims to initially decide upon a student learning profile and then continue to keep it relevant by dynamically changing the profile as the students' learning type may change over time. Figure 8-5 shows the adaptation of the system. This is accomplished by supplying out of profile content for the student to review and then decide upon how well it fits with their learning style. If they decide it fits well with them then weighting is added to the relevant learning style across both the VARK and Honey & Mumford test types. This is the fundamental distinguishing feature of this system – its ability to adapt unlike many other systems that have been developed to date.

This pseudocode details how the system adapts after the user finishes the two tests. If the user chooses to try different lessons which are not according to their learning style, the following occurs:

LoadEvent:

Open db

Read student profile

DO WHILE user LOGIN

Student_Style_VARK = GET highestResult FROM studentprofile.VARK
Student_Style_HONEY = GET highestResult FROM studentprofile.HONEY

//if user try visual lessons which is not his learning style

IF user_transaction = visual
 AND user_transaction != Student_Style_VARK THEN

 PRINT Lessons

//if user prefers the lessons

 IF user_transaction = link-“Click here if you like” THEN

//points will be added to each profile

 UPDATE studentprofile.VARK.visual + x_score

 UPDATE contentprofile.VARK.visual + y_score

 END IF

END IF

//if user try aural lessons which is not his learning style

IF user_transaction = aural
 AND user_transaction != Student_Style_VARK THEN

 PRINT Lessons

//if user prefers the lessons

 IF user_transaction = link-“Click here if you like” THEN

//points will be added to each profile

 UPDATE studentprofile.VARK.aural + x_score

 UPDATE contentprofile.VARK.aural + y_score

 END IF

END IF

//if user try ReadWrite lessons which is not his learning style

IF user_transaction = readwrite
 AND user_transaction != Student_Style_VARK THEN

 PRINT Lessons

//if user prefers the lessons

 IF user_transaction = link-“Click here if you like” THEN

//points will be added to each profile

 UPDATE studentprofile.VARK.readwrite + x_score

```

        UPDATE contentprofile.VARK.readwrite + y_score
    END IF
END IF

//if user try kinesthetic lessons which is not his learning style
IF user_transaction = kinesthetic
    AND user_transaction != Student_Style_VARK THEN

    PRINT Lessons

    //if user prefers the lessons
    IF user_transaction = link-“Click here if you like” THEN

        //points will be added to each profile
        UPDATE studentprofile.VARK.kinesthetic + x_score
        UPDATE contentprofile.VARK.kinesthetic + y_score
    END IF
END IF

//if user try activist lessons which is not his learning style
IF user_transaction = activist
    AND user_transaction != Student_Style_HONEY THEN

    PRINT Lessons

    //if user prefers the lessons
    IF user_transaction = link-“Click here if you like” THEN

        //points will be added to each profile
        UPDATE studentprofile.HONEY.activist + x_score
        UPDATE contentprofile.HONEY.activist + y_score
    END IF
END IF

//if user try reflector lessons which is not his learning style
IF user_transaction = reflector
    AND user_transaction != Student_Style_HONEY THEN
    PRINT Lessons

    //if user prefers the lessons
    IF user_transaction = link-“Click here if you like” THEN

        //points will be added to each profile
        UPDATE studentprofile.HONEY.reflector + x_score
        UPDATE contentprofile.HONEY.reflector + y_score
    END IF
END IF

//if user try visual lessons which is not his learning style
IF user_transaction = theorist
    AND user_transaction != Student_Style_HONEY THEN

    PRINT Lessons

    //if user prefers the lessons
    IF user_transaction = link-“Click here if you like” THEN

        //points will be added to each profile
        UPDATE studentprofile.HONEY.theorist + x_score
        UPDATE contentprofile.HONEY.theorist + y_score
    END IF
END IF

```

```

//if user try visual lessons which is not his learning style
IF user_transaction = pragmatist
    AND user_transaction != Student_Style_HONEY THEN
    PRINT Lessons
    //if user prefers the lessons
    IF user_transaction = link-"Click here if you like" THEN

        //points will be added to each profile
        UPDATE studentprofile.HONEY.pragmatist + x_score
        UPDATE contentprofile.HONEY.pragmatist + y_score
    END IF
END IF
//if user choose to view his default learning style
IF user_transaction = link-"my style" THEN

    PRINT Student_Style_VARK
    PRINT Student_Style_HONEY

    //display the lessons of user's learning style
    CALL display_appropriate_lessons METHOD
    PRINT Lessons
END IF

END DO

```

As the fundamental process driving the entire system, it is deemed useful to include a more detailed than normal process description at this stage of the documentation.

The system keeps a record of each student's unique learning profile by using two sets of four fields within a table. These fields contain a percentage weighting of the four types of learning styles from each of the two tests as follows:

VARK: Visual, Aural, ReadWrite and Kinesthetic

Honey & Mumford: Activist, Reflector, Theorist and Pragmatist

The system attempts to classify a students learning profile by initially subjecting them to a pair of tests, one each for VARK and Honey & Mumford. If, at the end of these tests, the system is unable to classify the students learning profile then more questions are presented until a clearer picture evolves. The system then stores these values for future use.

When a student comes to take a lesson, the learning profile is recalled and used to deliver lesson content that fits the students learning style most closely. There may be several sections of a lesson that deliver basically the same content but they will be

presented in different forms that are suitable for specific learning styles. This means that one lesson will teach the same facts and theories but will be delivered differently from student to student in an effort to supply teaching that fits the student's individual learning type.

The possibility that students' learning styles may change over time has also been catered by the system, in two ways. Firstly it allows students to 'step out' of their current learning style and take lesson content designed to be optimal for a different style. Once the content has been taken the student is questioned about the suitability of the content. If a student decides that it did indeed fit with his/her way of learning, the previous learning style profile is updated. The system takes the learning type of the content and adds a weighting to the current student learning profile depending upon the choice. For example, a student may choose to take a module intended for a VARK-Visual student that would not normally have been presented to him/her due to his/her current learning type profile. If the student finds it suits him/her, the VARK Visual score in his/her learning profile will be weighted accordingly – a score will be added to student's profile indicating his/her inclination towards this particular learning style. Students may re-take both tests at the same time in order to give a more accurate reading of their current learning style accordingly updating their profile. This is also useful for those students who feel they have taken out of type lesson content, agreed it was useful to them and now find their learning profile has changed out of type. Re-taking the tests allows the student to effectively reset their learning profile should they need to.

The fact that the system follows the choice implies that the content of a typical lesson can be changed if they opt to do so. It also implies that any mis-tagging on part of the administrator will be addressed by the choice of the students. Thus the profile of a typical student is also accordingly subject to change. The process diagram below presents an overall view of how the learning style of a student is first derived and then allowed to evolve.

