DESIGN, DEVELOPMENT AND EVALUATION OF TECHNOLOGY ENHANCED LEARNING ENVIRONMENTS: LEARNING STYLES AS AN EVALUATION TOOL FOR METACOGNITIVE SKILLS

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"I certify that this work has not been accepted in substance for any degree, and is not concurrently being submitted for any degree other than that of Doctor of Philosophy being studied at the University of Greenwich. I also declare that this work is the result of my own investigations except where otherwise identified by references and that I have not plagiarised the work of others".

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ABSTRACT

Recognising the powerful role that technology plays in the lives of people, researchers are increasingly focusing on the most effective uses of technology to support learning and teaching. Technology Enhanced Learning (TEL) has the potential to support and transform student learning and provides the flexibility of when, where and how to learn. At the same time, it promises to be an effective educational method (Wei and Yan 2009). One of the hottest topics in this field is adaptive learning (Mylonas, Tzouveli and Kollias 2004). Today, with the ability of advanced technologies to capture, store and use student data, it is possible to deliver adaptive learning based on student preferences. TEL can also put students at the centre of the learning process, which allows them to take more responsibility for their own learning. However, this requires students to be metacognitive so they can manage and monitor their learning progress.

This thesis investigates the impact of student metacognitive skills on their learning outcomes in terms of recalling and retaining information within a formally designed and TEL environment. The learning outcomes of students who study a subject consistent with their learning styles and another group of students who study the same subject in contrast to their learning styles are then compared to determine which group performs better. Based on this approach, a TEL environment is designed for undergraduate students to use for the purpose of collecting the required experimental data.

The results of this study suggest that effective use of metacognitive skills by students has a direct bearing on their learning performance and ability to recall information. The outcomes reveal that successful students use effective metacognitive skills to complete their studies and achieve their learning goals in a TEL environment. Therefore, it clear that metacognition can play a critical role in successful learning, and, furthermore, this approach can assist educationalists in understanding the importance of metacognition in learning and in considering how technology can be used to better to allow students to apply metacognitive skills. The designed TEL environment for this study can be utilised as a precursor to implement TEL environments that can be adapted to individual learning styles, and to support the development of metacognitive skills.

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Abbreviations

A: Active

B: Verbal

CMS: Course Management System

FSLSM: Felder and Silverman Learning Style Model

G: Global

I: Intuitive

ICT: Information and Telecommunication Technologies

LAMS: Learning Activity Management System

R: Reflective

RB: Rule-based

S: Sensing

TEL: Technology Enhanced Learning

Q: Sequential

V: Visual

Key Terms

The following definitions of key terms apply solely to this research study. They can be defined differently in other research studies.

TEL: The use of ICT and internet technologies to provide and enhance student learning.

Learning activity: A task undertaken by a student to attain a specific learning outcome within a TEL environment.

Adaptive TEL environment: An online learning environment that customises the learning activities of the course based on student learning styles.

Non-adaptive TEL environment: An online learning environment that provides students with learning activities of the entire course in which students need to actively find their own way of learning.

Learning style: A set of characteristics that shows how a student prefers to interact with the learning environment to receive and process information.

Learning preference: The way a student prefers to access and gather information.

Learning strategy: Techniques that students use and adjust during the learning process in order to achieve positive outcomes within the TEL environment.

Cognitive style: An individual’s habitual approach to organising and retaining information.

Cognitive strategy: Techniques that students use to manage their own learning processes, in order to develop effective way of learning that they need to use metacognitive skills.

Metacognition: Students awareness of their own ways of learning, which works for them, hence understand their own learning style/strategy.

CHAPTER 1 Introduction

This chapter provides an overview on the motivation and scope of this research, and explains the aims and objectives of this study. Subsequently, the research methodology and the structure of the thesis are also described.

1.1 Motivation and Scope of the Research

The emergence of the Internet and the latest ICT have brought a whole new dimension to almost every aspect of society, in particular to higher education. Learning and teaching in most disciplines now occur within technology-enhanced environments. ICT is used as a means for engaging in activities such as communication, socialising, networking and researching, but its unique possibilities also provide new opportunities for the design of TEL environments. In such environments, many factors can influence and promote student learning. A learning environment can involve a variety of elements, including an implicit pedagogical approach and learning activities. Motivations and learning styles of students are additional important factors able to influence their learning (Cemal Nat et al. 2011b).

Individual differences between students, including prior knowledge, learning goals and styles, have been considered (Liu 2007) to be principal elements, especially for adaptive learning. Adaptation in TEL is the process of customising the learning environment based on a student's learning needs, and a variety of approaches have been used to achieve this adaptation. One of the most widely used approaches is that of learning style theories, which identify learning styles of students mostly through questionnaires (Liu 2007). The aim of such adaptive learning offerings is to maximise student satisfaction, learning efficiency and educational effectiveness (Mulwa et al. 2010).

Magoutas and Mentzas (2007) have asserted that adaptive TEL environments hold much promise for future development as innovative technologies continuously appear in the field and have the potential to support the different needs of students. As well as providing facilities, they have led to enhanced education. The use of the adaptive presentation of learning materials has proven to be an effective way to support learning, as learners who have experienced such systems have demonstrated faster learning and more goal-oriented attitudes (Mulwa et al. 2010). In addition, many educational theorists and researchers have agreed that incorporating learning styles in education in order to offer adaptive learning has the potential to improve the progress of student learning (Mulwa et al. 2010).

In adaptive learning, the environment can adjust to student learning preferences, identified through different techniques; for example, learning style questionnaires or observations. Students are then provided with a tailored set of learning activities to aid their learning. However, non-adaptive learning environments provide students with the materials for entire courses, meaning that students need to take control of their learning (Selvi and Panneerselvam 2012).

In the literature, it is also reported that TEL can place students at the centre of the learning process by giving them the freedom to navigate through a wide range of resources, represented in text, graphic, animation, audio, and video forms, which are commonly presented in a non-linear way (Azevedo, Cromley and Seibert 2004; Mulwa et al. 2010). However, in such cases students are required to make decisions about what and how to learn and how much time to spend on material (Azevedo, Cromley and Seibert 2004).

1.2 Research Questions

Developing its focus out of the background research, this study aims to answer the following primary and subsidiary questions.

1. Is an adaptive learning environment a more effective means for learning compared to a non-adaptive learning environment?
    a. Did those who were provided with a learning environment suited to their learning style perform better than those who chose their own way of learning?

2. Is a questionnaire-based approach an effective method for determining student learning styles, in order to provide adaptive learning?
    a. Did those who studied a subject with respect to their learning styles perform better than those who did not?

1.3 Aims and Objectives of the Research

Prior research, taken into account in this thesis, focuses on how adaptive and non-adaptive TEL environments are designed, developed and evaluated. Accordingly, this study aims to develop the following main research objectives:

- Investigating the literature and designing two learning environments: (1) an adaptive TEL environment that provides customised learning based on a student's learning styles (2) a non-adaptive learning environment where all learning activities, including course content and examples, and support activity tools are freely available to all students. The TEL environments need to contain the relevant learning activities by considering student differences with regard to learning styles.

- Developing TEL environments to support learning of students by allowing them to study a subject using a variety of learning activities.

- Evaluating student learning outcomes and comparing them in light of their being produced in two different learning environments.

- Calculating self-determined learning styles of students and identifying their learning styles based on how they operate within the system. While learning within the non-adaptive TEL environment, students are free to use and navigate through the learning activities in order to find a way of learning that suits them best. Therefore, tracking and recording behaviours of students within the non-adaptive learning environment are required for identification of learning styles.

- Determining students who study the subject consistent with their learning styles and in contrast to their learning styles within the non-adaptive environment, and evaluating and comparing their learning outcomes.

1.4 Methodology and Structure of the Thesis

This section describes the methodology chosen to meet the research goals, and outlines the structure of the thesis.

The thesis is organised in six chapters as follows:

- Chapter 2 provides background information about this study. Firstly, it introduces TEL and its impact on learning, providing a discussion of adaptive learning concepts and learner modelling techniques in adaptive learning. The chapter continues by investigating existing adaptive TEL environments by focusing on adaptation techniques. Furthermore, a definition of learning styles, an explanation of common learning style models, a discussion of the impact of learning styles in TEL environments, and a discussion of learning styles and issues relevant to designing a learning environment are provided. It also contains a discussion of the concept of metacognition, issues related to metacognition, and their wider significance with regard to student learning. Finally, a discussion of the ways in which the research questions have been refined based on the literature review is provided.

- Chapter 3 includes discussions about the process of designing, developing and implementing TEL environments. This process is required to collect data in order to draw conclusions for this study.

- Chapter 4 explains the experimental design and methodology of the study as well as an application of a rule-based modelling method for detecting learning styles.

- Chapter 5 presents an analysis of the data, various statistical test results, and also discusses the findings.

- Chapter 6 concludes the thesis by reflecting on its contributions, limitations, and future directions.

CHAPTER 2 Literature Review

2.1 Introduction

This chapter provides an exposition of existing research in the field, with a view to developing the research questions identified in Chapter 1. Firstly, the fundamental concept of this research, TEL environments and their impact on learning, are investigated in this chapter. Secondly, the principle of adaptive learning in order to enhance student learning, and related subjects are discussed. With regard to this topic, several adaptive TEL environments are examined by focusing on the techniques used for providing adaptation. In addition, common learning style theories used in the design of adaptive learning systems are reviewed. The chapter continues with a presentation of common approaches for designing a learning environment to support student needs. Lastly, the chapter investigates methods for detecting and deducing the learning styles of students from their behaviours within TEL environments. However, after designing and running an exploratory experiment, it became clear that more reading is needed in order to be able to define learning behaviours of students within TEL environments and design a more robust experimental model. Therefore, following the results of the exploratory experiment, several more topics related to TEL, including the concepts of metacognition and self-directed learning, are also introduced and how this leads to a refinement of the research questions and objectives of the study are discussed.

2.2 Technology Enhanced Learning

With the advent of internet technologies and the closer integration of mobile and ubiquitous devices, learning and teaching has changed the way people view the learning process. It is indisputable that there are many ways of using technology to support student learning (Cemal Nat et al. 2011b). Technology has the potential to enhance and transform student learning, and allows the choice of when, where and how to learn. It promises to be an effective educational method that has drawn growing attention from researchers (Wei and Yan 2009). Elements such as learning goals, learning styles, learning pathways, and/or learning activities have been given significant emphasis for the purpose of designing such learning environments in order to develop contextual and domain knowledge (Jing and Lu Quan 2008).

Additionally, Bocconi, Kampylis and Punie (2012) report that teachers can utilise existing technologies (e.g. mobile) and recent technologies including augmented reality and immersive worlds to create experimental and experience-based learning activities. Innovative ways of using ICT allow teachers to introduce various pedagogical practices by organising newer forms of collaborative and open-ended learning activities. As well as enhancing student learning, the integration of new technologies may also develop the skills of teachers, their understanding of new teaching methods and improve the business services of institutions (Bocconi, Kampylis and Punie 2012).

New technologies have the potential to be personal and portable, thus enabling learning to be accessed from almost anywhere. There are a range of factors that drive the TEL revolution: TEL can be seen as both a result of rapid technological change and a response to changes happening in culture and society. TEL itself is viewed as a catalyst in a shift from discreet units of training to continuous learning. Education through the use of learning technologies is helping to prepare members of society for the new age (Meredith and Burkle 2006). Accessing learning via a personal choice of tools, ranging from mobile phones and hand-held computers, to online social networking and media-sharing websites, is gaining significance for 21st century students (JISC 2009).

Today, although educational innovation is often regarded as a challenging process in formal education settings, it is still one of the main aspirations for institutions all over the world (Foray and Raffo 2012). Educational innovation is the introduction of new educational tools, instructional practices and technologies that "…intend to add value to the educational process resulting in measurable outcomes" (Foray and Raffo 2012:14). Indisputably, the use of ICT made it possible to create new educational settings for learning in formal and informal environments (Bocconi, Kampylis and Punie 2012).

According to Conole (2008) technologies such as Google, Wikipedia, e-mail, and MSN Chat are core tools to support learning and have the potential to be used in a variety of ways to promote student learning. In addition, it has been argued that technology-enabled spaces (e.g. Second Life) and adaptation techniques offer exciting opportunities in terms of contextual, distributed and socially networked learning (Conole 2008).

Vishwakarma and Narayanan (2012) note that one of the latest computing paradigms, that of cloud computing, brought better solutions to real world problems and can be one of the best kinds of technology to be used for e-learning. JISC (2010:1) describes the term 'Cloud Computing' as "any computing capability that is delivered as a service over the Internet" . As it provides flexibility in accessing and delivering resources and services, it can also be used in educational institutions in various ways (Vishwakarma and Narayanan 2012). IBM (2010) argues that an academic cloud can enhance the learning outcome, support content delivery, ease sharing of resources, and reduce the operational and maintenance costs. It also helps to increase the availability of data and applications, mobility for students and institutions, and server and data storage capacity. Cloud computing offers three main services: software as service, platform as service, and infrastructure as service. Now it offers e-learning as a service for educational institutions (Vishwakarma and Narayanan 2012).

Whilst it is difficult to guess the future impact of technology on education, a number of reporting agencies have done this with some success. In the USA, the New Media Consortium's outlook (NMC) identifies 12 emerging technologies that are likely to impact on learners and institutions in science, technology, engineering and math subject (STEM). The authors of the report propose different time scales for widespread adoption. In one year or less, they suggest these will be the flipped classroom, massively open online courses (MOOCs), mobile apps and tablet computing; in two to three years, augmented reality, game-based learning, the internet of things, learning analytics; in four to five years: 3-D printing, flexible displays, next generation batteries, wearable technology (NMC Horizon Project Short List 2013).

On behalf of the European Commission, Institute for Prospective Technological Studies (IPTS), the MENON Network, has recently launched the Study Mapping and Analysing Prospective Technologies for Learning (MATEL) project. The aims of this study include "a) getting a better understanding of how technologies that are expected to play a decisive role in shaping future learning strategies will evolve in the short –medium term (5-10 years from now); b) understanding how the market of such technologies is expected to develop and c) identifying a set of strategies and actions to promote promising technologies, encourage implementation and ensure effective and inclusive deployment in formal, non-formal and informal learning environments." (MATEL 2013:1). The MATEL research team conducted a survey, which lasted fifteen months (December 2011 – February 2013). They called for input from experts to rank the top technologies that are expected to support educational change in Europe (MATEL 2013), and this work is still on-going.

Although the term ‘TEL’ is becoming more popular among researchers, ‘e-learning’ is still widely used for referring to the use of technology for learning (JISC 2009). Moreover, there are a range of terms for e-learning which include: tele-learning, online learning, distributed learning, distance learning and flexible learning. Furthermore, the concept of e-learning has numerous definitions and interpretations (Meredith and Burkle 2006; Tondeur, Braak and Valcke 2007). Descriptions of e-learning in the literature include the following: the use of internet technologies to deliver information for education and training; the application of technology to learning; and the use of technology to enable people to learn anytime and anywhere.

The applications of TEL themselves make it evident how technology adds value to learning and liberates the interaction between users and course contents (Pozgaj and Knezevic 2007; Suanpang and Petocz 2006) and in the context of asynchronous and synchronous learning environments (Dalsgaard 2005; Sun et al. 2006). According to Mulwa et al. (2010), it is expected that the unique ability of TEL to enable more personalised approaches to learning will radically alter the quality and effectiveness of the learning experience. Courses can be adapted to an individual student, and course materials can be reused and rearranged (Dalsgaard 2005). Also, TEL provides ubiquitous access to learning resources and collaborative learning (Meredith and Burkle 2006; Tondeur, Braak and Valcke 2007). Collaborative learning occurs when learners interact with each other and gain access to a wide variety of resources (Meredith and Burkle 2006). TEL creates connectivity between people and information, and opportunities for social learning approaches (Dalsgaard 2005; Meredith and Burkle 2006). It connects disperse groups of learners and individualised curricula that can deliver ‘just-in-time’ learning on a global basis and this enables corporations to create development structures that reflect the global nature of their business (Meredith and Burkle 2006). It can be easily managed even when catering for large groups of students (Cantoni, Cellario and Porta 2004), with student tracking and student management and administration (Dalsgaard 2005). Within such learning environments, learners are able to receive immediate and personalised feedback, active engagement with geographically distributed peers and access large amounts of materials (Mulwa et al. 2010).

Throughout this thesis the term 'TEL' is used and the definition adopted is the use of ICT and internet technologies to provide and enhance student learning. The ability of these technologies to capture, store and use individual data to enhance learning is viewed as a better way to meet the needs of students (Cemal Nat et al. 2011a).

2.2.1 The Impact of Technology Enhanced Learning Environments on Learning

As discussed before, there are seemingly limitless ways of using the Internet to enhance the quality of instruction, both in face-to-face courses as well as in distance courses (Wang 2007). Tools that gather information through the Internet provide great opportunities for searching the literature and establishing fast communication with international resources. Contact can be made with colleagues and peers regardless of geographical restrictions. The Internet already hosts an increasing variety of programmes and databases, making them available for effective and inexpensive learning to all kinds of students and professionals, from online tests to case studies and simulations (Schittek et al. 2001).

TEL couples advances in technology with the advent of the information technology highway to eliminate barriers of time, distance and socioeconomic status (Teo and Gay 2006). There are many technologies that are employed to deliver asynchronous and synchronous learning. Wang (2007) claims that students have little time to reflect on their learning and to communicate with their instructor what they are learning or having difficulty in understanding after each class session. In order to improve the quality of student learning, it is necessary to increase the levels of interaction of student-to-instructor, student-to-material and student-to-student. Integrated into classrooms, large or small, the Internet improves the interactions of students and instructors (Wang 2007).