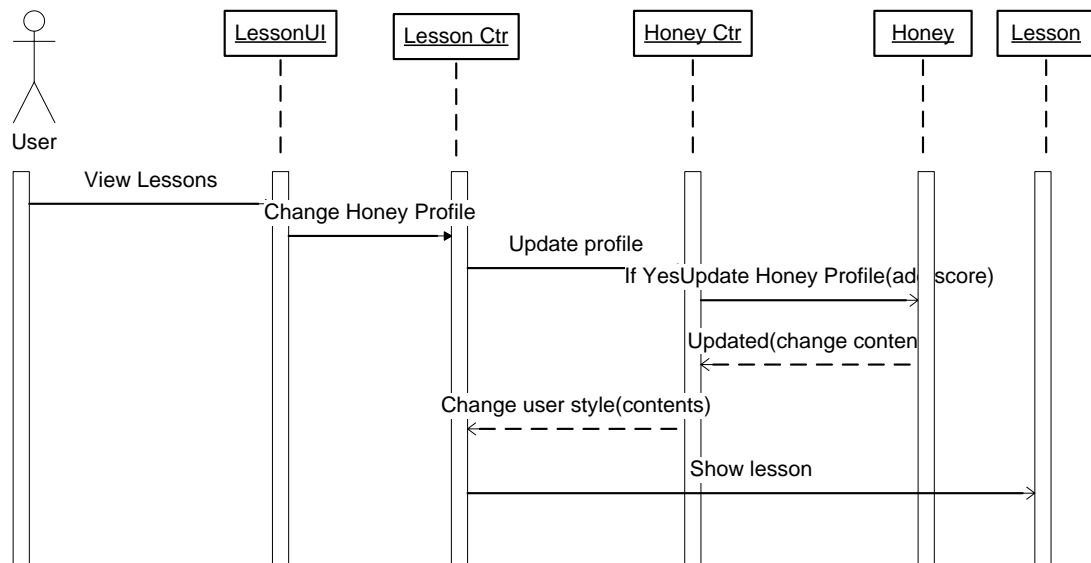


Figure 8-5: Evolving Student Model (based on the Honey and Mumford model)

As shown in the diagram above in Figure 8-5 , the user views a lesson. He then chooses a Honey and Mumford style and the contents are displayed according to the style. If the user chooses this style then his/her records are updated with a predefined value. The same steps are carried out for updating VARK.

8.3 Testing Adaptation

In this test we are using a model of learning styles called “VARK” to show the mechanism of rating the profiles of the learning item and users.

The data in Table 8-1 deals with assumed sample users. It is used to show how in real environment, there could be numerous learning items available to several users. In this particular case as being presented to demonstrate the functionality of the designed system, however, there is just one learning item and four users. The proposed test considers only one learning item and the set of assumed sample users in order to demonstrate its fundamental approach and functionality. It is appreciated that in case of real life where there could be a variety of learning items and a large number of users the

dimensions and results of this test are going to be quite complicated. For the very reason, it is later on recommended to find other solutions such as more complex equations or AI techniques.

Each user is categorised according to the learning style in which he scores highest (in this system the highest score tend to represent the preferred style of the user). For example, as in Table 8-1, a user will be considered to have visual style if he/she gets the highest score under the Visual category in his profile. Similarly, someone who gets highest marks under the section of Aural will be regarded as having Aural style.

Just like users, any learning item's profile is also regarded according to the highest scores associated with it. In terms of score system, it is a two way process – both the learning item and the user are influenced by each other's predominant style/highest score. For example, if a user with preferred style (profile) Aural approaches a learning item having Visual profile; scores will be added to the item under the Aural section while the user will find scores added to it under its Visual section.

If this particular learning item approached by a number of Aural users, it will keep on adding scores under the Aural category of the item. The situation may arise that the Aural score of the learning item takes over the Visual scores at which point the item will no more be regarded as a Visual but an Aural. On a similar note, if for instance a Kinaesthetic user approaches the same learning item, scores will be added to the item under its Kinaesthetic section while the user will find scores added to its profile under the Aural section.

In this particular set of tests four users have been assumed to be using a particular learning item. The users will be approaching the learning item in a random fashion as well as in a proper sequence. Both the random and sequential approaches were employed to in view of the real life situation where mostly the users are going to be in a random order. However, it is also possible that in certain instances there is a selected group of users with already determined learning styles, in which case the sequential approach is more likely than the random one.

The learning item as well as each user has a profile to help the system calculate and then adapt. Each test will be based on initial table of values. These values are considered as

profiles. These values are initiated intentionally by the researcher for the purpose of testing and exploring. The profiles in these experiments consist of four values: (Visual, Aural, ReadWrite, and Kinesthetics).

This system considers only one value which the highest value amongst the four. If the highest value is in the column of Visual then this user is considered a Visual user until another value becomes higher than this value.

More scores (+5) are added to these values if the user confirms that he likes this learning item. For example if the user is Visual and the learning item is Aural, and the user confirms that he likes this learning item, then more scores will be added to the visual column of the learning item and more scores will be added to the aural column of the user. Through this democratic way, it is expected that the learning styles of majority of users will influence the profile of the learning item if they are from one learning styles , for example whether they are visual or if they are aural.

In these experiments, only these who like the learning item and confirm preference are considered. Those who did not express their preference to the learning item will not be among the users and therefore no scores will be added.

The users and the learning item of these tests are dummy, and the values are initiated by the researcher, in real world, it might need more time to change. Each time a user declares he likes the learning item, more scores are added to the original values. The totals will then be converted into percentages.

The added value in these experiments is (+5). Although other scores were not tested, the sample graph demonstrates the fluctuations, and shows that the profiles can change over time.

The term *transaction* here means “Each time a user likes the learning item and more scores are added to the profile”.

The idea of the profiles is to help the system store the information regarding what are the preferences of each user, i.e. On occasion the user likes an item, this preference is stored in the user’ profile by adding more scores according to the preferred learning item. The profile of the learning item stores information about those who preferred it.

The profiles change because the match between the learning item and the users get closer. The learning styles of users also might change over time. Note that the profile of the learning item might have not been tagged or has been tagged wrongly. Enabling the profiles to change will enable the system to better the match and decide its suitability.

The tests aim to see what changes may take place as a result of repeated interaction/transactions between users and learning item. It is helpful though to see how the profile of the learning item transforms as a consequence of interaction with learners. In a way it represents the adaptability of the learning item for the benefit of the majority of users.

Four tests were conducted to explore the following scenarios:

Test1: to test the impact of users with different learning styles on the profile of the learning item. This test will show the effect on the profile of the learning item if there is no predominant style by the majority of the users.

Test2: the impact on a learning item with two equivalently high learning styles. This test will help to explore the profile of the learning item.

Test3: the impact on a user's profile that matches the profile of the learning item. This test will show the effect of the users with a predominant learning style on the learning item.

Test4: the impact on the profile of a user who does not have a specific learning style. This test will explore if the learning item is categorized in one learning style, and none of the users are supported by matching learning styles.

8.3.1 Test1 (the impact of users with different learning styles on the profile of the learning item)

Table 8-1: Initial values for test1(the impact of users with different learning styles on the profile of the learning item)

	Visual	Aural	ReadWrite	Kinaesthetic
Learning item	100	75	75	75
User1	100	75	75	75
User2	75	100	75	75
User3	75	75	100	75
User4	75	75	75	100

Test1 aims to investigate the impact on the profile of a learning item when it is chosen and preferred by four different students all having different preferred learning styles.

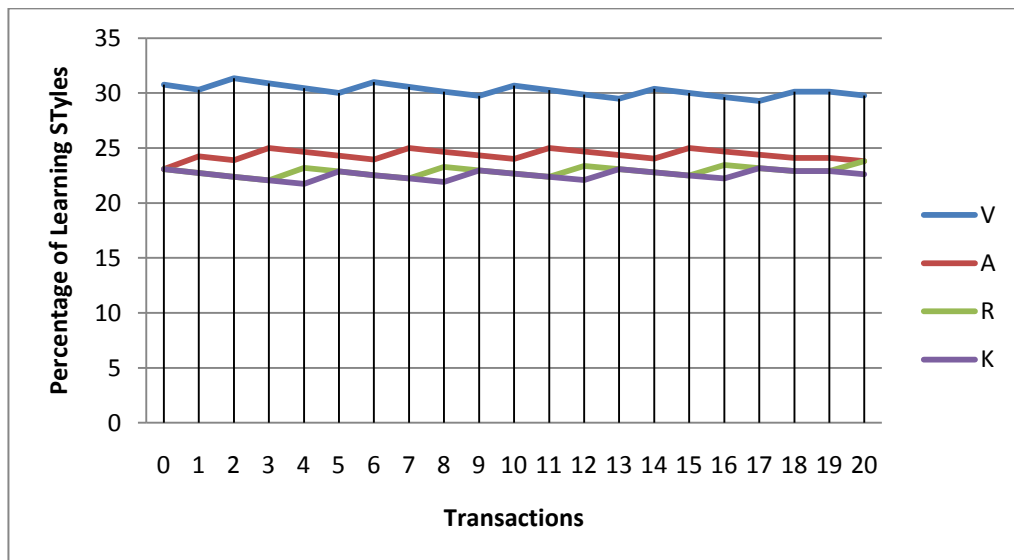


Figure 8-6: learning item

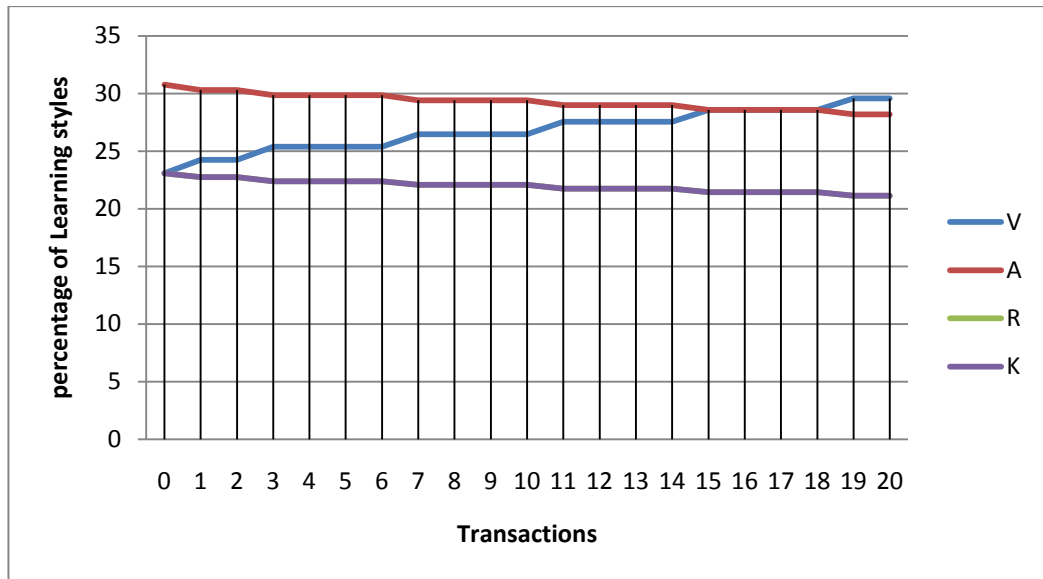


Figure 8-7: User2 (Note: K is over R and has the same value)

The results of test1 indicate that the learning item which originally has Visual profile remains unaffected by transactions as shown in Figure 8-1. Here, transaction refers to a user's choice or selection of a learning item. The profile of the learning item however is not consistent through the transaction but fluctuates depending upon the preferred learning style of the approaching users. For instance, if an Aural user approaches the learning item it will reduce the visual percentage (strength) of the learning item on the other hand, a transaction with a visual user will lift the percentage of the learning item's profile. Figure 8-2 showed the effect of transactions on user 2 that originally has Aural learning profile. As a result of the transactions the profile of the user will change from Aural to Visual preference – the strength of the Visual preference will gradually rise. While the other three preferences, Aural, ReadWrite and Kinaesthetic will remain almost the same. It was observed that after 21 transactions the predominant preference of the user had changed from Aural to Visual. Further transactions are going to add to the Visual preference of the user. In this case, the profile of user 2 was not matching the profile of the learning item, originally the two having Aural and Visual preferences respectively. The effect of the test will be very similar on the other two users ReadWrite and Kinaesthetic. The test gives an idea on how the profiles of both the learning item and users are going to be influenced by the mutual interaction.

Test1 shows that the profile of the learning item will not be affected if there is no predominant style by the majority of the users. In the example of this test (Test1), the profile of the learning item will remain as it was originally categorised because each

user does not agree on the opinion of other user regarding that item, since there is no agreement from all the users, or the majority of them. It might be preferable to have the learning styles of the users changed according to what they preferred based on their actions and confirmation that they preferred that specific learning item.

8.3.2 Test2(The impact on a learning item with two equivalently high learning styles)

This test aims to investigate the impact on the profile of the learning item which has two equivalently high learning styles by four users all having different preferences in terms of learning styles. The subsequent impact on the individual user will also be looked into.

Table 8-2: Initial values for test2 (The impact on a learning item with two equivalently high learning styles)

	Visual	Aural	ReadWrite	Kinaesthetic
Learning item	100	100	50	50
User1	100	50	50	50
User2	50	100	50	50
User3	50	50	100	50
User4	50	50	50	100

In this test, the learning item starts with two predominant learning styles: Aural and Visual.

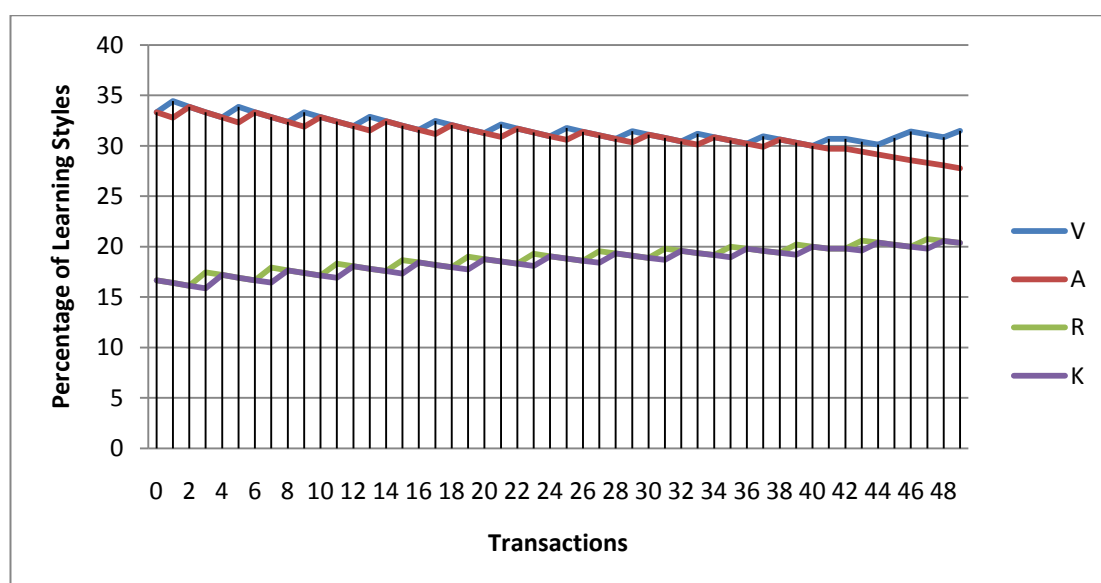


Figure 8-8: learning item

As the test progressed it was observed that the two predominant styles in the profile of the learning item (Aural and visual) gradually started to deteriorate due to the negative impact from the two users who approached it with different learning styles (ReadWrite and Kinaesthetic) as presented in Figure 8-8.