Asynchronous internet technologies that facilitate student learning involve various collaborative tools, such as e-mail and discussion forums (Wang 2007; Neal and Miller 2005). Also, most learning management systems have the ability to upload and share documents. E-mail is often used for informally exchanging resources to support group work, and in the context of professional and informal communications. E-mail allows students and instructors to interact with each other out of class. Students enjoy the time-independent and place-independent feature of e-mail that allows them to contact instructors at anytime and anywhere (Wang 2007). Students ask more challenging questions and instructors provide more thoughtful responses than they would in face-to-face interactions (Wang 2007). Discussion forums provide a mechanism for debate on specific topics asynchronously. In some forums users are allowed to attach files and documents to their messages. Sometimes discussion forums can be extremely effective if students are encouraged to participate and provide thoughtful responses rather than posting hasty responses (Neal and Miller 2005). Traditionally, class discussions are limited by class time and by the spatial constraints of the classroom. Discussion forums offer extra opportunities for students to interact with other students and instructors outside of the classroom and class schedule (Wang 2007). Undoubtedly, the use of ICT in learning enables students who are shy and/or are unconfident to raise questions in class, to more confidently engage (Hodgson, Lam and Wong 2007).

Synchronous e-learning technologies can be effectively used to support learning. It is advantageous that most of them can be archived for later review: their usefulness is not restricted to real-time interaction. Such technologies include audio/video conferencing, electronic white boards, screen sharing, Instant Messaging (IM) and web conferencing (Neal and Miller 2005; Pozgaj and Knezevic 2007). Audio conferencing allows users to interact in real time through sharing audio by utilising the telephone or Voice over Internet Protocol (VoIP). Video conferencing has favourably supplemented audio conferencing with the ability to sharing pictures. Electronic white boards are electronic versions of dry-erase boards, which are used in classrooms. In IM the interaction occurs between users by exchanging text messages at the same-time, same-place or same-time, any-place (Wang 2007; Neal and Miller 2005).

Rennie and Morrison (2012) mention that the wide availability and acceptance of social networking, software has made many educators think about possible practices for integrating them into their course design. The various social software tools relevant to education that they consider are part of Web 2.0 and includes Wikipedia (online encyclopaedia), folksonomy websites (e.g. del.icio.us, Flickr), blogging, Really Simple Syndication or Rich Site Summary (RSS), podcasting, e-portfolio, real-time audio and shared screen tools. They also point out that the creative use of social software helps in reducing costs and widening participation in higher education (Rennie and Morrison 2012).

Furthermore, Zhang, Flammer and Yang (2010) also draw attention to the fact that current students are born into a digital world where online sharing is very common: thus incorporating social media programmes and websites into learning, such as Skype, YouTube, Flickr, LinkedIn, Facebook, Twitter, Pinterest, Padlet (Harvey et al. 2013) and various blogging sites, provides a good opportunity for educators to foster collaborative learning. Today, many institutions have begun to use social media initiatives to facilitate information sharing and collaboration between instructors and students. The results of a study of campus social media initiatives show that universities are considering the use of social media tools for course content delivery as well as collaboration and decision making for group projects (Foroughi 2011).

Creative Classrooms (CCR) is another trend in the education industry, which is an innovative learning environment that includes applications of ICT to modernise learning and teaching practices. In this context the term 'creative' is regarded as providing innovative practices, such as personalisation, collaboration, active learning and entrepreneurship. Therefore, in CCR curriculum and content are open in order to support learners in developing 21st century skills including collaboration, communication and problem solving. Content and curricula need to be updated regularly with the active participation of education stakeholders and practitioners. It has been also reported that recent evidence-based research should be utilised in CCR. Additionally, in such ICT-enabled innovative environments, learning is flexible and engaging in order to meet individual preferences and expectations of students. In CCR, students have to take responsibility for their own learning progress as well as support each other in jointly creating learning content and context (Bocconi, Kampylis and Punie 2012).

The results of the Suanpang and Petocz (2006) study suggest that TEL can be an effective method for student learning statistics. Students in the online group achieve significantly higher results than those in traditional classes. The study reports that online students achieve higher learning outcomes in terms of grades and levels of satisfaction, compared to students in traditionally taught classes. The authors attribute this to the use of advanced technological support and the offering of diverse learning materials to online students (Suanpang and Petocz 2006).

TEL presents not only opportunities but also challenges to both institutions and students (Liu et al. 2007). Integrating the Internet into courses is a complex and challenging process (Uden and Damiani 2007; Cantoni, Cellario and Porta 2004). Institutions need to rethink their educational environment in light of new technologies in order to meet the challenges of a global context (Cantoni, Cellario and Porta 2004). With the aggressive development of computer technology, the Internet will play an even more important role in academic settings, presenting a greater challenge to institutions. The Internet is a resource that institutions cannot afford to ignore (Wang 2007). Integration of ICT with conventional teaching methodologies is a necessity: however, the design of systems needs to be flexible to allow instructors to deliver the material in multiple ways. Lecturers, system designers, and educational theorists must engage with heterogeneous and complex elements when considering the introduction of e-learning into the university sector (Flynn, Concannon and Bheachain 2005).

Using and adapting to technology can be a problem for instructors and students. Often lack of appropriate procedures and technical support are at present causing problems to arise in institutions. Online technical support is one of the most important support services for online learning environments (Liu et al. 2007). Providing support in TEL appears to be essential for successful ICT integration, whether academics are new to its integration or not. A bottom-up approach in helping academics to integrate technology into teaching is needed in order to achieve the goal of instigating good teaching practice. To promote the integration of TEL into higher education, wider and more concerted efforts are required (Hodgson, Lam and Wong 2007). The university sector should explore the possibility of providing a service for lecturers that meets key needs: these include providing advice on suitable instructional strategies, providing technological training and support, and teaching software design (Flynn, Concannon and Bheachain 2005; Herrington, Reeves and Oliver 2005).

In addition, student prior perceptions of TEL and experiences of technology are crucial to the success or failure of the endeavour. A negative perception of TEL potentially creates barriers to TEL: conversely, a positive prior perception motivates a student to engage with the learning systems. The increased computer literacy of positive associations with computer use in general does have an impact upon student openness to the concept of blended course delivery modules (Flynn, Concannon and Bheachain 2005). Blended learning combines multiple delivery media that are designed to complement each other, promote collaborative learning, facilitate social integration and improve learning outcomes (Uden and Damiani 2007; Liu et al. 2007). Blended learning mixes various event-based activities, including face-to-face classrooms, TEL and self-paced learning (Liu et al. 2007).

Students have to spend time on learning how to use technology to access course material and interact with peers and the instructor (Liu et al. 2007). Students in online courses may have a particularly high degree of anxiety at the beginning of the course: therefore, online learning methods can be stressful for some students. Students should receive guidance on how to psychologically prepare and self-organise for online courses (Liu et al. 2007). Moreover, technical support services should be available to help students log on, upload and download files, for troubleshooting, and so on. There is a possibility that technical problems may arise due to servers being down, network failure, database crashing, and incompatibility of new versions of software with learning management systems, and so on. Technical support should find ways to help learners during a disaster period. Students greatly appreciate getting technical problems solved the easiest and fastest way possible. Being motivated in an open, flexible and distributive learning environment can be very difficult sometimes. Technical problems that students cannot easily fix or that make them wait for a long time can put students behind schedule, and make them feel frustrated and unmotivated (Liu et al. 2007).

Conole (2008) notes that many students are comfortable in technology enriched environments. However, the skills of these students are not universal, as they have been gained for specific purposes: therefore institutions need to determine the skills gaps and support students accordingly (Conole and Alevizou 2010). Also, it has been argued that training to support the use of new technologies, as well as educator motivation are required when technology is integrated into teaching and learning (Foroughi 2011).

Approaching the topic from a different perspective, Herrington, Reeves and Oliver (2005) state that most TEL approaches of higher educational institutions are wrong. The writers argue that higher education institutions fail to perceive the difference between educating learners and simply providing them with information and content. They assert that TEL is failing in this context not because the need for quality and flexibility in higher education is declining, but because institutions have mistakenly identified themselves as being in the information industry rather than in education. They believe that education providers generally made the mistake of offering education as a product (product-oriented) rather than as a process (customer-oriented). Considering the educational approaches of course management software such as WebCT or Blackboard, it is easy to see why institutions might think that they are in the information industry. Most institutions of higher education appear to be focused on product issues such as content coverage, course structure, and pre-existing time arrangements such as semesters and hours of credit rather than customer issues such as learning and performance (Herrington, Reeves and Oliver 2005).

Instructors often expect students to keep to a regular and weekly study timetable, but such an expectation fails to take into account the significant advances made in higher education over recent years, which now accommodate irregular work hours, work responsibilities and family commitments: these, however, are often ignored in online learning. In flexible learning approaches students need more self-direction. Institutions need to carefully examine the policies and procedures that many have to be put in place to provide quality and consistency, but which inadvertently constrain innovative pedagogies and customer-focused practices online (Herrington, Reeves and Oliver 2005).

2.2.2 Conclusion of the Section

There is no doubt that TEL has the potential to promote and improve learning. However, it can be seen that there are various factors that can influence student learning in TEL environments. Each student has different needs shaping the learning process and adaptive learning addresses this issue by providing students with a learning environment that fits their learning preferences. Therefore, the next section discusses the concept of adaptation, together with methods that can be used for learner modelling and adaptive learning.

2.3 Adaptive Learning

According to Santos et al. (2003) adaptation can be described as providing a response, based on the preferences of learners. The most direct approach is to provide adaptation to learners according to their individual features. Adaptation is advocated as one of the important requirements for successful TEL since students mostly work on their own within such systems. In addition, being adaptive is significant for a TEL environment due to its potential use by a wide variety of learners (Liu 2007; Brusilovsky 1999). The characteristics of a student, such as prior knowledge, learning needs and learning goals have commonly been considered as the basis for adaptation in many studies. Learning styles are deemed as one of the most important sources for developing adaptation, as a key principle in TEL (Liu 2007).

Many researchers (e.g. Popescu 2010) agree that incorporating learning styles into education in order to offer adaptive learning has the potential to improve the progress of student learning. Presenting customised learning material and individual pathways of learning makes student learning easier. Previously developed adaptive TEL environments provide different levels of individualisation, including curriculum sequencing, and user interface and navigation of contents. Mulwa et al. (2010) argues that adaptation can be provided based on learner variables or instructional variables. Learner variables include cognitive abilities (e.g. reading skills, problem solving), metacognitive skills (e.g. self-assessment, reflection), affective states (e.g. motivated, frustrated) and additional variables (e.g. learning styles, social skills), whereas instructional variables involve feedback, content sequencing, scaffolding and views of learning materials (Mulwa et al. 2010).

Existing learning style models are mainly utilised in order to identify learner needs and provide adaptation in TEL environments. These are investigated in more detail in the next section of this thesis. Dunn and Dunn, Kolb's, Honey and Mumford's, and Felder and Silverman Learning Style Index (LSI) are widely known and used for identifying learner learning styles (Coffield et al. 2004).

It has been argued that students can learn efficiently, retain information longer, and apply knowledge more effectively when their learning styles are consistent with teaching styles (Liu 2007). Students can receive a customised learning programme incorporating greater choice in terms of when and where they wish to study. The development of this field is dependent on the emergence of new technologies, advances in learning, machine learning and artificial intelligence (Shute and Zapata-Rivera 2007).

2.3.1 Learner Modelling

In order to have the ability to offer adaptive learning, learner learning styles and preferences must be known. Brusilovsky (1996) mentions that learner modelling in adaptive TEL environments is more about sharing the duties between the system and the learner while modelling the user. In the literature, there are two different approaches for obtaining the required information about learners and modelling them: collaborative (cooperative) and automatic approaches. In the collaborative approach, learners provide information about themselves explicitly, for example, filling out the offered questionnaire before using the system in order to determine their learning style. In the automatic approach, the process of collecting data is done automatically based on the behaviours and actions of the learners while they are interacting with the e-learning system (Brusilovsky 1996 and 1999).

Commonly, an adaptation component is built to monitor learners while they are using the TEL environment, which collects the required data to describe user behaviours while using the system. A learner can be modelled after processing the gathered data and utilised to create an adaptation (Brusilovsky 1996). In other words, adaptation is achieved in four steps: Capture the learner data; Analyse the captured data; Select the suitable content or tools; and Present it to the learner (Specht 2002).

To date, most of adaptive e-learning systems gather data about learners based on the information they provide through particular questionnaires. This is, however, not necessarily the best approach, as learners might not be able to assess their own abilities appropriately.

In the following subsection, a discussion is provided on general aspects of two different approaches to learner modelling and how these techniques can be used to gather information about learning styles. Studies are introduced which have taken into account individual learning styles of learners to provide adaptive learning, and used two different types of learner modelling.

2.3.1.1 Automatic Modelling

In the automatic approach, the detection of learner learning styles and needs are done automatically based on their activities and actions while they are interacting with the TEL environment for learning (Graf, Kinshuk and Liu 2008). Systems can utilise path and navigation information that learners follow, time spent on each module and the number of visits to course elements in order to collect data about learners. Moreover, tracking learner actions and using the planned knowledge base to figure out the goal of the learner have been shown to be effective for different applications (Brusilovsky 1996).

The following paragraphs present studies, which analyse the behaviour of students in a TEL environment, based on a specifically selected learning style model and implicitly detect their learning styles to provide adaptive learning. Automatic student modelling can be used for building a student model from scratch and/or updating an existing student model. In the investigated studies, the automatic modelling method is utilised for creating and updating the student model and various techniques are used for deducing the learning styles to provide adaptation.

A study carried out by Graf, Viola and Kinshuk (2007) on automatic student modelling for detecting learning style preferences, based on the Felder and Silverman Learning Style Model (FSLSM), demonstrates that activities of students in a TEL environment can be utilised to obtain information about their learning styles. The study uses several sources of information about student behaviours with regard to content objects, outlines, examples, self-assessment tests, exercises and discussion forums. The number and the amount of time students spend on course content, outline and examples, indicate a pattern. For example, students who visit exercises often, spend a large amount of time on exercises, perform more self-assessment tests, and spend a low amount of time on studying content objects, are categorised as active learners. In contrast, students who take the directly opposite approach are classified as reflective learners. In addition, the amount of questions answered and the time spent on self-assessment tests are also viewed as relevant information for determining student learning styles. The outcomes of the study show the automatic modelling approach is appropriate for identifying learning preferences in terms of three contextual dimensions: active versus reflective; certain preferences relating to sensing versus intuitive; and visual versus verbal (these are all dimensions defined by the FSLSM). However, less accurate results are gained for what the Felder and Silverman Learning Style Model describes as the sequential versus global dimension.

Similarly, another study (Cha et al. 2006) is carried out on diagnosing student learning styles through their actions in an intelligent learning environment and customising the user interface to fit their learning needs. The system uses the Felder and Silverman Learning Style Model to identify and categorise students. A learner model component is utilised and dynamically updated according to student behaviour when using the system to provide an adaptive learning environment. In order to make data recognition easy for pattern classification, collected data about student behaviours is analysed with two different kinds of machine learning i.e. Decision Trees (DT) and Hidden Markov Models (HMM). DT is used for button click counters and durations, and HMM is used for analysing the sequential information of a student's learning process. They collect the required data and generate training patterns, which have been tested with both techniques. Test results show that DTs can be utilised for the visual versus verbal learning style dimension based on the time spent on the text-driven contents or picture-driven contents. HMMs are better for the global versus sequential learning style dimension by considering the number of clicks for the learning content selection through hyperlinks and sequences of buttons. In support of the sensitive versus intuitive learning style dimension both methods are possible however, some decision making processes may be needed depending on the gathered data. Testing results for the active versus reflective dimension show that in both methods the error rates are high: therefore, in order to train DTs and HMMs, insufficient data is obtained with these methods (Cha et al. 2006).

The outcomes of an experimental study by Popescu (2010), involving 64 undergraduate students, demonstrate that accommodating learning styles in an adaptive educational system has a beneficial effect on the learning process. In this study an implicit student model is used based on student behavioural data to adapt the course dynamically to student learning preferences. Unified Learning Style Model (ULSM), which includes learner characteristics from various learning style models, is used for student modelling and student learning styles that are identified by analysing their interaction with the system. In order to associate relevant behavioural patterns to learning style models, the rule-based approach is used and precise results are obtained. The goal of this study is to identify the difference between adaptive and non-adaptive course sessions in terms of learning gain, efficiency, learning effort and motivation. The results of this study show that providing matched courses to students has a beneficial effect on the learning process and providing mismatched courses has a detrimental effect (Popescu 2009 and 2010).

2.3.1.2 Collaborative/Cooperative Modelling

Alternatively, systems can obtain necessary information about learners by allowing them to be explicitly involved in the process of learner modelling. In this approach, learners collaborate with the system and give the necessary data by providing feedback when asked or by making a selection in a given context and updating their own learning model (Brusilovsky 1996).

The collaborative learner modelling or a self-reported informational approach has at least two potential downfalls. The first one is the inaccuracy of entered data. Sometimes, learners may enter deliberately erroneous data due to privacy concerns or a lack of knowledge about their own characteristics. The other one is the need for additional information during the learning process. Learners may feel that completing online questionnaires is time consuming and that it interrupts their learning process, and may subsequently provide invalid information in order to quickly obtain learning materials. On the contrary, collecting this kind of information may encourage learners to be more responsible about their learning (Shute and Zapata-Rivera 2007).

In contrast to manually gathering information about learning styles from students (in the form of a learning style questionnaire), the automatic approach is less prone to error. In the automatic approach, information is collected and analysed over a period of time rather than at one specific point of time. It also prevents potential inaccuracies arising from misjudged self-assessments on part of students (Graf, Kinshuk and Liu 2008).