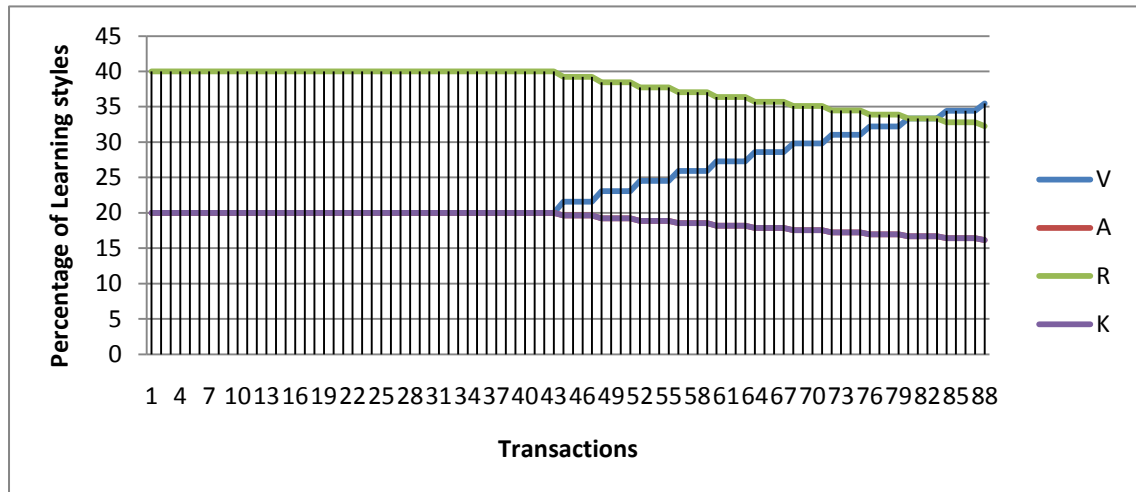


Figure 8-9: user3 (Note: K is over A and has the same value)

The Figure 8-9 reflects upon the profile ReadWrite user in terms of percentage. It can be seen that this particular user is influenced by the visual profile of the learning item but only after 44 transactions. This is the point where the visual style of the learning item overtakes other styles to become the predominant style of the item and onwards starts to dictate the profile of all the four users.

The figure 8-4 reflects upon the influence on the profile of user 3 which originally was ReadWrite. It took 34 transactions for the user before his preferred learning style started to get affected – as the visual preference starts to build up the ReadWrite preference starts to reduce. In this particular case, it took 82 transaction before Visual became the predominant preference of the user.

This test showed that when the learning item has two equivalently high learning styles, they compete each other as shown in the example (Figure 8-8). It may also be noted that eventually the Visual took over because of the order, i.e. the Visual of the learning item was before the Aural, then the Visual affected the profile of the users. Once the users became Visual they affected that learning item. This test is based on the assumption that the two styles of the profile of the learning item are equal. At the same time there are no majority of opinions of users to effect strongly the profile of the learning item. This

example might be poor especially when the profile of the learning item is new and not properly categorized. It might take longer time to get it corrected by users to settle down.

8.3.3 Test3(*The impact on a user's profile that matches the profile of the learning item*)

This test aims to investigate the interaction between the learning item and four users when the profile of the learning item matches with the profile of one user while the three other users have the same learning style which is different to that of the learning item and user 2.

Table 8-3 : Initial values for test3 (the impact on a user's profile that matches the profile of the learning item)

	Visual	Aural	ReadWrite	Kinaesthetic
Learning item	50	100	50	50
User1	100	50	50	50
User2	50	100	50	50
User3	100	50	50	50
User4	100	50	50	50

The impact of the interaction of the four users on the profile of the learning item is demonstrated in figure. The learning item initially had the preferred style of Aural. One of the four users also had Aural profile while the remaining three users had Visual profiles. Here as transactions started, one user was supporting the aural section of the profile of the item while the other three users were in favour of its visual section. It can be seen that due to the strong influence from the three visual users the scores under the visual section of the profile of the learning item quickly started to build up so that shortly they took over the scores under the aural section of the profile of the item. Consequently, shortly, the profile of learning item changed from aural to visual and kept progressing in the same direction. The role of the ReadWrite and kinaesthetic sections of the profile of the learning item remained insignificant. The Kinaesthetic profile of the learning item, for example, experienced a gradual decline because none of the users supported it.

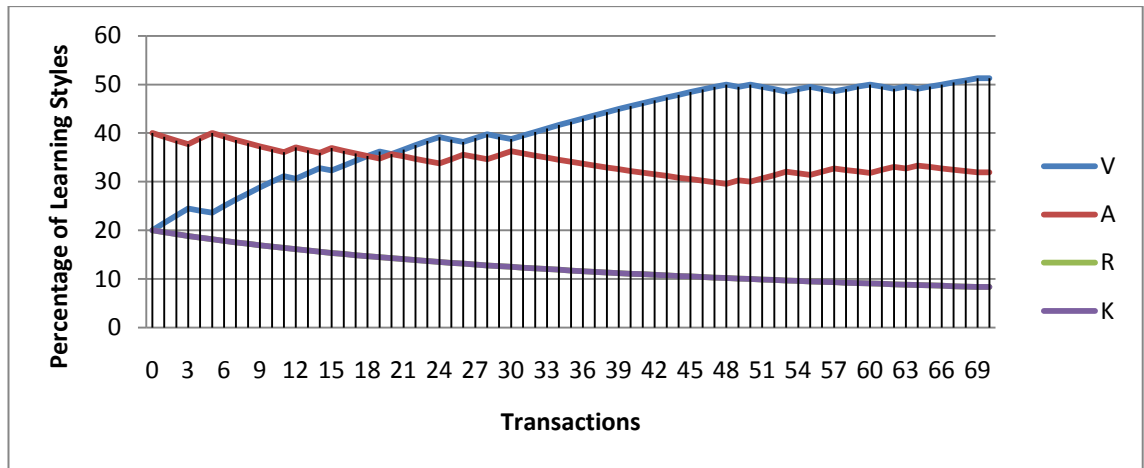


Figure 8-10: learning item (Note: K is over R and has the same value)

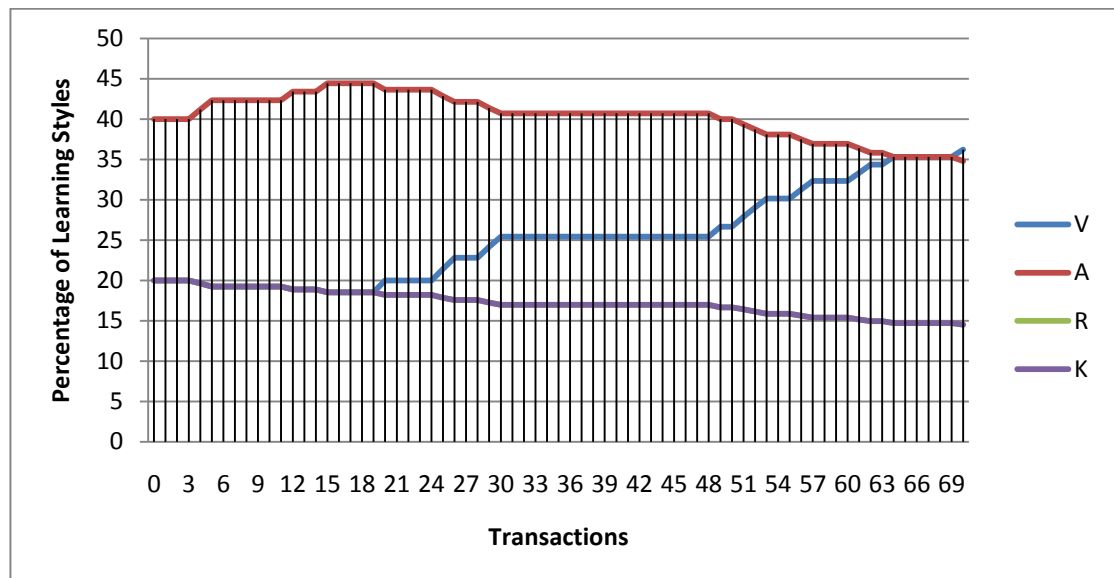


Figure 8-11: user2 (Note: K is over R and has the same value)

Figure 8-11 shows that user2 who was initially adapted to Aural profile started to experience a gradual decline in its preferred style due to the influence of the three visual users after some earlier support from the matching style of the learning item and gradually saw its aural style pushed downwards so much so ultimately it was taken over by the visual style.

This test showed the ability of the interaction of the majority of the users to change the profile of the learning item, and the learning item changes the profile of the individual user. This example showed that when the majority of users confirmed that they prefer certain learning item, and these users are Visual (for example), then the power of the majority affects clearly. This might be a good advantage of the mechanism of rating since the concept is based on preference of the users.

8.3.4 Test4(The impact on the profile of a user who has not a specific learning style)

This test aims to investigate the impacts on the profile of a user without any preferred learning style if the three other users and the learning item have learning styles different to each other. The consequent impacts on the profile of the learning item will also be looked into.

Table 8-4: Initial values for test4 (The impact on the profile of a user who has not a specific learning style)

	Visual	Aural	ReadWrite	Kinaesthetic
Learning item	100	50	50	50
User1	50	100	50	50
User2	50	50	100	50
User3	50	50	50	100
User4	50	50	50	50

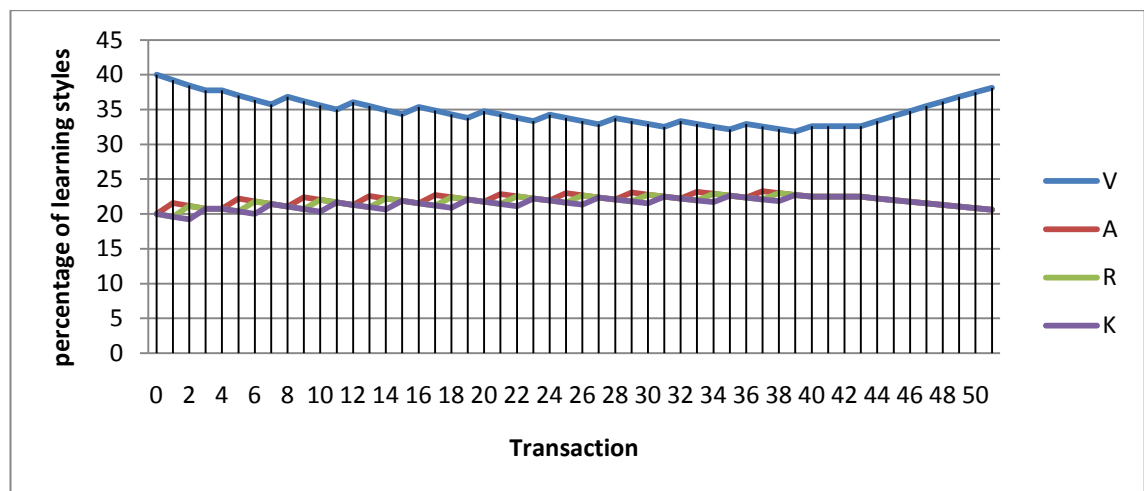


Figure 8-12: learning item

Here the learning item started with a predominantly Visual learning style. Three other users respectively had learning styles: Aural, Readwrite and Kinaesthetic while the fourth user had no preferred learning style. As the test progressed the profile of the learning item started to see an increment in the scores under the section of the styles matching to the three users that had preferred learning styles. Consequently in terms of percentage the preferred learning style of the learning item started to experience a gradual deficit. It was only after 45 transactions when the preferred learning style of the

learning item started to experience a consistent growth ultimately helping the learning item maintain its original style.

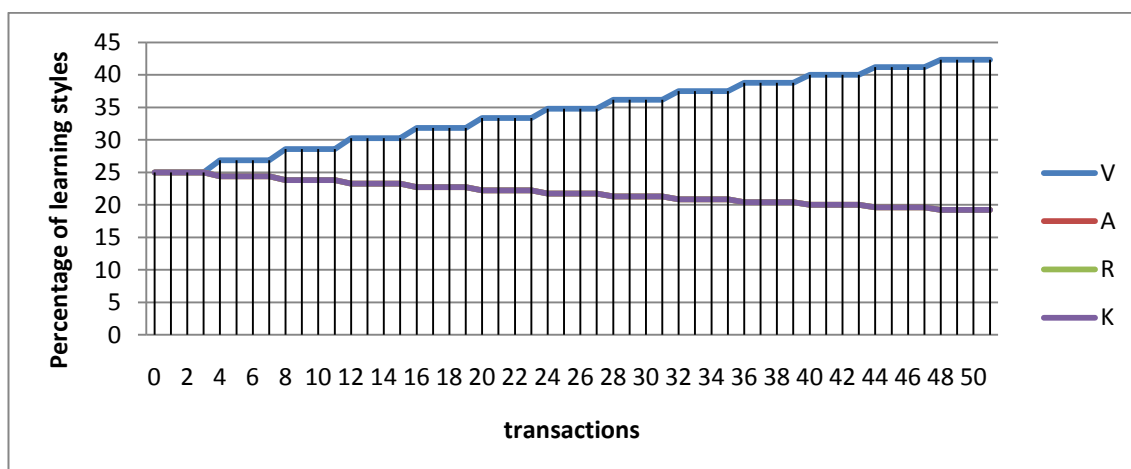


Figure 8-13: user4 (Note: K is over R and A and they have the same value)

The impact of the transactions between the four users and the learning item on the user without any preferred learning styles is discussed in the Figure 8-13. IT is observed that the user immediately experienced a growth in scores under the section matching to the the preferred learning style of the learning item and maintained that trend throughout the remaining transactions.

This test showed that when a learning item such as the example (Figure 8-13) was categorized originally as visual, and there is not any predominant learning style, it will go back to its original style. In addition, the effect of learning styles of users will not have a very strong effect if they were not supporting each other by being similar i.e. each one has a different learning style.