On the contrary Brusilovsky (1996) suggests that the number of visits or amount of reasonable time spent on a particular piece of content does not guarantee that the student has actually read the presented content. Therefore, this type of information may not be a reliable base for building learner models. Depending on the system's functionalities, both online help systems and intelligent tutoring systems can be utilised to have additional information for learner modelling. Online help systems are used with an objective to recognise the learner goals and the level of learner experiences. Intelligent tutoring systems are mainly used to create exercises based on learner responses (Brusilovsky 1996).

Cha et al. (2006) state that the data obtained directly from the user interface may not be suitable to be utilised to develop a learner model. To overcome this problem they also take into account the time that students spend chatting with friends and talking to instructors. By taking this into account, they use such data when constructing the required decision trees for the learner model.

From a different perspective, partial control of the learning process can be given to students to allow them to control their learning. There are a number of ways to achieve this such as by allowing students to choose actions from a list that the system recommends, getting student approval for a suggested action or permitting students to interrupt the execution of an action. Making the right selection on this continuum is considered important for guaranteeing the accuracy of the student modelling and decision making (Shute and Zapata-Rivera 2007).

2.3.2 Common Approaches Used for Providing Adaptive Learning

Approaches commonly used for providing adaptive learning by modelling the students are described in this section. According to Mödritscher, García-Barrios and Gütl (2004) there are four main approaches that can be used in adaptive e-learning systems.

2.3.2.1 Macro-adaptive Approach

This approach is commonly used for classroom teaching where the students are simply grouped or tracked by grades from assessment tests. This process results in a homogeneous grouping of students, which has minimal effects due to the groups' rare receiving of different instructional treatments. This approach was invented in the early twentieth century in order to be able to accommodate different student abilities (Fröschl 2005). In the macro-adaptive approach, instructional alternatives are selected mostly on the basis of the student's learning goals, general abilities, and achievement levels in the curriculum structure. The praxis-oriented model in this approach supports the defining preconditions for learning content, developing the appropriate competencies, adapting to the student learning styles and achieving different types of instructional objectives according to individual needs or abilities (Mödritscher, García-Barrios and Gütl 2004). Several macro-adaptive instructional systems such as the Keller Plan, the Audio-Tutorial System and Mastery Learning Systems were developed and used in many intuitions in the 1960s (Park 2001).

2.3.2.2 Aptitude-treatment Interaction Approach

The aptitude-treatment interaction (ATI) approach matches different instructional strategies to a specific student's characteristics. This approach proposes different types of instructions or even different media types for different students. The most important factors shaping student learning include intellectual abilities, learning styles, cognitive styles, prior knowledge, anxiety, self-efficiency and motivation to achieve.

Based on their own abilities students can have full or partial control over the style of instruction or the way through a course. In this approach three levels of control have been defined: complete independence, partial control within a given task and fixed tasks with control of pace (Mödritscher, García-Barrios and Gütl 2004). The results of this research demonstrated that student aptitudes influence their learning outcomes if they are offered different levels of control over their own learning. For instance, students with low prior domain knowledge perform better when they acquire limited control (Fröschl 2005).

2.3.2.3 Micro-adaptive Approach

This approach addresses adaptation of instructions on a micro-level by diagnosing a student's specific learning needs during instruction and providing instructional prescriptions for these needs. Monitoring student behaviour and performance, such as response errors and emotional states are used for optimising instructional treatments. It uses the temporal nature of learner abilities and characteristics, especially those which dynamically change (Mödritscher, García-Barrios and Gütl 2004).

Mödritscher Mödritscher, García-Barrios and Gütl (2004) who is the key author in this research area stated that the micro-adaptive approach, in terms of adaptive e-learning, has two main processes: (i) a diagnostic process which assesses student characteristics, such as aptitudes or the prior knowledge and indices of the task like difficulty level; (ii) a prescriptive process optimising the interaction of student and task by systematically adapting the learning content to the student's aptitude and recent performance.

Response sensitivity is another aspect of this approach and it allows systems to diagnose students with eye-tracker tools. Also, interactive communication is an important element for micro-adaptive learning systems, which considers the process of interaction between the student and instructor (Mödritscher, García-Barrios and Gütl 2004).

2.3.2.4 Constructivistic-collaborative Approach

The constructivistic-collaborative approach focuses on how an e-learning system can be integrated into the learning process following the constructivistic pedagogical approach. It puts emphasis on the use of collaborative technologies, which are often considered essential components of TEL environments. The student plays an active role in the learning process where the knowledge is constructed with experiences in the specific knowledge domain according to the constructivistic learning theory. In this approach an adaptive system enables learning with the aid of learning activities and cognitive structures of the content by focusing on how knowledge is gained.

Supporting collaborative learning activities can be a powerful learning experience for adaptive instructional systems with a pedagogical approach. Dimensions of collaborative learning include the following: participation, social behaviour, performance analysis, group processing and conversational skills (Mödritscher, García-Barrios and Gütl 2004).

2.3.3 Investigation on Adaptive TEL Environments

This section examines existing adaptive TEL environments and adaptive techniques in the context of the previously introduced theoretical approaches for adaptive learning. The description of the systems focuses on what kind of adaptation features they used in order to provide adaptive learning based on student needs.

2.3.3.1 ELM Adaptive Remote Tutor

Episodic Learner Model (ELM) Adaptive Remote Tutor (ART) is an intelligent interactive learning system that uses several adaptive techniques to offer different levels of adaptation to support learning programming in LISP. ELM-ART is one of the first adaptive TEL environments. It combines two kinds of learner models for adaptation. It offers adaptation on link annotation and customised curriculum sequencing by adopting a multi-layered overlay model and by using customised examples for programming problems, developed through diagnosing problem solutions with an ELM (Brusilovsky, Schwarz and Weber 1996).

The ELM-ART provides all the learning materials in the form of an adaptive interactive textbook enhanced with significant interactive features, such as tests, interactive programming support and interaction with instructors and other learners (Weber 1999). It has two different types of knowledge representation: the electronic textbook incorporating all lessons, sections, and units, which is based mainly on domain knowledge and deals with acquiring this knowledge, and the ELM used with the procedural knowledge necessary to solve particular programming problems (Weber and Brusilovsky 1997).

2.3.3.2 Adaptive Hypermedia Architecture

Adaptive Hypermedia Architecture (AHA!) is an open source adaptive hypermedia system for TEL that has been experimented with using different research groups in different countries. It provides two types of adaptation including adaptive presentation and adaptive navigation support (Specht 2000). Adaptive presentation is used to support the 'canned text adaptation' category in Brusilovsky's taxonomy (Brusilovsky 1998), which allows for the inclusion or exclusion of fragments. In addition, AHA! supports multimedia adaptation by using the SMIL format (Stash 2007).

Regarding the adaptive navigation support, AHA! provides three kinds of adaptation: the link anchor tag, an arbitrary number of icons and the link destination. This link adaptation technique involves choosing from among three link classes (good, neutral, bad) based on the "desirability" and "visited" status of the link destination. Different link adaptation can be used in each "view" of the presentation layout. Furthermore, learners can change the link colour where the default colour scheme is blue, purple and black for good neutral and bad, respectively (Stash 2007).

In AHA! the user model is created and updated for each learner every time the learner visits a page. The learner model is used to determine how the presentation of the next page should be modified and which advice should be given to the learner regarding which links her or she should subsequently follow (De et al. 2002).

2.3.3.3 Active Learning For Adaptive interNET

Active Learning For Adaptive interNET (aLFanet) is an adaptive TEL environment that integrates adaptive techniques from Intelligent Tutoring Systems (ITS), Adaptive Hypermedia systems (AHS) and Computer Supported Collaborative Learning (CSCL) systems (Santos et al. 2003; Santos, Boticario and Barrera 2005).

aLFanet supports different models: user model, group model, contents and activity model, service model, interface model and recommendations model. aLFanet adapts to learner preferences, habits, features, interests and needs in three different areas which are;

- Adaptation of the instructional design when providing different course contents, activities and services to the learner, according to what the author has specified.
- Adaptation of the interaction when providing support to learners while interacting inside a course.
- Adaptation of the presentation, thus presenting a different user interface to each learner according to his or her user model.

aLFanet provides facilities for user management, learners/tutors assignment to the courses, permissions management, user data privacy and definition of new presentations layouts. Also, advanced pedagogical models are provided, based on the concept of active and adaptive learning, that can be determined by the course authors at the time of design to support learner's interactions during run time (Santos et al. 2003; Santos, Boticario and Barrera 2005).

2.3.3.4 Cognitive Flexibility in Adaptive Learning Environments

Cognitive Flexibility in Adaptive Learning Environments (COFALE) is an open-source adaptive TEL environment supporting cognitive flexibility and it is based on a Tutor Web-based Learning Content Management (ATRC group 2004). It provides the means for adaptive use of pedagogical devices and communication support, besides learner modelling and adaptive content presentation (Hatzilygeroudis, Koutsojannis and Papachristou 2006).

In this system the instructor can implement various types of learner models, such as 'novice' and 'expert'. Also, in COFALE the learning content can be decomposed into quite primitive content units, so that the system can present each student with different content units. For example, simpler examples for a 'novice' learner and advanced for an 'expert' learner can be presented. The second level of learner modelling is that of 'mental models' of learners is also supported by COFALE. At the end of each content page, a learner is encouraged and guided to undertake a number of learning activities, depending on his/her current 'mental model' about the concept of the study (Chieu 2007).

Furthermore, learners can use a search tool to search for peers and ask for help while learning with COFALE. Also, some 'expert' learners may be referred to 'novice' learners by the system, so they can exchange ideas. In doing so the system implements adaptive communication support. In COFALE, a tutor can associate a test with a specific learning goal. The system can automatically create a test and define associations between a learning concept and corresponding questions. However, the instructor needs to create and store questions in the system's database beforehand (Chieu 2007).

2.3.3.5 Adaptive (Advanced) Learning Environment

Adaptive (Advanced) Learning Environment (ALE) (Kravčík et al. 2002) is an integrated adaptive e-learning environment that produces customised courseware for learners depending on their current state of knowledge, their preferences and learning styles based on the Felder and Silverman Learning Style Model. The system can adapt the sequence of contents according to the chosen learning strategies such as additional explanation, prerequisite explanation or comparative explanation, provided by course authors (Specht et al. 2002; Kravčík and Specht 2004).

ALE can adapt to the student by utilising the learner model and also the learner can influence the adaptation by means of their preferences. Learners can specify their preferred language, learning style (via related questionnaires) and media type. Based on these preferences the system selects the appropriate learning environment components and the way in which they are presented. The domain model that includes the learning objects, their metadata and relations between them, and the learner model, which records all the learner's events, are utilised to provide content adaptation. Furthermore, in order to show the annotated course structure, adaptive navigation support techniques are employed. Adaptive link annotations using icons and texts are used to represent the different states of learning objects (Specht et al. 2002).

2.3.3.6 Discussion of Adaptive TEL Environments

Recently, technological advances help to enrich TEL environments and support instructors to continuously monitor the appropriateness of their instructional delivery methods, and modify them if needed. Mulwa et al. (2010) states that adaptation in TEL environments has the potential to encourage learner participation and improve motivation, and experiences in the following areas: specific navigation aid and selection of content. They also identify several limitations of such systems in the following areas: evidence of the impact of new technologies on learning outcomes, how to build effective learner models, and the complexity of environments for learners (Mulwa et al. 2010).

Adaptive TEL environments generally either provide high levels of adaptivity on a specific content domain or generic independent environments that provide essential levels of adaptivity. The first developed adaptive systems date from the 1960s and 1970s and the idea of adaptive learning can be traced back to the early 1900s. The most common adaptation approaches focus on learning materials and navigation support. Also, constructivist learning or collaborative technologies are considered as significant aspects of adaptive learning (Mödritscher, García-Barrios and Gütl 2004).

Undoubtedly, one of the most significant features of adaptive systems is the role of students in student modelling. Most adaptive systems let students provide more information about their needs and goals for building and updating the student model. In addition, students are allowed to modify the classic interface of the system according to their preferences (Brusilovsky 1998).

The majority of today's TEL environments are prototypic and experimental systems with basic interfaces. They do not include prompt services and reusability of the learning context for the modern e-learning context (Brusilovsky, Wade and Conlan 2008).

2.3.4 Conclusion of the Section

Throughout this section, the concept of adaptive learning and related issues are introduced. How learning preferences of students can be fulfilled within a learning environment is also discussed with examples from literature. It can be concluded that technology may have a positive as well as negative impact on student learning depending on the design of the learning environment and the course structure. Today, the learning design and learning activity concepts that can be utilised in various ways to provide adaptive learning are gaining popularity in the TEL field. Most researchers agree that adaptive learning environments will increasingly appear in the future due to the fact that they have the potential to enhance learning.

It has been apparent that learning styles are commonly used as the basis for adaptive learning and they are considered important factors that influence student learning. Therefore, in order to take this discussion further the following section aims to present and discuss widely used learning style theories.

2.4 Learning Styles

In addition to tools and techniques, it has become evident that pedagogy plays an important role when designing a learning environment. Dalsgaard (2005) states that the integration and use of technology, underpinned by pedagogical theories, is crucial for educational development and improvement. Therefore, technology needs to be designed explicitly to support learning activities as well as student learning needs in a learning environment (Mulwa et al. 2010). Although there are positive statements about the influence of learning styles on education, questions also exist regarding the most effective ways of using learning styles to achieve greatest benefit (Wilson 2012), and some of these are discussed in this section.

It is widely accepted that the learning requirements and preferences of each student tend to be different (Liu et al. 2007; Cantoni, Cellario and Porta 2004; Uden and Damiani 2007; Wolf 2002) where some students prefer certain methods of learning more than others. The one-size-fits-all approach is not suitable while each student has different prior knowledge of domain, backgrounds, learning styles, interests and preferences (Siadaty and Taghiyareh 2007). The terms cognitive styles, learning styles, learning strategies and learning preferences are used by educators to classify these components of learning, and to define the way people learn. After reviewing the literature, it has become apparent that the research field of learning styles is extensive and complex, and there is no single and generally agreed upon definition of learning styles, nor any scientifically proven basis for them. However, the parameters are useful to explore the way TEL can support metacognition and learning (Coffield et al. 2004).

The term cognitive style and learning strategy are often used in a similar context. Rayner and Riding (1998:7–8) argue that cognitive style is "the way the individual person thinks" and "an individual's preferred and habitual approach to organising and representing information". They state that a learning strategy consists of "those processes, which are used by the learner to respond to the demands of a learning activity" (Rayner and Riding 1998:8). In order to show the difference between these two concepts Riding and Cheema (1991:195–196) claim that "strategies may vary from time to time, and may be learned and developed" and "styles, by contrast are static and are relatively in-built features of the individual". In addition to this perception, Heineman (1995) agrees that cognitive style is a fixed or static feature of an individual that affects his/her approach to organising and processing information during learning. According to Pask (1976) learning strategies can be defined as short-term methods that can change over time, and according to instructor, subject and situation.

Some researchers (e.g. Felder 2005) describe learning styles as ‘flexibly stable’, arguing that previous learning experiences and environmental factors may create preferences and strategies rather than styles, and that style may differ from context to context. However, Coffield et al. (2004) argue that looking at context based learning and learning biographies, as opposed to styles, is a more enlightening path of research.

Honey and Mumford (1992:1) define learning styles as “a description of the attitudes and behaviours which determine an individual’s preferred way of learning”. Felder (1996:18) defines learning styles as “characteristic strengths and preferences in the ways they [learners] take in and process information”. In addition Kolb (2000) argues that a learning style is not a fixed characteristic but “a differential preference for learning, which changes slightly from situation to situation. At the same time, there is some long-term stability in learning style” (Kolb 2000:8).

The previous discussions of learning style models and assessment instruments point some of the negative consequences of the extreme diversity that exists in this field. The amount and ambiguity of definitions, terms, and even underlying theories are confusing. Researchers and organisations may be justified in promoting their learning style theories but in fact this diversity harms the field in general. The variety of approaches highlights the complexity of learning style concepts. Wilson (2012) claims that there is a need for further and more focused scientific studies in the field (Wilson 2012).

Notwistanding, and despite continued debate about the effects of learning styles on academic achievement, there is strong evidence that learning styles influence the attention and learning experiences of students (Kratzig and Arbuthnott 2006). This, in turn, may influence achievement and success in schools (Wilson 2012).

It can be concluded that there is no single agreed definition for the theory of cognitive/learning style, and researchers in this field have defined them in multiple ways. Throughout this thesis, a number of terms are used and defined. The term 'learning style' is defined as a set of characteristics that shows how a learner prefers to interact with the learning environment to receive and process information; 'Learning preference' is defined as a way students prefer to access and gather information. 'Learning strategy' is defined as techniques that students use and adjust during the learning process to achieve positive outcomes within the TEL environment. 'Cognitive style' is defined as an individual's habitual approach to organising and retaining information. The next section describes several widely used learning style models and discusses their use in TEL environments.

2.4.1 Common Learning Style Models

There are certain models which are extremely influential and popular in learning styles: in the US, for instance, the Dunn, Dunn and Price Learning Styles Inventory is used in a large number of elementary schools, while in the UK Kolb's Learning Style Inventory, Honey and Mumford's Learning Styles Questionnaire, Myers-Briggs, and Felder and Silverman Learning Styles Inventories are widely known and used. In addition, the VARK questionnaire is used to identify learning preferences of students (VARK 1992; Coffield et al. 2004).

"Between 1902 and 2002, the learning styles theory expanded significantly, with no fewer than 71 different models published during this 100-year period." (Wilson 2012:14). Each of these models has a unique focus on student preferences and abilities. In the literature, there are various attempts to categorise these learning style models (Wilson 2012).