All the four tests demonstrated the effect of the profile of the learning item on the learning styles of the individual users, and the effect of the learning styles of the users on the learning item. The technique used in the above tests is simplistic in nature and takes only the highest score into account. The researcher believes that the adaptation issue is worth to be investigated thoroughly by future researchers. More methods are still needed to be explored and applied.

8.3.5 *The need for an AI technique*

The presently proposed system has a limitation in terms of its scope and application in dealing with users in real life that it only considers the predominant profile of a user in terms of the highest score under various sections of learning styles. For example in case of an Aural user, the system will overlook the scores under the Visual, ReadWrite and Kinaesthetic sections even though the difference between aural and any of the other three sections could be nominal. Sometimes user may have inclination for two different learning styles with one slightly edging over the other. In such cases, the present system does not appear to be robust enough to take the second in queue preference into account. It is therefore recommended to explore a more complex adaptation routine, or apply the artificial intelligence techniques such as Bayesian Networks to deal with such scenarios as will be shown in a number of studies. It is worth exploring if AI can help the real life complexities tackle in a more appropriate fashion. It is therefore suggested that some AI techniques be looked at in terms of enhancing these adaptation systems.

8.4 Bayesian Networks

8.4.1 *Introduction*

Bayesian networks are essentially used to encode uncertain expert knowledge [252]. Bayesian networks (BNs) are important due to their effectiveness in probability theories, employment in various contexts, and its applicability. In addition, they are easy to interpret, encode relationships and conditions, and can be determined from data.

A number of studies dealing with learning styles have utilized AI techniques to enhance the adaptation of systems. Bayesian networks (BN)[253] technique is one of the prominent AI techniques that have been used in such studies as further noted.

Bayesian networks are also termed as belief networks. They belong to the probabilistic graphical models (GMs) used to signify knowledge about an indecisive realm. Therefore, Bayesian networks (BNs) merge principles from probability theory, graph theory, statistics and computer science.

Bayesian networks are popular in machine learning, artificial intelligence and statistics. Bayesian networks are rigorous mathematically and can be understood instantly. They

represent joint probability distribution effectively by using random variables. This feature of BNs is used to diminish the number of parameters significantly, which is required to describe the joint probability distribution of the variables. In addition, the directed acyclic graph structure can be considered as the qualitative part used to specify the quantitative factors of the Bayesian networks. Bayesian networks are used for inferential examination to determine associations among variables, as well as descriptions of these associations[254].

8.4.2 *Bayesian Networks Techniques*

Influence Weights and Likelihood are widely used techniques used in educational systems; including systems that deal with learning styles [252]. Through the use of Bayesian networks the assessment of the joint distribution of a set of random variables can be simplified by exploiting conditional independencies among these variables. In addition, Bayesian Networks' graphical nature allows users to obtain a visual overview of the problem at hand. Many fields have taken advantage of the use of Bayesian interface, including computer science [252].

In order to understand better Bayesian networks, it is important that their main terms be explained. The first one is the **Bayes net**, which is also known as a **belief net**. It is comprised of a set of nodes, which represent variables of interest. In addition, they are connected by links to indicate dependencies, and include data about the relationships between the nodes (often in the form of conditional probabilities). Its main application is in prediction, diagnosis, probabilistic modelling, learning from data, as well as forming a basis for building decision nets. The next one is the **belief**. The belief of a node is the set of probabilities (one for each of its possible states), when the currently entered findings are taken into account by using the information encoded in the Bayes net. In other words, the belief is the marginal posterior probability distribution of the node, using the findings and the Bayes net model. Furthermore, the plural form of the term "beliefs" is used to refer to each of the probabilities in the set. The third one is **the node** which can be defined as a component of a Bayes net or decision net, which is used to represent a variable of interest [255].

More in depth information and research about Bayesian networks or any of its terms or techniques should be done in future work. It is the purpose of this chapter to only

provide readers with a brief overview of BNs and its components in order to gain general knowledge of the subject.

8.4.2.1 *Influence Weights*

The state distribution of a node in a Bayesian Network is not dependent on the set of its non-descendants, provided that the set of all its parents is present. . The conditional probability table (CPT), also known as “link matrix”, is used to relate states of the parent nodes to those of a child node. It includes entries for all combinations of the child and parent node states. The CPT is sometimes applied to refer to the deterministic function table of a node, because it contains information about the node’s conditional probabilities.

CPT’s main feature is that, “the alteration in the probability over a change in any parent node is independent of the other parent nodes”. If a parent condition changes, then there is no change in the probability. The important features of Influence Weights could be summarized as follows:

1. It identifies the most significant parent nodes.
2. Allocates non-normalized weights to all other nodes.
3. Calculates the information provided by the parent nodes in percentage.

8.4.2.2 *Likelihood*

This method assumes that, each of the parent nodes has the same conditions as they have in typical distribution. The change in any child node always produces the same change in the conditional probability tables.

8.4.3 *Previous Studies*

This section reviews three of the previous studies that utilised Bayesian Networks

8.4.3.1 *Learning Styles Recognition in e-learning environments with feed-forward neural networks*

This study [256] was conducted to make use of an artificial neural network model that works the way the human brain does, to correctly define the students' learning styles. the researcher believes that using artificial neural network is more efficient than using predefined questionnaires. The study used Felder & Silverman model to construct an

artificial network. There were no students' participating the testing of the system, as it was a hypothesis and the findings are theoretical in nature. The mechanism of the system was similar to that of workings of the human brain; when the input was given to the network, the information was received by and travels through middle layer or hidden layers, if it reached a particular threshold. Then it was again propagated to the output layer only if it is high enough to travel through output layer. Thus for the values to be processed and outputted, it depends on several parameters like input intensity, neuron weight, momentum & speed, and time. There were a number of inputs such as (Reading material, and What kind of material is the student most interested in?, Access to examples, and how many of them has the student accessed to?, Answer changes and does the student change the answers of the exam before he hands it over? If yes, what is the percentage of answers he has changed?, exercises and how many exercises has the student accessed to?, exam delivery time and what is the relation between the student's exam delivery time and the units' time to solve?). these values are encoded into intervals (-5 ; +5) as expected be the neurons in the input layer of the network. **Intuitive** or **sensitive** learning styles are determined based on the **perception**. **Active** or **reflective** learning styles are determined based on the **processing**. **Sequential** or **global** learning styles are determined based on the **understanding**. The neural network architecture itself resembles the Bayesian network. Every element in the neural network seems to be co-related with each other; however, the input received is independent of the previous output layer, as the input could be received either from the environment or the previous output, and the type of input received is independent of the previous output. Thus the interrelation and independencies make up the neural networks that work in a similar manner with the Bayesian networks that uses probability of one instance happening, related or not, to the previous event. Though not having been introduced, the neural network model shows promising results for correctly defining the students' learning styles & building the most profiting environment for learning. "Firstly, an automated mechanism for style recognition facilitates the gathering of information about learning preferences, making it imperceptible to students. Second, the proposed algorithm uses the recent history of system usage so that systems using this approach can recognize changes in learning styles or some of their dimensions over time." [256]. The artificial neural network model presented seems to prove as a novel mechanism to be embedded within computer assisted learning programs. However, since the study and results were all in theoretical point of view, further research might

need to be done and the use of neural network in real-time would be needed to prove the mechanism and results. As the authors concluded, there seems to be a lack of theoretical coherence and a common framework (Coffield et al. 2004b, p.145) [13] . Thus the study might need hard evidence that the neural network stands up to its promised value. They use Influence Weights technique.