Coffield et al. (2004) state that considerable research has been carried out on all aspects of learning styles over the last 30 years and most of them refer to higher education and professional learning. Their extensive critique reveals that the learning styles field is not unified. They group the most common theories into theoretical, pedagogical and commercial categories. 13 major learning styles models are identified with respect to their importance in the field from a theoretical perspective, their common use, and their impact on other learning style models. Also, they find that there are very few robust studies that offer reliable and valid evidence for practice based on empirical findings (Coffield et al. 2004).

This section aims to provide an overview of nine common learning style models. The grouping of the models is based on a report by Coffield et al. (2004) that critically reviews the literature on learning styles and this report has been widely used in many research studies (Aziz et al. 2013, Penger, Tekavčic and Dimovski 2008; Foster 2008; Graf 2007). The learning style models in Table 1 are selected because of their widespread use and theoretical importance. A further reason for their selection is their potential use in a TEL environment, or their current application in existing TEL environments.

Learning styles and preferences are largely **constitutionally based** including the four modalities: VAKT.	Learning styles reflect deep-seated features of the **cognitive structure,** including ‘patterns of ability’.	Learning styles are one component of a relatively **stable personality type.**	Learning styles are **flexibly stable learning references.**	Move on from learning styles to **learning approaches, strategies, orientations** and **conceptions of learning.**
• Dunn and Dunn	• Riding	• Myers-Briggs	• Herrmann • Kolb • Honey and Mumford • Felder and Silverman	• Entwistle

Table 1: Coffield’s continuum of learning styles (Coffield et al. 2004)

2.4.1.1 Dunn and Dunn Learning Style Model

This model is developed based on the belief that environmental factors, opportunities to move around the classroom, working at different times of the day and taking part in different kind of activities, impact on student preferences and learning outcomes, in addition to their innate intelligence. According to Dunn, such factors can affect learning negatively. The model is first formed in 1974 and extended over the years (Dunn and Dunn 1974; Dunn and Griggs 2003). This model aims to identify individual learning styles and help with the planning and implementation of instruction to address these learning styles.

The Dunn and Dunn model categorises learning styles into 5 areas, which they call stimuli: these are (1) environmental, (2) emotional, (3) sociological, (4) psychological, and (5) physiological variables, which are all deemed to significantly influence an individual’s learning (Dunn and Griggs 2003).

The environmental stimuli include sound, light, temperature, and furniture or seating design, according to individual preferences. The emotional stimuli incorporate the level of motivation, degree of responsibility, persistence, and the need for structure. The sociological stimuli consider whether individuals prefer to learn alone, in pairs, in pairs as part of a team, with a support from authority, or in varied approaches (as opposed to working within a consistent arrangement of social groupings). The physiological stimuli include perception preferences such as visual, auditory, kinaesthetic or tactile, time of day, mobility while learning, and the need for food and drink. The last stimuli (psychological), which deals with information processing elements including global/analytic style, hemisphericity preferences and impulsive/reflective preferences is not available in the initial version of the model.

The model uses a questionnaire to identify learning style preferences of students. There are various versions of the questionnaire that are developed in grade 2, grade 3, grade 4 and grade 5-12 versions for children according to US grades. The questionnaire consists of 104 3-point (true, uncertain, false) or 5-point (strongly disagree, disagree, uncertain, agree, strongly agree) Likert scale questions to detect student learning styles. Additionally, there is the Building Excellence Inventory (Rundle and Dunn 2000) version for adults that involves 118 questions and which employs a 5-point Likert scale. Results of the questionnaires show a high or low preference for each factor.

2.4.1.2 Kolb's Learning Style Model

According to Kolb (1984), learning is the process out of which knowledge is constructed, and incorporates both captured experiences and transformations. It is thus evident that Kolb's learning style theory is developed based on Experiential Learning Theory (Kolb 1984), which gives significance to experiences in the learning process. In this model, learning is perceived to be a four-stage cycle: immediate concrete experience (CE) is the basis for observation and reflection (RO); observation leads to abstract conceptualisation (AC); and these serve as guides in creating active experiences (AE). Following this theory, Kolb divides learning styles into four categories, each producing four different types of knowledge.

Type 1, the converging style (abstract, active) is based on abstract conceptualisation and active experimentation. An individual whose strengths lie in practical application, problem solving and decision making belongs to this category. In contrast, type 2, the diverging style (concrete, reflective) relies on concrete experience and reflective observation. People who adopt this style of learning are imaginative, good at viewing concrete situations from many perspectives, and adapt by observation rather than by action.

Type 3, the assimilating style (abstract, reflective) emphasises abstract conceptualisation and reflective observation, a style employed by individuals who use inductive reasoning to create theoretical models, and who are more concerned with ideas and abstract concepts than with people. Type 4, the accommodating style (concrete, active) focuses on concrete experience and active experimentation, thus making it an opposite way for leaning to the assimilating style. Those who adopt such a style (accommodators) prefer doing things, carrying out plans and getting involved in new experiences. In addition, they can adapt to changing circumstances and solve problems.

The Kolb's learning style model uses a forced-choice ranking method to measure individual's learning styles. The primary model is first developed in 1976 and revised several times. Individuals need to complete 12 sentences that describe learning in their preferred way. Each sentence has four endings and the individuals are asked to rank the endings with respect to what best describes how they learn (4 = most like you; 1 = least like you). The results of the test show an individual's preference for the four modes (AC, CE, AE and RO). Also, their preference with regard to active/reflective and concrete/abstract dimensions of learning can be derived from the preferred modes.

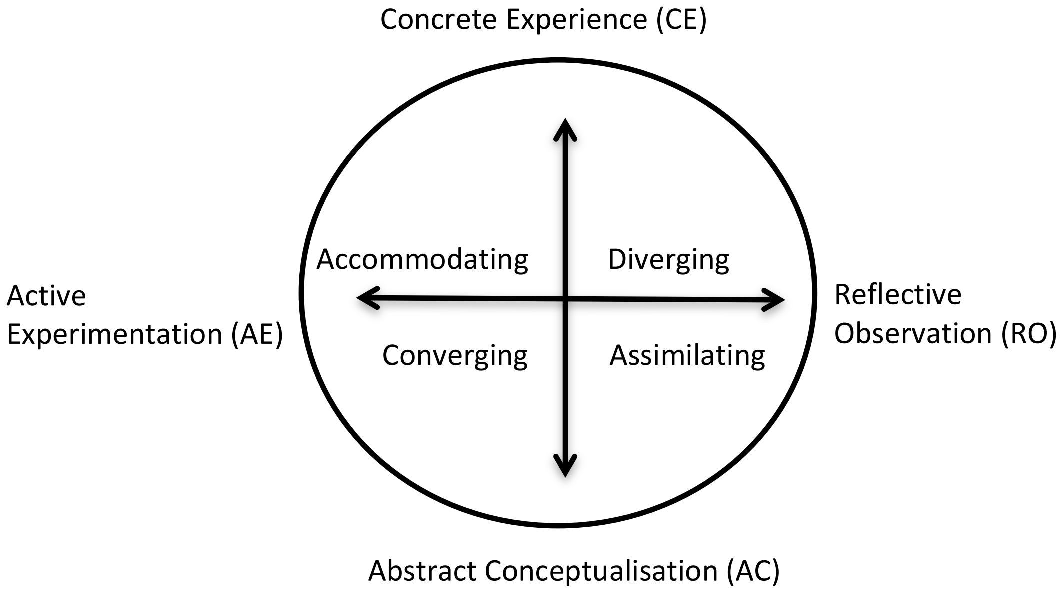

Figure 1: The Kolb's Learning Styles

2.4.1.3 Myers-Briggs Type Indicator

The Myers-Briggs Type Indicator (MBTI) (Myers and McCaulley 1985) is not designed particularly for learning and its main aim is to make Jung's theory (Jung 1968) of human personality understandable. However, the application of the theory is extended beyond making Jung's theory intelligible. Coffield et al. (2004) states that MBTI has a considerable academic impact as many articles have been written about it and it is widely used in the training world. Although MBTI is a personality test, it can be used in the learning field as the personality of individuals has an impact on their way of learning.

Based on Jung's theory the MBTI classifies personality types into four dichotomies: extroversion (E)/introversion (I), sensing (S)/intuition (N), thinking (T)/feeling (F), and judging (J)/perceiving (P). A total number of 16 types can occur with all possible combinations.

The extroversion and introversion dimension deals with the manner in which a person interacts with others. Extroverts tend to focus outwardly and gain energy from others, whereas introverts tend to focus inwardly and gain energy from their own thoughts and ideas. The sensing and intuition category concerns how a person processes information. Sensing people prefer to acquire information via their five senses and experiences, whereas intuitive people prefer to use their intuition and focus on possibilities. Behaviours shown when evaluating information are made sense of by the thinking and feeling dichotomy. People in the thinking group focus on objective facts, while feeling-type people focus on subjective meanings and values. The last dimension, judging and perceiving, refers to how people make conclusions about any given situation. It proposes that judging people use timely and planned decisions such as step-by-step approaches, and that perceiving people focus on process-oriented and decision-making methods that make them more flexible.

The 93-item Form M is the standard version of the MBTI (Myers et al. 1998). Also, the 126-item Form G (1985) and an abbreviated (50-item) version are available. The test includes a list of forced-choice questions about the four bipolar scales and personality type detection based on the answers. In order to describe a person's personality type a combination of all four preferences needs to be taken into consideration.

Figure 2: The four bipolar scales of the MBTI

2.4.1.4 Honey and Mumford's Learning Style Model

Honey and Mumford (1982) are inspired by Kolb's learning style model and worked four years to evaluate individual differences in learning preferences, before developing their learning styles questionnaire. According to Honey and Mumford (1992:1), a learning style is "a description of the attitudes and behaviour which determine an individual's preferred way of learning". Following this description, instead of asking individuals to define how they learn, as Kolb does, they produce a questionnaire to investigate general behavioural tendencies rather than direct learning.

The model develops Kolb's active/reflective and concrete/abstract dimensions further and divides learners into four types: Activist (similar to Accommodator), Reflector (similar to Diverger), Theorist (similar to Assimilator) and Pragmatist (similar to Converger). Activists like new experiences, interact with others and work in small groups, and they are ready to take action. Reflectors prefer to learn by observations and reviews. They need time to think and reflect before coming to a conclusion, and learn better when they are provided with expert explanations and analysis. Theorists are learners who tend to think about problems in a step-by-step manner. They learn better from lectures, concepts, case studies and models. Learners in the pragmatist category prefer to apply principles learned in the real world therefore they are interested in laboratories and fieldwork, and enjoy experimenting with techniques to see if they work.

Honey and Mumford's approach to identifying learning styles is initially published in 1982 (Honey and Mumford 1982), revised in 1992 (Honey and Mumford 1992), replaced in 2000 (Honey and Mumford 2000) and again revised in 2006 (Honey and Mumford 2006). The learning style questionnaire involves 80 items (20 items for each style) in total. Learners are asked to tick the statements with which they agree. Then, ticked items (one point each) are added up for each learning style in order to discern a learner's learning style (Honey and Mumford 2006).

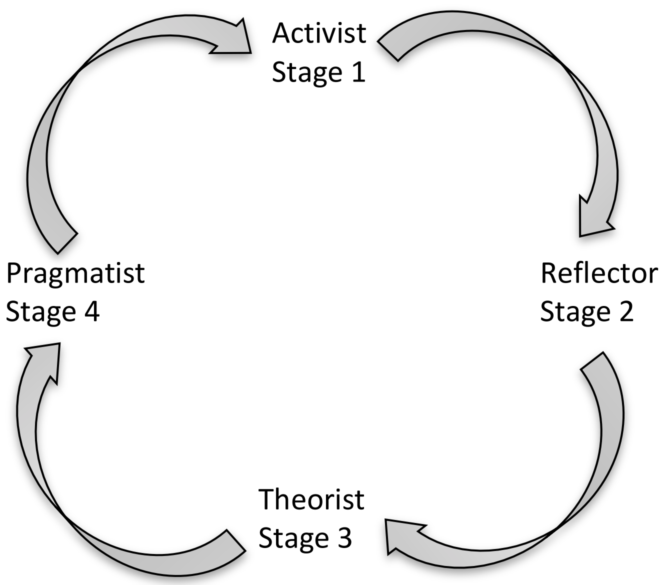

Figure 3: Dimensions of Honey and Mumford's learning cycle

2.4.1.5 Herrmann 'Whole Brain' Model

The first version of Herrmann's 'Whole Brain' model is inspired by the brain-based theory of hemisphere dominance (Herrmann 1989) and is developed in 1982. Split-brain research, advanced by Roger Sperry in 1964, emphasises fundamental differences between the left and right cerebral hemispheres. However, Herrmann (1989) also takes into account hypothesised functions of the brain's limbic system. Herrman (1989) claims that the brain functions of each individual are not genetically inherited, but they can result from teaching, life experiences and cultural influences.

Herrmann's 'Whole Brain' model identifies four different modes or quadrants in the brain: Quadrant A is actively employed by what he terms 'Theorists' (cerebral, left hemisphere), quadrant B by Organisers (limbic, left hemisphere), quadrant C Humanitarians (limbic, right hemisphere) and quadrant D Innovators (cerebral, right hemisphere). Quadrant A (upper left), learners prefer to acquire facts, apply analysis and logic, and think through ideas. Learners who are in quadrant B (lower left) mode learn by organising, structuring and sequencing the content and prefer to acquire skills with practice. Quadrant C (lower right) type learners are interested in learning through listening and sharing ideas, by moving and feeling, and through people-oriented discussions. Learners who are categorised as quadrant D (upper right) type are characterized as visual, intuitive and who can learn from experimentation.

The model detects the preferred quadrant on the basis of a 120-item self-report instrument. The test includes questions about handedness, motion sickness, strong and weak school subjects, work elements, key descriptors, hobbies and adjective pairs. At the end, the calculation shows the primary, secondary and tertiary mental preferences, or thinking styles, of learners, which are sometimes, also referred as learning styles (Coffield et al. 2004).

2.4.1.6 Riding's Model of Cognitive Style

Riding's cognitive styles analysis (1991) is developed to identify the way people think and the way in which they process and represent information. The model proposes categorisation of styles according to two fundamental dimensions which are considered to be independent of each other: the wholist-analytic dimension is derived from field-dependent and field-independent research by Witkin et al. (1977), and verbal-imagery dimension related to Paivio's dual coding theory (1971) (Coffield et al. 2004).

The wholist-analytic cognitive style categorises people according to those who tend to process information either as an integrated whole (wholist), and those who process information in discrete parts of that whole (analytic). Wholists can grasp and view concepts as complete whereas analytics can capture concepts in parts and have difficulty integrating them into complete wholes.

The verbal-imagery dimension can be defined as people's tendency to represent information either in words (verbaliser) or in images (imager). People in the verbal category are good at working with verbal information. In contrast, imagers prefer working with visual information (Riding and Mathias 1991; Riding and Watts 1997).

The instrument for this model is a computerised assessment tool and the scoring is based on a comparison of speed of response (not accuracy) on a matching task. The test consists of three parts. The first part includes items for verbal-imagery dimension, the second part items related to wholist cognitive style and the third part a set of items for analytic cognitive style. People answer each question by pressing a true or false button. Then, the computer calculates response speed and compares response times between different parts of the test in order to detect cognitive styles of individuals.

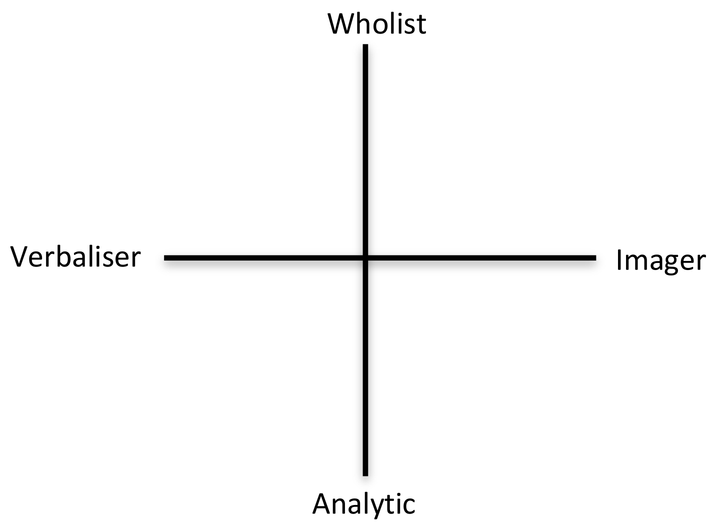

Figure 4: The two dimensions of the Riding's Cognitive Style Model

2.4.1.7 Felder and Silverman Learning Style Model (FSLSM)

The Felder and Silverman Learning Style Model (FSLSM) is formulated by Richard M. Felder and Linda K. Silverman in 1988, and the instrument is developed by Richard M. Felder and Barbara A. Soloman in 1997. FSLSM is designed to determine the most significant learning styles of engineering students and assist instructors in constructing their teaching strategies in order to address student needs. The model categorizes students according to their way of receiving and processing information. Initially the model had five dimensions, however later (in 2002) the inductive /deductive dimension is deleted and the visual/auditory category was changed to visual/verbal. The latest version of the model assesses learning styles in four dimensions: active (A)/reflective (R), sensing (S)/intuitive(I), visual (V)/verbal (B), and sequential (Q)/global (G) (Felder 1988). Learning style dimensions in this model are not novel. The sensing/intuition dimension is taken from Jung's theory of psychological types (Jung 1968), the active/reflective dimension is from Kolb's learning style model (Kolb 1984), and the sequential/global dimension is based on Pask's learning style model (Pask 1976). Also, other dimensions of the model and dimensions of some other models have shaped components of the FSLSM (Felder 1988).

In the active/reflective dimension learners are categorised according to their way of processing information. Active learners tend to retain and understand information best by trying things out. They prefer to discuss, work in groups and explain things to others. Reflective learners, in comparison, like to quietly reflect on the material quietly at first. They like to work alone and write short summaries of learned material in order to retain the information more effectively (Cemal Nat et al. 2011a).

The sensing /intuitive dimension distinguishes learners according to their perceptions of learning materials. Sensing learners prefer to learn facts and concrete learning materials. They often like solving problems with standard approaches, tend to be patient with details, and are generally more practical and careful. Intuitive type learners like discovering possibilities and relationships. Intuitors tend to work faster and be more innovative than sensors. They do not like repetition and are better than sensors at grasping new concepts.

The dimension of visual/verbal classifies learners according to the way that they prefer to receive information. Visual learners remember best what they see, thus responding better to information contained in pictures, diagrams, flow-charts and movies. They may use highlighters to colour-code their notes in order to remember them better. Verbal learners learn better from written and spoken explanations (Cemal Nat et al. 2011a).

In the sequential/global dimension learners are characterised according to their understanding. Sequential learners prefer to learn in a linear trajectory of learning in which each step follows on logically from the previous one. In order to find solutions they tend to follow logical, step-by-step learning paths. In contrast to sequential learners, global learners tend to learn in large jumps, absorbing learning materials randomly and acquiring information suddenly. They can solve complex problems quickly or put things together only after they have grasped the big picture.

In order to identify learning styles, Felder and Soloman (1997) develop a 44-item questionnaire that consisted of questions with two possible answers. Each learner has a personal preference for each of the four dimensions. The learning style preference for each dimension is expressed by an odd integer ranging [-11, +11] since each four dimension is associated with 11 questions. Answers have values +1 and -1, for instance, when answering a question that belongs to the active/reflective dimension with an active preference: the student's score is incremented by +1 for active preference, while for reflective preference it is decreased by 1 so add -1.

The model has three score scales for each learning style preference which are strong, moderate and balanced. Based on this assumption, 64 different student models are considered possible. A student model consists of 4 different dimensions and each dimension has 3 possible options: strong on first preference, balanced on both preferences and strong on second preference. As an example for the first dimension a student can be Active, Active/Reflective or Reflective.

Some student learning style examples are as follows:

- **ASVQ** Student model indicates strong preference on active, sensing, visual and sequential types.
- **RS/IVG** Student model indicates strong preference on reflective type, balanced preference on sensing and intuitive types, and strong preference on visual and global types.

Additionally, Felder and Spurlin (2005) state that the dimensions in FSLSM have parallels in other learning style models (see table 3). Also, this model combines the similar dimensions and this combination is unique for this model.

Learning Style Models	Felder & Silverman	Honey & Mumford	Myers & Briggs	Kolb's
Categories	Active/Reflective	Activist/Reflector	Extraverts/Introverts	Active/Reflective
	Sensing/Intuitive	Pragmatist/Theorist	Sensors/Intuitors	Concrete/Abstract
	Visual/Verbal	--	--	--
	Sequential/Global	--	--	--

Table 2: Similarities between different learning style models

2.4.1.8 Entwistle's Approaches to Learning

Entwistle's conceptual model (Entwistle 1990) is developed to comprehend student approaches and skills required for effective approaches to learning, and their intellectual improvement. Entwistle believes that student approaches to learning influence their orientations in relation to learning and their conceptions of it (Entwistle 1990). The learning style models, which are developed by Pask (1976) and Marton (1976) have significant impacts on this model. Learning and studying approaches are described in three categories: deep approach, surface approach and strategic approach.

A deep learning approach is defined as understanding the ideas for yourself, including relating ideas to previous knowledge and experience, investigating patterns and underlying principles, and checking evidence and relating it to the conclusion. Another important feature of this approach is awareness of the development of one's own understanding while learning. Students with surface learning approaches focus on meeting course requirements by treating the course as unrelated bits of knowledge, memorising facts and carrying out procedures routinely. They prefer to study without reflecting on purpose or strategy. Students in the strategic approach category intend to achieve the highest possible results in terms of grades by combining deep and surface approaches. They put regular effort into studying, managing time and monitoring the effectiveness of their ways of studying.

Several versions of the questionnaire have been developed to identify student approaches to learning. The first version, Approaches to Studying Inventory (ASI), is based on Biggs' Study Behaviour Questionnaire (Biggs 1993) and it is revised in 1995 (Entwistle, McCune and Walker 2001). Then, the ASSIST is developed in 1997 together with the development of a Course Perception Questionnaire (Ramsden and Entwistle 1981). The third, and longest, version, the Approaches to Learning and Studying Inventory (ALSI), is developed from earlier inventories (Entwistle, McCune and Walker 2001). The inventory has 36 items that each can be answered on a five-point Likert scale, indicating the degree to which students believe the statement is true for them. Scores are created by adding together the scores which contribute to each approach (Entwistle, McCune and Walker 2001).

2.4.2 Discussion of Learning Style Theories and Models

This section outlines the major issues relating to learning styles, particularly focusing on those relevant to the present study. It further highlights uncertainties in the learning styles field. Although there is plenty of research on learning styles, there does not seem to be any general agreement on, or acceptance of, one single theory. This field of research is complex and involves a much wider pedagogical, as well as philosophical, literature than that related to the learning style models discussed in this chapter.

For each learning style model researchers have made different claims about theories and their ideas behind them. Where some theorists (e.g. Riding and Cheema) define learning styles as fixed and unchangeable, others (e.g. Kolb) define learning styles as modifiable from context to context, similar to learning strategies.

Besides, the existence of numerous learning style models leads to various criticisms and open questions including, which model is most suitable and which one should be used for a specific learning context. There is a need to be highly selective in learning style models as all of them can measure learning styles through the use of developed instruments (usually questionnaires). For example, the result of Coffield et al.'s (2004) examination on reliability and validity of Dunn and Dunn's, Gregorc's and Riding's learning style instruments suggested that these instruments should not be used in education or business. In addition, similarities among, and relevance of, learning styles are another challenge for educators. For example, as explained in the previous section, Honey and Mumford (1982) derive their learning style model from Kolb's learning style model (1976) and Riding's cognitive style model (1991) is developed out of Witkin's (1977) field-dependent and filed-independent work. Therefore, there is a need to investigate learning style models and dimensions in more detail and bring clarity to their relationships.

Aiming to evaluate the instruments of learning style models, much research has been conducted to measure the validity and reliability of learning style models, and review the psychometric properties of their measurement. Coffield et al. (2004) report that some of the popular instruments (e.g. Dunn and Dunn, Riding and Gregorc) are relatively poor in terms of their reliability and validity. Also, it has been noted they have a negligible impact on pedagogy. Study of Coffield et al. (2004) include four criteria to be fulfilled at the minimum level for evaluating the instruments: construct validity, predictive validity, internal consistency reliability, and test-retest reliability.

Furthermore, inconsistent results from studies investigating the impact of learning styles on student learning outcomes produce a different kind of criticism in the field (Graf 2007). It has been claimed by Coffield et al. (2004) that there is no consensus based on hard empirical evidence that the matching approach has a significantly positive effect on student achievement. Reasons given for this include small sizes of samples used in research studies (Jonassen and Grabowski 1993; Curry 1991), standardised tests, and supervision of students by lecturers when research is carried out (Coole 2008).

Despite the number of available learning style theories, arguments against the existence of learning styles exist in the literature. Some researchers (Curwin and Mendler 1999; Willingham 2009) deny the existence of learning styles by stating that a course subject should be taught in the manner that the topic demands. For example, a teacher should teach geography by paying attention to visual style where the shapes of countries are illustrated even though a student is an aural learner (Riener and Willingham 2010).

Cunliffe (2011) and Willingham (2008) also believe that learning styles do not exist, as they say that this is not how the brain works and theories that try to make a connection between learning styles and the functionality of the brain are not reliable. However, Riener and Willingham (2010) take the debate further and state, "…in claiming that learning styles do not exist, we are not saying that all learners are the same. Rather, we assert that a certain number of dimensions (ability, background knowledge, interest) vary from person to person and are known to affect learning" (Riener and Willingham 2010:34). In addition, Fleming (2012) argues that "the absence of evidence about the benefits from knowing one's learning style does not mean that benefits don't exist." (Fleming 2012:1).

Theories and critiques of learning styles widely differ from one another, which make it difficult to reach a consensus on a holistic model for learning styles that incorporates all learning styles, dimensions and aspects (Coffield et al. 2004). According to Coffield et al. (2004), drawing a simple conclusion when there is so much complexity in the field is premature, given the current lack of consensus among researchers.

The concept of learning styles has been intensely debated and examined over the years and there is evidence for and against their existence. Whilst they are considered controversial, there is significant research in the area (e.g. Coffield et al. (2004) and Wilson (2012)) that provides some clear evidence of their existence and usefulness. The arguments also show that the value of learning styles is a contested area. However, it remains one of interest and sufficient importance to be the subject of on-going research.

Matching and Mismatching Approaches

There are discussions about the impact of providing a TEL environment that matches student learning styles and mismatched learning environment on student learning. Kolb (1984) advocates mismatch learning by claiming that it may encourage students to be creative and grow personally. Also, Matthews (1996) argues in agreement with Kolb, that mismatching can promote the development of the individual in the long term. According to Riding and Rayner (1998), when individuals mismatched with learning environment may develop learning strategies to deal with learning materials that are not suitable to their learning styles. Opposing the view that learning styles have relatively fixed characteristics, they claim that learning strategies can be developed and modified to meet the demands of the environment.

Grasha (1984:51) asked the following question: “How long can people tolerate environments that match their preferred learning style before they become bored?” Grasha argues that people need to be stretched in order to learn and thus this stretching may mean deliberately creating a mismatch between student learning style and the teaching methods. The author takes this argument further by claiming that even those individuals with strong preferences for particular learning styles preferred a variety of teaching approaches to avoid boredom.

On the contrary, Felder (1993) states that mismatch learning is not a beneficial exercise in the educational setting, where it may cause negative impacts on student learning outcomes. Findings of other studies, including that of Zapalska and Brozik (2006), support Felder’s argument, showing that the achievement of college students can be improved by providing instruction in a manner consistent with individual learning style. When students have a strong preference for the manner in which new material is presented, it is difficult for them to learn when educators fail to present material in their preferred way. Therefore, it is important to consider student learning styles while developing an online course, and in order to help students succeed in online education instructors need to understand how they learn, how they perceive and how they process information. (Zapalska and Brozik, 2006).

Similarly, Dunn et al. (1990) report that teaching students with their preferred learning style directly improve their learning achievements. The findings of Lindsay (1999) reveal that student satisfaction and learning outcomes increase when they are taught in their preferred way.

After reviewing nine studies showing that learning is more effective when there is a match and other nine studies that discuss learning is more effective where there is a mismatch, Smith, Sekar and Townsend (2002:411) conclude that “for each research study supporting the principle of matching instructional style and learning style, there is a study rejecting the matching hypothesis".

Furthermore, Kratzig and Arbuthnott (2006) state that learning style theories may not be consistent as their research study presents statistically insignificant correlation between the results obtained from two different learning style assessments that are collected from the same participants. They claim that the insufficient data-driven results may cause some researchers to believe that there is a strong connection between learning styles and personal preferences (Kratzig and Arbuthnott 2006).

The existing research demonstrates that presenting learning materials in a variety of ways (i.e. multiple learning pathways), thus stimulating learning in all types of students, is important for success in grasping a topic or subject (Coole 2008). It is clear that there is no one specific method that can facilitate positive learning experiences and can reach all students. Therefore, while designing and delivering learning materials the diversity of students needs to be considered. However, the argument remains whether matching teaching and learning styles help students achieve significant academic improvements (Wilson 2012).

2.4.3 Learning Styles in TEL Environments

Despite the high number of studies investigating the impact of learning styles on student learning outcomes, there is a little research focusing on the relevance of existing learning style models to TEL (Richmond and Cummings 2005). Cooze and Babour (2007:11) ask "Is there a particular learning theory that should be the focus during the process of instructional design for online learning?" and state that answer to this question is not straightforward but needs focus on the use of technology for learning. In addition, Coole

(2008) states that when designing an online course, the decision on which learning style model should be utilised is undoubtedly a challenging one for instructors as new e-learning styles are likely to emerge from the examination of student behavioural data.

In traditional classroom-based learning it is difficult to address the different learning styles of multiple students because teachers need to regularly change their teaching styles. However, with the aid of technology it is easier to adopt teaching styles based on student preferences. TEL facilitates the tailoring of a course and can make it widely accessible to a large number of people. Several studies have been conducted in the area of adaptive learning that utilise learning styles to provide responses to student needs (Selvi and Panneerselvam 2012). The existing adaptive systems that use learning styles are presented in section 2.3.3.

Orton (2003) shows that the models developed by Kolb (1976) and Honey and Mumford (1992) can be applied and adapted to TEL environments. The author also describes the four learning styles included into these models and explained how they can be addressed in a TEL environment. Moreover, McLean (2004) examines the same set of learning styles and concludes that they can be addressed within online learning environments. For example, the author suggests that the individual who has an 'activist' learning style can be provided with opportunities to explore conversations, take part in quizzes and exercises that allow them to discover new experiences. Also, the author believes that TEL can help activists to guard against their weaknesses.

Carver et al. (1999) and, Kuljis and Liu (2005) argue that the FSLSM is the most appropriate model for use in adaptive TEL environments. FSLSM is one of the most widely used models and many studies have been conducted that deal with student modelling and providing adaptive learning with the use of the model (Graf and Kinshuk 2008).

A research study is carried out by Coole (2008) that aims to evaluate whether traditional learning styles can be implemented in a TEL environment. The author brings students together to work in groups on a shared task using an e-discussion forum. The results of the study show that 21% of participants prefers learning style, which involve using the e-discussion forum for learning and for resolving professional issues. However, the remaining 79% is used it for social interaction or does not engage with it at all. Therefore, Coole (2008) conclude that TEL environments may allow different kind of learning styles to emerge as it is not clear how the remaining participants choose to learn or work through the issues.

2.4.4 Conclusion of the Section

The literature includes many varying views and beliefs concerning learning styles and models, each with their particular focus. When designing an online course, the question of which learning style model should be utilised is undoubtedly a challenging task for instructors. Coole (2008:63) states that "the answer to this question, in terms of online learning, is not straightforward but tends to lead one to focus upon technology and what it enables in terms of learning. That is, the promise of online learning posits that the learner is the focus of learning and not the content." In addition, Zapalska and Brozik (2006) argue that if instructors know about differences in learning styles then they are better able to modify their teaching strategies and techniques in online education, and create a learning environment that will maximize the learning potential of each student.

In January 2006, the British Government commissioned an expert working group to look at future learning spaces (2020 Vision 2006). The '2020 Vision' report proposes an educational ambition for personalised learning and discusses such issues as teaching strategies to support personalised learning, how to utilise new technology to realise personalised learning, and how to use the curriculum flexibly to increase personalised learning opportunities (Cemal Nat et al. 2011a).

Learning theories diverge based on the fact that individuals learn and acquire knowledge in a variety of different ways. These differences among students within a learning context can appear in areas of general skills, information processing and application of information to new situations. The strategies that can be used for online courses in order to address individual differences in learning styles include, but are not limited to, providing course content in multiple formats such as audio-streaming and written text, and allowing individuals to access course materials in several ways. Encouraging active and collaborative interaction with activities that are both individual and group-based is another strategy that can be used for online learning.

Before proceeding further, it is necessary to provide some background to learning design approaches: while investigating the literature it came to light that the design of the learning environment plays an important role in enhancing and facilitating student learning in TEL. It is one of the most significant recent developments in TEL, and within a TEL context the aim of the learning design is to present new opportunities to increase the quality and variety of teaching and learning (Britain and Liber 2004).

2.5 Issues in Designing a Learning Environment

In order to achieve the aims of this study, the TEL environments need to include various learning activities to support the learning needs of different students. By considering the fact that the field of learning design allows instructors to design high quality, effective and creative learning experiences for students (Cameron 2009), this section aims to describe and provide background information about the approach to learning design. In addition, two existing learning management systems that represent good examples of the learning design concept implementation are evaluated.

Dalziel argues that “Learning Design is a descriptive framework for activity structures that can describe many different pedagogical methods” (Dalziel 2009:1), and every learning practice has its own underlying learning design (Koper 2005). Additionally, Beetham and Sharpe (2007) state that ‘Learning Design’ is a term that connects theory and practice, and involves a systematic approach by considering a set of practices that are constantly adapting to circumstances. The process of designing learning activities, modules of learning or learning environments is called ‘learning design’ by Koper (2005). Another definition, which is provided by Donald et al. (2009), defines Learning Design as the documentation of a learning activity in such a way that other instructors can adapt and reuse it in their own context. Similarly, Conole (2008:207) notes that Learning Design is “the range of activities associated with creating a learning activity and crucially provides a means of describing learning activities”. Due to the fact that most of the definitions of Learning Design include that of a means of describing learning activities, a more comprehensive definition could be a “representation of teaching and learning practice documented in some notational format so that it can serve as a model or template adaptable by a teacher to suit his/her context” (Agostinho 2006:3). Cameron (2009) assert that this is a commonly accepted meaning by researchers in this field. On the other hand, Goodyear and Yang (2009) believe that the term ‘Learning Design’ suggests that designers help learners to renounce their learning responsibilities, and that it can undervalue the active input of the learner if it is not used with caution: consequently, they prefer to use the term ‘educational design’ instead.

It is possible to develop hundreds of different learning practices depending on the course objectives (Koper 2005). Different perspectives and associated pedagogies or combination of perspectives can be involved in a learning design. According to JISC (2009), it can also be argued that successful learning may depends on integrating different approaches. Also, Koper (2005) argue that effective learning design enables students to learn and develop better.