8.4.3.2 *Adaptive Bayes for a Student Modelling Prediction Task based on Learning Styles (GIAS)*

The aim of this study [257] was to develop a model that would find the convenient authoring tool for teachers to define and fit the course materials according to the student's learning styles in web-based learning. The study mainly created a system that used Adaptive Bayes to model the student behavioral patterns and feed it to the system where teachers could make use of the information to design appropriate course contents. GIAS is the name given to the system which was developed for this purpose, more specifically it constructs authoring tools the teachers, while Felder-Silvermans model was use to draw out the students' learning style. A web-based tutorial in Plane Geometry planned for math students at University of Averio led to the creation of the GIAS system. GIAS system had three components: Domain model, Student Model & Instruction Module, and all processes made use of the Adaptive algorithms. Domain model has the course components, editable by the lecturer; Student model has the profile, cognitive and course overlay parts. The students' Learning Style was obtained using the ILS. The Instruction module was responsible for course, topic and test generations. The adaptive Bayes algorithm is capable of adapting new information for creating course contents appropriate for the student. The student's learning style, knowledge level and available resources are considered in listing out the appropriate course contents presented together with the second list, though not so appropriate, as other sources of study. The students' knowledge level, learning styles' are maintained, as the "predictive model", and if the changes in these attributes occur in next visit, they are updated. (Castillo et al.) The learning style model used for acquiring student information was based on Felder & Silvermans learning style model. The core processing architecture of the GIAS system is based on Adaptive Bayes algorithms, an incremental adaptive version of Naive Bayes. [257] The Adaptive Bayes, though completely identical to Naive Bayes, contains an updating scheme that could make changes to the preferences stored when discrepancies occur. Though the study didn't

extend to the use of Bayesian networks to infer the learning styles, it was primarily based on Bayes theorem. The experiments using artificial data sets used showed that Adaptive Bayes seems to be a good and simple choice for concept drift scenarios in user-modeling. Further investigations with real data-sets, in a web-based environment predicting students' preference by their interaction in the learning environment, would need to be done to prove the use of the Adaptive Bayes. They use Influence Weights technique.

8.4.3.3 *An enhanced Bayesian model to detect students' learning styles in Web-based courses*

The aim of this study [37] is to explain in detail exactly how the Bayesian theorem works, including intricate details and examples of where it has been proven to be a valuable resource previously. It is not aimed at a novice to the subject, but to a student already aware of the process, but wishes to educate themselves further in the inner workings and calculations involved in each area. Many working case examples are used, including intricate calculations, theories and questions on how it can be used best. All benefits are explained, along with some of the lesser benefits, where another theorem might be more appropriate for the particular situation. Abstracts and real examples are provided within the paper that have been tried and tested with detailed results to learn from. Through making tight comparisons with other case studies, it has been found that indeed, the capabilities of a BN model are well aligned to assist with analyzing a students working and learning behaviour. To uncover the more active learners of the group, it was encouraged to use the internet as a resource for their work. However, it was found that students turning to the web for education actually altered their learning habits slightly, by default. This showed that learning styles are very adaptive to their surroundings and situations, which might lead the Bayesian network confused, should it not be calculated properly. If keeping with one style of learning, it proved that the BN approach could give extremely accurate results. In summary, the BN models, so long as circumstance has been taken into account, can provide one with highly relevant and precision results on a students learning style. They use Likelihood technique.

8.4.3.4 *Relationship between the existing and previous systems*

Relationship: The above studies and the system of this thesis have adaptive learning styles to their surroundings and situations. In addition, they all deal with student's

learning styles in web-based learning. All findings are theoretical in nature. The previous works are trying to implement Bayesian networks to deal with learning styles. This adaptive system is developed to represent tutorials to learners based on research conducted using “VARK” (Visual, Aural, ReadWrite and Kinaesthetic), and “Honey and Mumford” models of learning styles. While other systems used Felder & Silverman model to construct an artificial network in order to deal with the learning styles. Although it was shown that Bayesian networks techniques were being utilized, this method cannot be applied in its current state in the context of this study. This is due to the fact that the current usage is designed on the basis on Felder and Silverman theory, whereas this study is based on VARK and Honey & Mumford theory. Thus, it is recommended by this work to explore if the Bayesian networks can also be used with these Learning styles, i.e. VARK and Honey and Mumford.

8.4.4 Bayesian Networks and computerized educational systems

The Bayesian Networks can be used in a computerized educational system that helps to define the appropriate material according to the student's learning styles in web-based learning. It may assist to create a system that helps to model the student's behaviours. BN helps the educational system to be more accurate and efficient

8.4.5 Recommended Improvements in an Existing System

According to the above mentioned studies, by implementing Bayesian networks in an adaptive system, following improvements may result. The present work therefore also recommends further investigation to study if the use of BN will improve the adaptation of the developed system in order to deal with real life complexities.

The presently proposed system has a limitation in terms of its scope and application in dealing with users in real life that it only considers the predominant profile of a user in terms of the highest score under various sections of learning styles. For example in case of an Aural user, the system will overlook the scores under the visual, ReadWrite and kinaesthetic sections even though the difference between aural and any of the other three sections could be nominal. Sometimes user may have inclination for two different learning styles with one slightly edging over the other. It is therefore recommended to apply the artificial intelligence techniques to deal with such scenarios. It is worth exploring if AI can help the real life complexities tackle in a more appropriate fashion.

A Bayesian network is not implemented in my system but the used approach served the purpose of this research successfully without any Machine Learning techniques or Bayesian Networks. It is recommended to study if integrating Bayesian networks in the system in order to obtain information from the available data about both the learners and the learning items using the two models of learning styles of this thesis Honey and Mumford, and VARK.

One of the main arguments to recommend Bayesian networks is that they have a bidirectional message passing architecture. Unsupervised learning can be defined as learning from evidence. Supervised learning can be defined as an expectation of an action, respectively. Because of the ability of Bayesian networks to pass evidence (data) between nodes and apply the expectations from the world model, they can be viewed as bi-directional learning systems.

Allowance of subjective a priori judgments, direction representations of causal dependence, non monotonic reasoning, sensory experience distillation, and human thinking process simulation are very important features of Bayesian Networks.

The Bayesian networks graphical model is to link probabilistic relationships among distinct variables.

The ability to handle incomplete data sets once a dependency is discovered offers no problem to Bayesian networks. BN automatically takes this into account when encoding for natural dependencies. Bayesian networks are useful in learning about causal relationships. Knowledge of causal relationships assists in extrapolating for presence of intervention and is useful in understanding the problem domain. they can simplify the combination of domain knowledge and data through causal semantics. This is particularly helpful when data is inadequate or can be expensive. Encoding using this semantic is helpful in gaining more information on prior or domain knowledge applications to real-world analysis. The encoding of relative strengths of correlations with corresponding probabilities is also the advantage of the Bayesian networks.

8.5 Summary and conclusion

Bayesian Networks are well-liked approach for decision-making and interpretation in problems that may engage uncertainty and probabilistic reasoning. Bayesian networks make available an ordinary demonstration for conditional autonomy.

This chapter showed a suggestion to use Bayesian Networks in order to be used by computer systems in educational field. In the modern era, this technology is executed in several systems to construct scalable and available solutions of greater efficiency and accuracy.