Instructors create different learning designs by using various pedagogical techniques to provide learning practices with their everyday lesson plan. Successful teaching involves a variety of strategies for motivating and engaging students. Besides well-designed learning materials, providing individual or group activities in the form of discussions, simulations or problem-solving exercises for learners helps to generate more effective learning. It has been argued that people learn better when they are actively involved in doing something (Britain and Liber 2004).

Learning activities that learners are involved with can be sequenced or structured into a learning workflow to promote more effective learning within a learning design concept. Students undertake a number of tasks, which are learning activities, for example, finding resources from the Web or contributing to a discussion forum in order to achieve intended learning outcomes (Conole 2008). Instructors create a workflow by selecting and sequencing learning materials and activities for each lesson. A learning design may be constructed by the branching of workflow into parallel activities or different routes to be taken based on a test result within a sequence. Creating a workflow by orchestrating activities according to a sequential order, and timing them, is considered to be one of the key features of successful teaching (Britain and Liber 2004).

As already discussed, with the increasing trend towards supporting learning activities a new structure for designing TEL environments is required. Two learning environments, namely Learning Activity Management System (LAMS) and Creation of Study Environments (COSE 2007), both of which put emphasis on learning activities, collaboration and student-centred learning, are investigated in the following sections.

2.5.1 Learning Activity Management System

LAMS executes the most comprehensive implementation of the concept of Learning Design. The idea behind LAMS is to facilitate good educational practice by focusing on the design of learning activities by using EML and IMS LD representational formats (LAMS).

The early versions of LAMS are developed with a focus on a range of activity tools, particularly collaborative activity tools based on the general concepts of EML and IMS LD. Recently, however, the goals of LAMS development with IMS LD specification do not match, therefore LAMS diverge from IMS LD and lead to the notion that LAMS is ‘inspired’ by IMS (Dalziel 2006). The aim of this specification is to provide a framework of elements that can define any design of the teaching and learning process in a formal way. It has three levels of Learning Design: Level A includes activities and roles as reusable components that can be designed to fit into a workflow, Level B adds properties and conditions to Level A, which allows for the adaptation of activities and activity sequences based on learner preferences, and Level C adds notifications to Level B that allows for communication between system components (IMS Global 2003).

The LAMS visual authoring tool for Learning Designs allows rapid adoption and sharing of instructional strategies, and creation of simple linear pedagogical approaches: however it limits the amount of information that can be included into complex instructional designs, such as spiral pedagogies, which cannot be easily adapted to a linear format. Moreover, LAMS has an 'Optional Activities' feature, where instructors can include supplementary activities to their learning design in addition to the linear sequence and allow learners to choose from among several different activities. As a support for management of linear flows that includes controlling the release time of subsequent activities to learners, LAMS provides a 'Stop Point' feature as well (Dalziel 2011).

LAMS has another limitation in the area of roles as it does not provide automation for a more sophisticated role structure, as is suggested in IMS LD. It includes basic roles, a teacher and student role, with relevant functional differences in activity tool behaviours. Only the 'Chat and Scribe' tool has different functionalities for two types of student roles: a special 'scribe' role for one student who can edit answers to questions based on group discussion and a general discussion role for all students (Dalziel 2011).

Furthermore, the LAMS implements broadly define the Learning Design concept at its most basic level, in particular representing many different instructional strategies, such as role-plays, problem-based learning and web quests within a single environment. A range of different approaches can be represented with the choice of tasks and instructions given to students. For instance, despite the fact that the tools are presented in a linear sequence with revisiting option for any activity in a sequence, research tasks (using a Search Engine) can be combined with an open-ended discussion forum to create constructivist-style learning experiences (Dalziel 2011).

A Learning Design developed in LAMS can be exported as a file and shared with other instructors. Although, the export format is not exactly the same as IMS LD (but is similar to it), LAMS sequences can optionally be exported in IMS LD 'Level A' format (Dalziel 2011).

The outcomes of the Masterman and Lee (2005) report show that LAMS may support effective practice in terms of instructor practice and learner experience, and LAMS affords both a reflection on practice and a sharing of learning designs with others. They state that the current interface and functionality of LAMS make it more effective as a system for authoring learning designs than as an environment for promoting the acquisition of new knowledge and skills. They also added that LAMS has the potential to take the teaching and learning experience in exciting directions for both teachers and students (Masterman and Lee 2005).

LAMS promotes adaptive learning by enabling authors to create branches and direct students to different paths in the same sequence according to their assessment result or learning preferences. For instance, based on the outcome of a questionnaire students can be directed to the relevant learning materials. It includes system-automated branching (teacher allocation at run-time, group-based or input based) or student-selected alternative pathways (optional sequences) (Dalziel 2011).

2.5.2 Creation of Study Environments

COSE is another system that allows instructors to create activity-based learning designs. It supports a constructivistic approach for creating learning designs, which emphasises student activities and collaboration. Currently, COSE is in conformance with IMS specifications for content packaging and interchange facility (COSE 2007). It is designed to facilitate instructors in structuring learning activities in a top down manner, starting from learning outcomes. The COSE model encourages learning to be organised based on the following three elements: (1) learning objectives, (2) learning activities and (3) learning outcomes (COSE 2007).

COSE uses IMS standards for some of its components such as personal metadata import/export facility. However, it is extensible and allows the integration of other learning specifications including IEEE LOM (IEEE Standards Association 2003). COSE has the potential to support a variety of different pedagogical approaches. In COSE content and activities are assigned to a group of learners rather than assigning only a body of content to learners, as the aim is to foster a learner-centred approach to learning. COSE considers the course as a group of people: therefore, a very deep-nested structuring of people can be achieved, for example, discussion groups, work groups or a combination of these. This feature makes COSE learning designs and related contents adaptable to some extent (Britain and Liber 2004).

In COSE each course consists of a set of learning opportunities, which can be any form of an activity and a collection of resources. Each of them is accompanied by learning objectives as well as instructions. Students are encouraged to find and create their own peer groups for collaborative work and, share and annotate resources. Instructors can also create groups or subgroups and assign or de-assign learning opportunities to groups. COSE allows instructors to share or re-use their learning designs and also publish the chosen content onto a CD to be used offline. Moreover, the contents can be packaged in IMS standards format and exported (COSE 2007).

In comparison to LAMS, when COSE records student actions on the system it simultaneously allows them to get a parallel view: thus, students can see exactly what they are doing. In addition to this, students can review and annotate their activities and submissions with the Profiles tool (Britain and Liber 2004).

What is evident from the outset, in terms of the capability of two systems, is the creation of activity-based learning designs: however, LAMS can handle sequential learning activity design more explicitly than COSE. According to Britain and Liber (2004) this is a rapidly growing field that will cause more learning design tools to appear in the near feature.

It can be observed that monitoring is one of the key additions to TEL environments. LAMS and COSE have the capability for monitoring what students are doing on the system. However, Britain and Liber (2004) stated that the crucial point about monitoring students is the difference between monitoring student actions and monitoring whether any learning is taking place. LAMS allows instructors to monitor student real-time progress through an activity sequence and to start a conversation within the active sequence when needed.

From the student-centred point of view, the systems put the emphasis on the user feedback, specification of student groups and student responsibilities. Students are allowed to provide feedback at certain stages of their learning so that instructors can adapt sequences correspondingly. Regarding student responsibilities, in particular, COSE facilitates student self-organisation which allows them to set groups.

In comparing the two systems, LAMS could appear to have significant advantages as it facilitates adaptive learning with its branching feature and inclusion of various learning activities as well as different learning content formats which is important for supporting student different learning needs.

Before proceeding further, it is necessary to reiterate here that one of the objectives of this study is to find out and compare the learning outcomes of students who study in contrast to their learning styles and others who study consistent with their learning styles in, non-adaptive TEL environment to determine which group of students performed better. As a result, the literature in this area was reviewed in more detail to investigate the specific techniques for identifying student learning styles from their behaviours within a TEL environment. This review is presented in the next section.

2.6 Detecting and Calculating Learning Styles from Student Behaviours in TEL Environments

In this section, the use of existing learning style theories in TEL environments, investigation into how learning styles of students can be identified from their learning behaviours and various methods that can be utilised for calculating learning styles are presented. In addition, a discussion of similar studies in relation to strategies used to detect learning styles is provided.

As discussed earlier, in section 2.4, students have different learning styles and needs. Despite the fact that the investigated learning style models are developed for traditional learning, they have been used in many studies for online learning. However, in order to be able to identify learning styles of students from their actions within an online learning environment, mapping between student behaviours in a classroom environment and a TEL environment is required. Therefore, the relevant behavioural clues for detecting learning styles need to be determined based on student traditional learning behaviours (Graf 2007). When the required clues are collected from student behaviours, their learning styles can be calculated. In the literature, there are a variety of methods that can be utilised to calculate learning styles.

The methods, which are discussed in this chapter, are based on the analysis and interpretation of student behaviours in TEL environments. There is a range of methods used for learning style identification. Popescu (2009) notes that implicit/automatic student modelling presents a challenge, in that it is difficult to determine what does student action indicate for each learning style preference included in a selected learning style model.

2.6.1 Discussion of FSLSM with Relation to TEL Environments

As mentioned earlier, Carver et al. (1999) and, Kuljis and Liu (2005) argue that the FSLSM is the most appropriate model for use in adaptive TEL environments. It is one of the most widely used models and a considerable amount of research has been conducted that deals with student modelling to provide adaptive learning. Some of the studies considered all dimensions and some only particular dimensions of FSLSM (Graf, Kinshuk and Liu 2008).

The FSLSM categorises students with respect to their ways of processing, perceiving, receiving and understanding information. Correspondingly, it classifies instructional methods to address proposed learning style dimensions (Felder and Silverman 1988). As explained earlier, the learning style dimensions in this model are not novel but have developed out of other learning style theories (i.e. Kolb's Learning style model). Also, dimensions of some other models including those contained in Pask's model (1976) has an effect on determining components of the FSLSM (Felder and Silverman 1988). A student's learning style is calculated for each of the four dimensions and valued between +11 to -11. Graf (2007) states that this enables detailed descriptions of the student learning styles and help to provide more accurate adaptivity than the other theories. The strength of the learning style preference can be measured by using the scale between +11 and -11, and integrated into the adaptation process. Also, a weak preference for a learning style can be identified and handled (Graf 2007).

2.6.2 Determining and Mapping Student Behaviours to FSLSM Learning Style Preferences

Considering that most of the learning style models proposed are for traditional learning rather than for online learning, Graf (2007) investigates the relationship between student behaviours and the questions of the FSLSM questionnaire in an online course.

Graf's (2007) study aims to (1) find out whether students with different responses for the questions of the FSLSM questionnaire behave differently in the online learning environment and (2) determine if correlations exists between student behaviours in TEL environments and their learning style preferences. These are discussed in the following paragraphs.

In the study a number of system features are used to address the different needs of learners. In order to present the content of the course, content objects are used in different formats including graphics and texts. The number of visits and the time spent on content objects are included as patterns for this system feature. In addition, patterns related to the number of visits and duration, for outlines of chapters (as outlines are explicitly indicated in FSLSM), are considered. Another pattern related to examples of the subject is involved and associated with the number of visits and duration. Furthermore, self-assessment tests are included for students to check their knowledge, and the following patterns are extracted from several dimensions of the completed tests: the number of answered questions, if a learner performed all available tests at least once, the test results, the frequency of revised answers, the time spent on the tests, the duration for checking test results and achieved results on each kind of question. Exercises that are provided for practising are attached with the number of visits and time spent on exercises included as patterns. In order to allow learners to communicate, discussion forums are added and the number of visits to the forum, time spent on the forum and the number of posted messages are recorded as patterns. Moreover, the navigation between learning objects, the number of logins to the system, frequency of skipping objects, number of visits and time spent on course overview page are considered as patterns. Patterns regarding the sequence that deals with learner visits to particular types of learning objects are also incorporated into this experimental study (Graf 2007).

The results demonstrate that students with preferences for different learning styles act differently in the online learning environment. It as also reported that students with different learning styles used different features of the system, such as examples, exercises, and navigated differently through the course and visited particular features in a different sequence. The author states that the results can be used as recommendations for providing adaptation based on learning styles in online learning and can also be used to argue that various features are needed to support a specific learning style (Graf 2007).

Graf (2007) finds several correspondences and disjunctures between student behaviours and their learning style preferences in agreement and some in disagreement with FSLSM regarding the relationship between student behaviours and their learning style preferences. The author reports that further investigations are needed for the correlations, which are not explicitly supported by and in disagreement with FSLSM. The author also notes that significant relationships exist between students who belong to different dimensions of

FSLSM and specific system features that they used with specific behaviours e.g. sequential learners preferred step-by-step navigation through the course. The author interprets the results in a way that each feature is needed to support a specific learning style preference and therefore plays an important role in adaptive learning.

2.6.3 Investigation on Methods for Calculating Learning Styles from Student Behaviours

In this section, Bayesian Networks, Rule-based modelling, Decision Trees and Hidden Markov Models, which are commonly used for deducing learning styles, are investigated. The studies identify the learning styles of learners by analysing their interaction with the online learning environment, in the form of behavioural patterns.

2.6.3.1 Bayesian Networks

A Bayesian network (BN) is a compact and directed graph model that represents uncertain relationships among variables in a domain (Jensen 1996). The random variables are represented by nodes and the correlation between the nodes are shown by directed arcs, which form a direct acyclic graph (Jensen 1996; García et al. 2007). A BN represents a probability distribution of the variables. Each node is associated with a conditional probability table (CPT) that specifies the quantitative probability of each possible state of the node given each possible combination of states of its parents. Probabilities are not conditioned on other nodes if there are nodes without parents. Learning in Bayesian networks can on one hand deal with the structure of the Bayesian network (structure learning) and on the other hand with the conditional probability distribution (parameter learning), which refers to the process of calculating the values of the CPT (Daly, Shen and Aitken 2011).

In order to demonstrate the effectiveness of Bayesian Networks, García et al. (2005 and 2007) carry out two experiments. They investigate student behaviours in a Web-based education system to detect the learning styles of the learners based on FSLSM. In total, 11 patterns are observed, relating to the active/reflective, sensing/intuitive and sequential/global dimensions of FSLSM. The visual/verbal dimension is discarded, as the authors do not include relevant system features for this dimension. Patterns related to chat, discussion forum and mail are considered for the active/reflective dimension. Exam revision time, exam delivery time, number of proposed exercises, number of changed exam answers, number of accessed examples and type of reading materials patterns are included for the sensing/intuitive dimension. Student exam results and their way of accessing information are incorporated as a pattern for the sequential/global dimension.

Bayesian Networks are used for representing and identifying learning styles of students. The nodes in a BN represent the different behaviours of students that determine a given learning style. The relationships between the learning styles and the relevant patterns are represented by the arcs, which connect the nodes. In the first experiment the proposed approach is evaluated with data collected from 10 students. The results of the FSLSM questionnaire are compared with the results from the proposed approach. In order to distinguish between them, for example, active, balanced and reflective learning style preferences, a 3-item scale is used and a precision formula that calculates the degree of similarity between the results is applied. As a result, a precision degree of 100% for the sequential/global dimension and a precision degree of 80% for the active/reflective and sensing/intuitive dimension are obtained (García et al. 2005).

In the second experiment, data based on the actions of 27 students are used for evaluating the BN approach. Results from the proposed approach and FSLSM questionnaire are compared to measure the degree of similarity. Precision degrees of 58% for the active/reflective, 77% for the sensing/intuitive and 63% for the sequential/global dimension are found. García et al. (2007) note that the low degree of precision obtained for the active/reflective dimension is due to the little use of communication tools by the students. When they conduct interviews with students they find two reasons for why they do not use communication tools: (1) the students do not like using such tools and (2) the tools are not promoted to the students as useful tools for communication. Based on these findings they state that promoting communication tools might provide better results for identifying student learning style preferences for the active/reflective dimension. Also, the findings show that student previous experiences in web-based courses have an impact on their navigation style: for example, inexperienced students demonstrated more sequential behaviours.

In general, García et al. (2007) conclude that the results obtained are promising and that the BN approach provides good results for the sensing/intuitive dimension. Although BN can support detecting students in the active/reflective and sequential/global dimensions, encouragement on using communication tools and the inexperience of the students are important factors.

Graf (2007) carry out a similar research study to García et al. (2007) and used BN to infer learning styles of students from their learning behaviours based on FSLSM. In Graf's study, FSLSM questionnaire results are compared with the detected learning style preferences in order to measure the effectiveness of the proposed approach.

Four dimensions of FSLSM are considered and in total 40 patterns are included. Actions on communication tools (e.g. use of the discussion forum), performances on self-assessment tests and exercises, and content visits are used as patterns relating to the active/reflective dimension. Patterns related to performance on quiz questions, visiting examples, number of conducted self-assessment tests and exercises are considered for the sensing/intuitive dimension. Performance on quiz questions which are related to graphics and texts, and discussion forum actions are included as patterns for the visual/verbal dimension. Finally, for sequential/global dimension activities related to course outlines, performances on quiz questions that deals with overviews of concepts or connections between concepts and details, and student navigational behaviours are used as patterns. In total, 127 students participated in this study, but data is only collected and evaluated from 75 students, due to the data requirements. A Bayesian network is created for each learning style dimension of FSLSM and five runs are conducted for each Bayesian network in order to achieve reliable results. The collected data are separated based on a 10-fold technique and for each run a different set of data is used.

Finally, the average results of five runs are accepted and moderated, and degrees of precision ranging from values between 62.5% and 68.75% are obtained for all dimensions, which are displayed in Figure 5: 62.50% for active/reflective, 65.00% for sensing/intuitive, 68.75% for visual/verbal and 66.25% for the sequential/global dimensions.

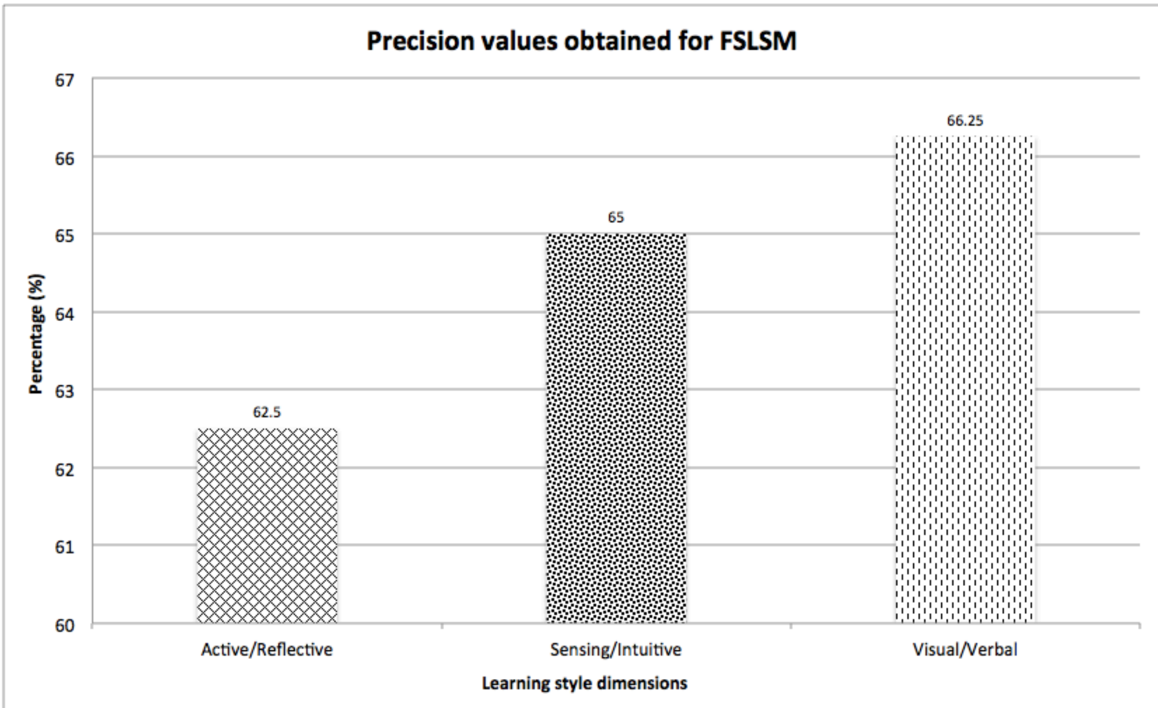

Figure 5: Precision values obtained for FSLSM in the study of Graf (2007)

Regarding the use of Bayesian networks for evaluating the results, García et al. (2007) achieve higher degrees of precision than Graf (2007). García et al. (2007) conducts only one run whereas the degrees of precision in Graf's study range from 56.25% to 87.5% when five runs are conducted.

2.6.3.2 Rule-based Modelling

A rule-based modelling method is based on if-then-else rule statements that are used to formulate the conditional statements to construct a complete knowledge base. Rule-based models can be fairly sophisticated through using if–then–else statements (Clariana and Strobel 2007).

In the literature it has been reported that students with a preference for a specific learning style behave in a particular way while learning. The results of a study carried out by Graf (2007) shows that students with different learning styles act differently in TEL environments. The idea behind this rule-based modelling method is that of observing the learning behaviours of students to collect clues about their potential learning style preferences. Then the method is applied in order to calculate learning styles from a number of matching clues. Graf (2007) claims that this method is similar to the method that is used for computing the learning styles in the FSLSM questionnaire, therefore it has the advantage of being applicable to this type of data. She also reports that the method might prove problematic for estimating the importance of the different clues that are particularly used for calculating the relevant learning styles.

In order to compare and find out which method is more effective, Graf (2007) also applies the rule-based modelling (literature-based) approach to evaluate the same set of data that she used for the Bayesian networks in order to infer learning styles. The author reports that the rule-based modelling approach yields better results than the Bayesian network approach. The results indicate a high degree of precision for all dimensions, ranging from 73.33% to 79.33%. The degrees of precision that are achieved for the active/reflective, sensing/intuitive, visual/verbal and, sequential/global dimensions were 79.33%, 77.33%, 76.67% and 73.33% respectively.

A study that aims to provide an individualised learning experience based on learning styles of learners is conducted by Popescu (2009). A Unified Learning Style Model (ULSM) that includes learner characteristics from various traditional learning styles models is used and adapted for e-learning. The number of patterns that are taken into account for all 6 dimensions was over 100. Regarding the patterns, the number of visits and durations are considered for all learning objects, tests, navigation buttons, course outline, chat, discussion forum and individual assignments. In total, 71 learner learning styles are determined using a rule-based modelling method and the following precision rates are obtained: 73.94% for the visual/verbal dimension, 82.39% for the abstract/concrete dimension, 78.17% for the serial/holistic dimension, 84.51% for the activeExperimentation/ reflectiveObservation dimension, 71.13% for the carefulDetails/ notCarefulDetails dimension and 64.08% for the individual/team dimension.

2.6.3.3 Decision Trees and Hidden Markov Models

A decision tree (DT) (Dunham 2002) is a decision support tool that uses a tree-like graph to classify data. It classifies data by posing a list of questions about the features associated with the data items. Nodes in a tree represent questions and once the first question has been asked, the choice of subsequent questions depends on the answer to the current question. The first question is asked at the root node. Based on the answer to a question, a particular node is selected and the appropriate branch is followed to further nodes. A terminal node with no branches is called a leaf. Data trees produce the rules of classification that can be used for pattern recognition (Foote 1994). Hidden Markov Models (HMM) (Rabiner 1989) are probabilistic models that are used to describe sequential data represented by a sequence of observations (Foote 1994). In order to diagnose student learning behaviours within TEL environments, DT and HMM approaches are generally used together. DT shows the actions of the students and HMM shows the sequence of the actions. Fok, Wong and Ip (2005) observe that the HMM approach serves as a formal framework for representing different learner models that can be used to predict learner aptitude and personalised learning activities within the system.

An adaptive learning environment based on FSLSM is developed by Cha et al. (2006) in order to investigate the use of DTs and HMM approaches to identify learning styles of students. Learning style preferences of students are diagnosed implicitly by analysing their behavioural patterns while using the interface of the learning system, using DTs and

HMMs. Four dimensions of the learning style model are considered by observing several patterns for each of them. DTs and HMMs are constructed for each learning style dimension. Behaviours and participation preferences on activities such as quiz, chat, discussions and interests in reviewing other learner and professionals' discussions are considered as patterns. Picture-driven and text-driven contents, number of clicks for additional material button and next/previous buttons as well as section hyperlinks to visit contents and overview buttons are also used as patterns. In addition, patterns dealing with the differences in the number of trials and the correctness of answers on quiz questions are included. In total, the behaviours of 70 students are observed and in order to build decision trees the data related to the number of button clicks, the durations of activities, the trial rate of the quiz, and so on, are used for the construction of the DTs. In such cases DTs can handle only click counters of each button: however, HMMs can be used to handle the sequence of clicks. As can be seen from Table 4.2, DTs provided better results for the visual/verbal dimension, with a 0% error rate, while HMM performed better in the sequential/global dimension, with an error rate of 14.28 (Cha et al. 2006). Graf (2007) attributed this to the fact that HMMs can consider sequences of the actions that are more relevant to sequential/global dimension. Moreover, an error rate of 22.22% for the active/reflective dimension and 33.33% for the sensing/intuitive dimension are achieved with both methods.

The findings from this study demonstrate that DTs and HMMs are both suitable approaches to identifying student learning styles from their behaviours. However, one approach is more suitable than the other depending on the dimension of the considered learning style model.

	Sequential/Global	**Visual/Verbal**	**Sensing/Intuitive**	**Active/Reflective**
DTs	28.57%	0.0%	22.22%	33.33%
HMMs	14.28%	14.28%	22.22%	33.33%

Table 3: **Error rates of DTs and HMMs (Cha et al. 2006)**

2.6.3.4 Evaluation of the Methods

In the four studies that were analysed in the previous section, various methods, ranging from Rule-based modelling to Bayesian networks, Decision trees and Hidden Markov models, used to implicitly identify learning styles of learners, are discussed. Table 4 and Figure 6 summarise the degrees of precision rates (showing how close the results obtained from the modelling method are to the results obtained from FSLSM questionnaire) of learner modelling methods based on FSLSM in following studies: Cha et al. (2006), García et al. (2007) and Graf (2007), and ULSM in Popescu (2009) (only dimensions that correspond to the FSLSM dimensions are included).

Modelling Method	Research Study	Active / Reflective	Sensing / Intuitive	Visual / Verbal	Sequential / Global
Decision Trees	Cha et al. (2006)	66.67%	77.78%	100%	71.43%
Hidden Markov Models	Cha et al. (2006)	66.67%	77.78%	85.72%	85.72%
Bayesian Networks	García et al. (2007)	58%	77 %	N/A	63%
Bayesian Networks	Graf (2007)	62.50%	65.00%	68.75%	66.25%
Rule-based Method	Graf (2007)	79.33%	77.33%	76.67%	73.33%
Rule-based Method	Popescu (2009)	64.08%	82.39%	73.94%	78.17%

Table 4: Precision rates of learner modelling methods in four different studies

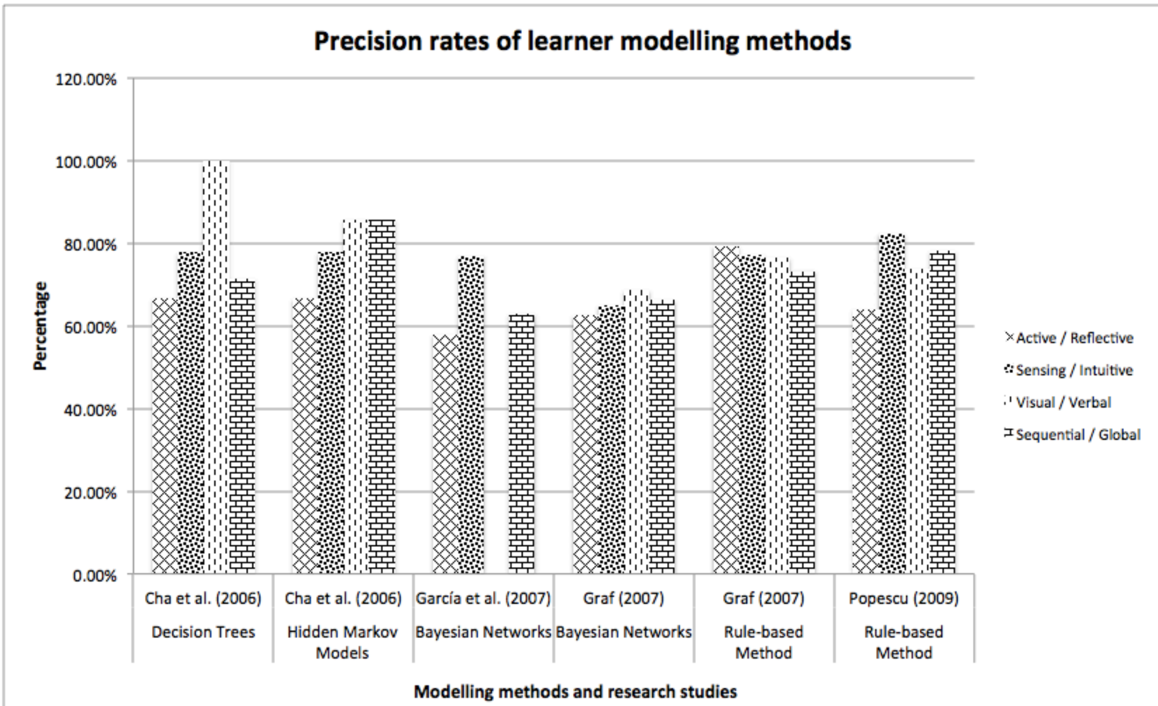

Figure 6: Precision rates of learner modelling methods in four different studies

It can be observed that the Rule-based modelling method yielded a high degree of precision for all dimensions of FSLSM in two studies: Graf (2007) and Popescu (2009).

2.6.4 Conclusion of the Section

The section investigated the use of FSLSM in TEL environments and how student behaviours can be mapped to their learning styles. The literature incorporates debates about whether learning style models that are developed for traditional classroom learning are suitable for online learning, in order to support students in this digital age. In addition, Coole (2008) states that new e-learning styles could emerge from the examination of student behavioural data.

The reviews included in this chapter demonstrate that learning style preferences of students based on FSLSM can be detected from their learning behaviours within an online learning environment. However, an analysis of the studies also highlights the importance of, and need for, different learning environment features to support each learning style. Therefore, it can be concluded that when students are provided with elements supporting their specific learning styles it is possible to detect their learning styles. This approach is in agreement with Felder and Silverman (1988) and Felder and Soloman (1997) as they claim that if the learning environment does not support learning styles of learners they might experience difficulties in learning. Therefore, they suggest providing an environment with many features supporting different learning styles.

Furthermore, different learner modelling methods are discussed regarding their ability to calculate learning styles. As a result of related studies, Rule-based modelling, Bayesian networks, Decision trees and Hidden Markov models are shown to be useful in computing learning styles from student behavioural data. In addition, study that was found to be most relevant to this study is Graf (2007), which is discussed extensively in this chapter.

Before proceeding with further literature review, it should be noted that after reviewing the literature covered so far the decision was taken to design an exploratory experiment, which is described later in chapter 3 and 4. However, after running this experiment it became apparent that an additional literature review is required in the area of metacognition: when students were given freedom to determine how to access and use a variety of online resources, they needed to manage their learning and monitor their progress as well as time. The literature refers to this as self-directed or self-regulated learning which is a form of metacognitive, guided learning. In this form of learning students can take more control over their learning and develop leadership of their own 'learning curve' (Flynn, Concannon and Bheachain 2005). Therefore, the next section aims to extend the literature review of this study by discussing the concept of metacognition and issues relevant to it.

2.7 Metacognition in TEL Environments

It has been reported that in most TEL environments students have the freedom to navigate through a wide range of resources, represented as text, graphics, animation, audio, and video, which are commonly presented in a non-linear way (Azevedo, Cromley and Seibert 2004; Mulwa et al. 2010). Therefore, learning in TEL environments requires students to regulate their learning by making decisions about what and how to learn, how much time to spend on the material, and determining whether the material has been understood or not (Azevedo, Cromley and Seibert 2004). TEL allows students to take more control over their learning: i.e. it provides a more heutagogic, as opposed to pedagogic/andragogic, model of learning and therefore works best for students who are motivated, self-directed, well organised and strategic. The current approaches used in TEL are less effective for those who require more support and direction for their learning (Cemal Nat et al. 2011b).

Zimmerman (2008) argues that TEL environments have the potential for improving learning, but they require skills such as goal setting, monitoring, controlling cognition and generating self-motivation. Moreover, the author argues that the improvement of technology based learning environments can assist students in using self-regulated learning strategies (Zimmerman 2008). Azevedo and colleagues (Azevedo, Cromley and Seibert 2004) also indicate that learning in a TEL environment requires self-regulatory skills to organise, navigate, and combine information into feasible mental models and that students experience particular difficulty in using metacognitive skills in TEL environments. They find it difficult to appropriately plan, set goals and reflect on their progress (Cemal Nat et al. 2011b).

An understanding of learning styles, such as being aware of one's own learning processes and exerting control over one's learning strategies, can be used to support or increase metacognitive awareness (Siadaty and Taghiyareh 2007). Students can use different learning styles to select different learning pathways, and access and process information that influences the content and development of the learning process (Ulieru et al. 2008; Cemal Nat et al. 2011b).

Although instructor design for learning and TEL environments can offer various options to promote student learning, students are required to take more responsibility for their learning due to the fact that recently, most TEL environments place students at the centre of the learning process. Therefore, as mentioned previously, students are required to regulate their learning by taking more responsibility for it. The engine that drives self-regulated or self-directed learning is metacognition. Shannon (2008) suggests that students use metacognitive skills to identify suitable learning strategies in appropriate learning situations.

The term metacognition is introduced by Flavell to describe people's own thinking processes and how they gain control over them. One can define the concept of metacognition as "knowledge and cognition about cognitive phenomena" (Flavell 1976:906). Metacognition denotes both a student's learning and an awareness of that learning, how the student controls their strategy selection and changes plans when needed. Students who are aware of their motives, responsibilities, and personal cognitive processes, and have control over their learning strategies, use metacognition (Phelps et al. 2002). Barak (2010) develops the definition of the concept further by adding that metacognition involves the use of strategies to control cognitive activities in order to meet a particular goal.

Vogel-Walcut and Fiore (2010) state that students with strong metacognitive skills can foresee problems that may arise during a learning experience, and they are able to better allocate their cognitive resources to learning to cope with such difficulties. Such students are better able to monitor their learning experience and develop perspectives with regard to more or less important pieces or areas of information, which they need to understand or investigate. Veenman (2012) also suggests that metacognitive skills help students to acquire an ability to steer and control their own learning, as well as develop problem-solving behaviours. Furthermore, according to Phelps et al. (2002:481) metacognitive awareness "empowers learners to become more independent in their approach to learning with, and about, computers in the future". Student metacognitive skills may provide distinct advantages in the context of rapid change, such as the ability to keep up-to-date in the field of Information Technology, where knowledge of using a particular piece of software is likely to become out-of-date in a short period of time (Cemal Nat et al. 2011b).