Bayesian networks technique has the ability to present support in a broad range of actions. To modify and improve values they sustain the probabilistic inference. Bayesian networks eagerly allow qualitative assumptions without conventional computational inefficiencies to determine the joint probability. It tends to support composite modelling including decision making systems, sensitivity analysis and information value. They support statistical induction, causality investigation and computerized learning (it may involve causal relationship discovery, network discovery, and parametric discovery).

The chapter presented has tested the adaptation of the developed system to a certain extent as determined by the scope of this work. Four test scenarios were explored to show the future researchers the feature of adaptation that is based on the two-way process of interactions. They also showed that the application of AI techniques (such as Bayesian networks) can be helpful in this respect and is recommended to future researchers to use them in order to enhance the adaptation of the developed learning system. One of the possible AI techniques that can be used here is BN.

Chapter 9

Conclusion

Using learning styles is considered advantageous for the learning process. It increases student motivation to learn, and makes lessons more lively and interesting. When learning is presented according to learners' preferences, it has been proven to induce effective learning. The use of different learning styles enhances the learning and performance and expands conformability and capability of learning. Knowing a learner's own learning style not only has an influence on how they learn, but can also affect how they absorb and interpret the information stated within the process.

It was the aim of this thesis to further our understanding of the individual learning styles, and investigate how combining two models of learning styles would affect students' achievements and satisfaction. This study was based on a combination of the learning styles suggested by VARK [4] and Honey and Mumford [5].

The main purpose (testing learning gain and satisfaction) was to test if there was a difference between presenting a lesson according to two models of learning styles, one model, or none, focusing on two main concepts: learning gain and users' satisfaction. It was an aim to build a web-based educational system to test the combination of the two models of learning styles, and to check its workability and users impression.

This research found that both models are measuring different aspects, as it has been attested in previous literatures. In the latter case, Honey and Mumford measures experiential learning (how the student wants to experience the learning process) and VARK focuses on how one prefers to perceive information.

The key findings from this study, indicated that there was a significant difference between users' recognition of a lesson presented according to two classifications of learning styles, one and none of the users' learning styles. By implication, those who were presented with the lesson according to two of their learning styles may have had more opportunity for them to recognise that the lesson was presented based on their learning styles, compared to those with one or no customisation. It was found that

participants enjoyed using the system; they considered it useful and beneficial to their understanding of the lesson. These results were not unexpected, because the system was supposed to present the lesson based on the participants' learning styles. The findings of this experiment indicated the workability of the system, in addition to the impressions of users of the method. Therefore, it can be concluded that the system was working properly – it presented the lessons according to the students' learning styles. Workability is needed to be tested to proceed to the next experiment (testing user's achievement and satisfaction). It is important that e-learning designers' awareness is raised in terms of taking learning styles into consideration when developing e-learning systems, due to the appreciation which was noticed by the learners.

The findings support the view that the models used in this study do not focus on the same aspects and each one observes the learner from a different perspective. VARK focuses on how the students perceive learning, while Honey and Mumford examines how an individual would like to learn. Based on this statement, it can be concluded that increasing the number of models of learning styles can be beneficial to the learner. Additional research is required to determine the effectiveness of combining two or more models. In addition, further research based on other models than VARK and Honey and Mumford would be beneficial. Further and more heterogeneous experiments would improve and enhance the conclusions based on this thesis.

The findings of this study allowed the author to encourage educational institutions not only to utilize e-learning techniques, but also to implement learning styles in those technologies.

Findings emphasize the need for educational institutions to adopt e-learning techniques and implement learning styles.

The second experiment of this research found that participants who used two learning styles showed a higher learning gain, and had higher levels of satisfaction across all three factors; usability, perception of learning and preference, compared to those using only one or no learning style. Furthermore, those using only one learning style showed higher learning gains and had higher levels of satisfaction than those with no learning style. This answers the question "Is there a difference between presenting a lesson according to two models of learning styles, one model, or none? The difference with

this experiment is that it focused on two main concepts: learning gain and user satisfaction”. This enforces the argument that matching learning styles with teaching practice is more effective for student achievement. Furthermore, as a practical implication, the results have shown that it is beneficial to use two learning styles to improve both learning gain and user satisfaction.

Therefore there is a direct positive relationship between applying two models of learning styles in e-learning techniques and learning gain and satisfaction of the users. The effectiveness of learning styles on the learning gain is a much debated phenomenon. This research has shown that there is a direct positive influence of learning styles on learning practices. The results from this study provide additions and further stress out the findings in previous studies. This study found that:

- the application of two models of learning styles (VARK, and Honey and Mumford) in learning, results in improvement of learning gain and satisfaction of students
- students who were taught according to their learning styles achieved higher test and attitude scores and therefore support using learning styles.
- as a result of adopting to learning styles both the learning gain and satisfaction are improved.

Limitations of the study

Despite the fact that this study has identified the effects of using two models of leaning style preferences (VARK; Honey and Mumford) on students’ academic achievement and satisfaction, it had the following limitations:

1. This study is limited by sample size, further research should aim to utilise a higher sample size to improve the reliability of the results
2. The results of this study have assumed students honesty when filling out the questionnaire, dishonesty may affect the results.
3. This study was focused on a selected sample of Saudi Schools. It can however be applied elsewhere with due changes. This limitation is due to the influence by social and cultural practices as mentioned in section 7.5 in Chapter 7.
4. Through the use of quantitative inferential statistics, such as correlation, the scientific analyses in this study remain only correlational in nature, without in-depth reference to qualitative factors which might have affected the results.

Suggestions for future research

Further work should build upon this research by investigating different models of learning styles. Additionally further research should examine more models of learning styles; combining three models or more, as each model of learning styles is looking at the student from a different perspective. It is suggested that the use of more complex adaptation techniques; or Bayesian networks may strengthen the findings of future work. It is recommended to consider the potential of employing different demographics of participants in order to determine if those factors affect the effectiveness of learning styles. Future research should investigate different topics and academic disciplines, to determine if results are consistent with these findings.

Recommendations and application

This work can only be considered significant and of value if some of the recommendations and suggestions are implemented and result in improvements in the educational practise. The application of recommendations would benefit educational institutions' decision makers, educators, students and e-learning designers.

1. Decision makers in educational institutions have an important contribution to the provision of a positive classroom atmosphere, which stimulates teaching and learning, they are recommended to utilize learning styles (VARK, and Honey and Mumford together).
2. Educators must consider the variety of learners and teaching techniques that can be applied to enhance their teaching ability and students learning, learning styles have been shown to be of benefit to learners by increasing both their motivation and performance.
3. Students are increasingly encouraged to take responsibility for their learning. Therefore having the ability/facility to determine the way in which they learn best with improving their learning abilities and performance.
4. E-learning designers should put in their consideration the usage of learning styles in the design, development and creation of effective e-learning systems.

For the learner, they can be used to improve on how they learn. For e-learning educators, it can be said that they are encouraged to make use of learning styles, similar to traditional teachers. The designers of e-learning systems should take into consideration that using two learning styles instead of one is better than using one or none.

It is important to apply the theories of learning styles in teaching, whilst also considering other factors that influence learning achievement such as society and culture, individual ability, willingness, motivation, and learning environments. Despite these factors, implementing a preferred learning style, either on its own or in conjunction with other factors will benefit the presentation of educational materials.

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Appendices