Several researchers, including Azevedo and Cromley (2004), confirm that students who do not have the ability to regulate their learning in a TEL environment learn little, and that the use of such environments for these types of students rarely provides them with a deep understanding of complicated subjects. Commonly, regulating cognitive systems, organisation of, and access to, different representations of information, and determination of an adequate instructional sequence, are seen as challenging for students (Azevedo and Cromley 2004).

Vogel-Walcut and Fiore (2010) also suggest that in order to facilitate student overall retention and use of knowledge, a major goal of education must be to assist students in monitoring their learning. They support the notion that metacognition is a particularly useful strategy for learning trajectories that require an awareness and regulation of one's cognitive processes. Promoting the development of metacognitive skills encourages students to reflect on their own cognition, which can lead to an improved engagement with learning materials. Encouraging students to develop metacognitive skills can assist them in transferring their skills to other learning or performance situations. Additionally, in the literature it is reported that despite the different characteristics of students, metacognitive support can improve learning regardless of differing learning styles (Cemal Nat et al. 2011b).

Kirsh (2005) discusses the concept of metacognition from a different perspective and argues that well-designed learning environments can facilitate metacognition. He suggests that good visual designs promote cognitively efficiency. For example, a poorly written paragraph requires more cognitive effort for comprehending it than a well-written one, which perhaps contains keywords or phrases that are italicized, and that presents a readily apparent topic that stands out from the rest of the text. A good visual design promotes good workflow, in terms of planning, monitoring and evaluating learning progress, as typically students have multiple tasks to perform. Visual cues structure the design of the interaction in a TEL environment and have the potential to make a significant difference in the effectiveness of metacognitive development. Kirsh (2005) also notes that the interface design of an environment needs to help students to manage the resources, and provide tools, support and advice. The success of a TEL environment "depends as much on the details of how tools, content and support are implemented and visually presented as on the simple fact of their presence" (Kirsh 2005:1). For example, discussion forums and chat rooms are not used if students do not notice them. Content are not visited if the links, which identify them, are not well marked. Students need to actually register the presence of the information at first, and subsequently progress to appreciating its importance (Cemal Nat et al. 2011b).

In order to increase student metacognitive awareness, Siadaty and Taghiyareh (2007) state that learning styles can be utilised as students can use them to take full advantage of learning strategies to process information. In addition Naznean (2009) believes when students know their own learning styles they can reflect on their learning styles and use appropriate strategies that are functional for their individual style to control their own learning conditions. However, Merrill (2002) claims that the majority of students are unaware of their learning styles: therefore, when they are left to their own devices, they are unlikely to start learning in new ways.

Among the debates about metacognition, Coffield et al. (2004) consider the research carried out by Entwistle (1990) and Vermunt (1992) valuable as they demonstrate that while the motivations, metacognitive and cognitive strengths, and weaknesses of learners are all key features of their learning style, these are also a function of the systems in which learners operate.

Self-regulated Learning

Self-regulated learning is a form of metacognitive guided learning whereby students set learning goals for themselves, monitor their progress, and regulate and control their cognition (Azevedo and Cromley 2004). Self-regulation is the ability to develop knowledge, skills and attitudes that can be transferred from one learning environment to another, as well as to a leisure and work environment (Boekaerts 1999). Students who are aware of their learning strengths and weaknesses are self-regulated students (Benmimoun and Trigano 2009). Self-regulated students can organise, manage and adapt their thoughts into skills that are required for learning (Shannon 2008). They continuously monitor their progress towards a goal or outcome and redirect efforts when necessary (Shannon 2008). Students need to be aware of their own thought processes and monitor the effectiveness of their learning strategies to develop the ability to self-regulate (Zimmerman 2008). Self-directed learning has been reported as one of the key life and career skills, which are necessary to prepare students for the workforce (Lai 2011). Furthermore, it is essential that students attain strategies such as identifying the main points in a given task, asking questions or dealing with a task from start to finish (Barak 2010), and be motivated to use developed or newly acquired self-regulatory strategies effectively (Matuga 2009). However, Carneiro, Lefrere and Steffens (2007) argue that this approach moves from what learners are required to do in order to be self-regulated to the development of a TEL environment that embodies the necessary features for supporting learners to carry out such actions.

Within TEL environments, student achievements are influenced by the level and effectiveness of applied self-regulation techniques, or the ability to plan, monitor and evaluate their own behaviour and learning strategies (Matuga 2009). A study by Azevedo, Cromley and Seibert (2004) investigated whether undergraduate students could regulate their own learning about the circulatory system using a hypermedia environment. The results demonstrate that students who regulate their learning by using effective strategies monitor their understanding, adapt their time and effort, and subsequently show a significant improvement in their learning. By contrast, those who used less-effective learning strategies limit their ability to manage their metacognitive monitoring activities and fail to show a significant improvement in their learning.

A study to measure student self-regulation is carried out by Zimmerman (2008) who employs learning diaries, which are collected at the end of each week, to structure a series of questions regarding events during a study session. Students are asked to complete a questionnaire that includes items about motivation and learning strategies at the outset and at the end of the study. The control group is asked to complete a pre-test and a post-test but does not receive self-regulatory training or use the diaries. Zimmerman (2008) reports that students who received self-regulatory training display significant improvements in the areas of intrinsic motivation, self-efficacy, effort, attention and self-motivation, whereas those in the control group show only increases in self-motivation (Cemal Nat et al. 2011b).

Azevedo and Cromley (2004) provide evidence to show that not all students have the ability to regulate and deploy certain key strategies during their learning. However, the presence of a tutor, who assist them in establishing goals and using effective strategies for regulating their learning, create a significant improvement in learning. Students who are given a list of goals to guide their learning are less effective at regulating their own learning (Cemal Nat et al. 2011b).

From a different point of view, Woolfolk and Margetts (2007) state that metacognitive skills vary between individuals and this may be because of biological differences (nature) or learning experiences (nurture). This approach opens another investigation area, which is called nature versus nurture in educational psychology, and the following paragraphs explain and discuss this paradigm. In this thesis, the term 'metacognitive skills' is defined as the ability of a student to take control of their own learning, self-assess themselves and reflect on the learning process.

Nature versus Nurture

The nature versus nurture debate in educational psychology questions whether individual differences in metacognitive abilities result from biological differences or through differences in individual learning experiences (Woolfolk and Margetts 2007). McInerney and McInerney (2006) claim that students develop metacognitive strategies as part of their usual learning and observation. In the literature it has been reported that student metacognition can be prompted to support their ability to monitor their own learning through instructional methods (Gunter, Estes and Schwab 2003). In this sense, metacognitive support can enhance effective learning and Wagster et al. (2007) points out that metacognitive skills training can help students to prepare for future learning. According to Azevedo (2005), supporting student metacognition and self-regulated learning within a learning environment can motivate students to learn from challenging tasks. It has been argued that concept maps and instructional maps can promote the use of metacognitive strategies and that they should be included into online learning designs (Hsiao 1997).

2.7.1 Conclusion of the Section

In this section, various concepts and philosophies of learning are studied, and the section discusses the impact of learning environments and learning needs on learning outcomes. It is shown that the success of this impact depends on the nature of learning environment design, and the levels of responsibility given to students.

It has become apparent that effective learning depends on two key elements: the design of a TEL environment and student skills. When students use metacognitive skills to manage their learning they can produce a better learning outcome. Metacognition has proven particularly beneficial for encouraging students to anticipate and reflect upon their own cognition when the development or use of metacognitive skills is promoted by a learning environment. However, it is also important to incorporate relevant metacognitive and support activities into TEL environments by considering student differences in skills and preferences. Furthermore, it has been noticed that learning styles can be utilised to support metacognition.

An examination of the existing literature has led to the development of a more specific focus for the present study: it has been decided that it is cost effective (in terms of time and effort) and more interesting, in terms of the consideration of the effects of metacognition in TEL environments, to investigate the impact of metacognitive skills applied by students on their learning performance. Therefore, a refined version of the research questions is presented in the next section.

2.8 Refining Research Questions

The results of the exploratory experiment, which are explained in section 4.1, have provided enough reason to investigate more on topics relating to designing a more robust experimental model, and how students time-manage and take responsibility for their own learning. In the first experiment, students are provided with learning activities based on their learning styles and allowed to use the TEL environment anytime, anywhere. However, the data collected from this experiment did not help in drawing meaningful conclusions as it became apparent that students utilised the TEL environment in various ways that did not necessarily match their learning styles and many of them did not complete the study. Therefore, additional literature review about metacognition was carried out to understand and describe learning behaviours of students. The concept of metacognition implies that students use metacognitive skills to manage their learning and the design of TEL environments can promote these skills. The new understanding of the impact of metacognition on student learning within TEL environments and results from the first experiment led to a revision of the research questions as follows:

Refined primary question

How do metacognitive skills demonstrated by students influence their learning performance within a formal technology enhanced learning (TEL) environment?

Refined subsidiary questions

- Do students recall information better when they use TEL environments based on their learning styles?
- Do students retain information better when they use TEL environments based on their learning styles?

In this thesis, 'metacognition' is defined as student awareness of their own ways of learning and the use of the TEL environment accordingly to achieve positive learning outcomes. The FSLSM, one of the most widely used models, to deal with learner modelling and provide adaptive learning, is chosen as an assessment method for determining students who behave according to their learning styles within the learning environment. Regarding the learning performance measurement recall (information retrieval from short term memory) and retention (information retrieval from long term memory) type of assessment, tests are provided at different times to students.

2.8.1 Refined Aims and Objectives of the Research

As a result of modifications to the original research question, the research procedure has now also been adapted, and is outlined below:

- The study designs a non-adaptive learning environment based on the chosen learning style model to meet learning needs of students. The TEL environment needs to incorporate the relevant learning activities by considering differences in learning styles.

- The study develops a non-adaptive TEL environment to support student learning by allowing them to use or develop metacognitive skills. Students must be able to use metacognitive skills to manage their learning, particularly when they are given freedom to determine how to access and use a variety of online resources.

- The study calculates student self-determined learning styles and identifies learning styles from their learning behaviours. While learning within the non-adaptive TEL environment students have freedom to use and navigate through the learning activities in order to find a way of learning that suits them best. Therefore, the tracking and recording student behaviours is required for identifying learning styles.

- As a results of the initial experiment, the decision was taken to use the non-adaptive TEL environment to allow students free choice of learning materials and permit an objective comparison of their learning achievements and performance. In order to compare student learning achievements and show the differences, in this study students are grouped as matched – those who use the system based on their learning styles, and mismatched – those who do not use the system based on their learning styles. Within the non-adaptive TEL environment learning styles of students was determined through the learning style questionnaire. Performance of students was then monitored to determine weather or not their selections were consistent with their learning style. From this, groups of students were identified as matched, and other groups as mismatched, and on the basis of their learning performance their use of metacognitive skills was assessed.

CHAPTER 3 Designing and Developing Technology Enhanced Learning Environments

Issues related to the process of designing, developing and implementing the TEL environments, required for data collection, are discussed in this chapter. Furthermore, the challenges involved in designing and developing the learning systems are explained. Documents about the user interface design are provided in the appendices.

Two different experiments are carried out at different times for this study (1) an exploratory experiment is conducted before refining the research questions and (2) the main experiment, is conducted after refining the research questions based on the exploratory experiment, which are explained in the next chapter. In order to answer the initial research questions, various student data (e.g. learning outcomes and behaviours) needed to be gathered from two differently designed learning environments. Therefore, two learning environments with two different designs were developed and used in the exploratory experiment to investigate whether adaptive TEL environments are more efficient than non-adaptive TEL environments in the context of assessing particular outcomes (i.e. recalling and retention). However, for the main experiment only a non-adaptive learning environment is improved and used.

The literature suggests that using learning styles is one of the most common methods for providing adaptation, thereby after reviewing the various learning style models, the use of FSLSM, reported as the most appropriate and feasible learning style theory with respect to design and development of TEL, is the most suitable step to take. In terms of implementing the TEL environments, LAMS is chosen as the best means of doing so as its capabilities facilitate the adaptation of various system features based on student learning styles identified with FSLSM.

This chapter aims to describe two different learning design approaches that are initially used for the exploratory experiment and only one of which (non-adaptive) is used for the main experiment. The learning design approaches for providing adaptive learning through a process of profiling students using FSLSM and free-use of the TEL environment are explained in the following sections of this chapter.

3.1 Design of TEL Environments

This section discusses the various arguments on how necessary learning activities are chosen to develop the learning environments and support students with different learning styles to provide adaptive learning.

3.1.1 Incorporated Learning Activities based on FSLSM

In this section selected course elements and system features are explained. The recommendation of each element is based on the FSLSM itself and the corresponding teaching styles of instructors in a classroom, together with the learning styles of students are suggested by Felder and Silverman (1988) and Felder and Soloman (1997). Also, specific aspects of the learning environment that are selected, and which are typically available in TEL environments, are based on suggestions from the literature. These include course contents, examples, subject overview, subject outline, self-assessment test, recall type assessment test, practical exercises and support activity tools. The course subject is divided into six sections and all required learning materials are included for each of them. There are numerous variables with regard to the make up of the learning environment, and each of these can be adjusted to suit student preferences. Furthermore, the chosen features have the potential to support students with different learning styles based on the selected learning style model. In addition, as stated in Table 5 below, each course aspect is chosen with respect to learning style dimensions in order to provide adaptation and acquire information about student learning styles from their behaviours within the TEL environment.

Learning Styles & Dimensions		**Corresponding Teaching Style in Classroom**		**TEL Environment**
Active	Processing	Active	Student Participation	Support Activity Tools (Chat, note-taking tool, etc.)
Reflective		Passive		
Sensing	Perception	Concrete	Content	Subject Examples
Intuitive		Abstract		
Visual	Receiving	Visual	Presentation	Content Presentation (Video, audio, picture, text)
Verbal		Verbal		
Sequential	Understanding	Sequential	Perspective	Learning pathway
Global		Global		

Table 5: Reflections of the FSLSM in classroom and the TEL environment.

3.1.1.1 Course Elements to Support Active/Reflective Type Students

Active learners are characterised by their ability to retain and understand information by discussing, applying or explaining the learned material to others. By contrast, reflective learners tend to think about the concepts quietly first and they like to work alone. Also, in order to retain the material more effectively they prefer to stop periodically in order to review and think about what they have read, and write short summaries of their reading.

To accommodate this second type of student support tools are provided which suit their particular approach to processing and acquiring information.

Chat tool and Discussion Forum: The chat tool and discussion forum allows for discussions to take place, and suits the active more than the reflective type of student. It is reported that active learners use these tools more often to ask about, discuss and themselves explain the studied materials to others. In contrast, reflective learners prefer to spend less time on such tools and, when they do, participate passively by repeatedly and carefully and reading the messages, but rarely responding to any conversations taking place.

Mind mapping tool: This tool is included to support the reflective type of student with information processing. It enables them to reflect on the information presented to them.

Note-taking tool: This tool allows learners to write notes and amend or revisit them at any time during their learning. Since reflective learners prefer to spend more time thinking about and reflecting on course contents, the note-taking tool would be useful for them in terms of writing summaries.

Subject Outline Page: This course element lists all the topics included in the learning session and also aims to support reflective type students by allowing them to reflect on the learning materials.

Practical Exercises: In order to allow active learners to try things out and improve their understanding of a topic, practical exercises are provided.

Self-assessment Test: A self-assessment test is provided to give reflective learners an opportunity to answer a set of questions to reflect on the course contents and check their acquired knowledge.

3.1.1.2 Course Elements to Support Sensing/Intuitive Type Students

Learners in this group are distinguished according to their perceptions of learning materials. Sensing learners prefer to learn facts and study concrete learning materials, whereas intuitive learners are more comfortable with abstract materials. Moreover, in order to learn from concrete materials, sensing learners prefer to solve problems with standard approaches, and dislike complicated problems. They also remember and understand information best if they see how it connects to the real world and they tend to be more practical. Intuitive learners like discovering possibilities and relationships. Moreover, learners in this category tend to be more innovative and like challenges more than do sensing learners. Imaginative and practical types of examples were used for each section of the subject being studied in order to facilitate student perceptions of learning materials in our system.

Practical-type Examples: These examples, which use real-life scenarios and include step-by-step instructions, are provided for students belonging to the sensing category in order to help them learn by appreciating the concrete application of the course material.

Imaginative-type Examples: Imaginative type of examples, which allow students to be creative and find their own way to solve the problem are added for intuitive learners to encourage their creativity and ability to discover possibilities.

3.1.1.3 Course Elements to Support Visual/Verbal Type Students

In this category learners are differentiated according to the way that they prefer to acquire information. While visual learners remember best what they see, such as pictures and videos, verbal learners learn better with written and spoken explanations.

Content Presentation Formats: Four different presentation types for course content are used to support visual and verbal type students in order to enhance their way of receiving information. Learning content, which is explained through video recordings and pictures, are created for visual students who are able to receive information easily from demonstrations and pictures, whereas audio and text-driven contents were added for verbal learners, as they are better at learning from spoken or written words.

3.1.1.4 Course Elements to Support Sequential/Global Type Students

Learners are characterised according to their understanding of information in this dimension. Sequential learners are described as learners who prefer to learn in a linear fashion and in order to find solutions they tend to follow logical and stepwise learning pathways. By contrast, global learners are defined as learners who tend to learn in large jumps and absorb learning materials randomly. Also, it has been reported that global learners can put pieces together only once they see the ‘big picture’. They are interested in overviews and find connections between different areas, whereas sequential learners are more interested in the details. Therefore the following system features were added for learners in this dimension.

Learning Pathways: In order to encourage an understanding of the subject, students are provided with a sequential pathway to follow, or with an opportunity to create their own learning pathway. For example, as sequential learners gain understanding by working through the learning activities step by step, with each step following logically from the previous one, they are provided with the opportunity to access learning activities in the presented order. In the TEL environment first section contents of the subject and then examples for each section are presented. Global learners are allowed to choose their own pathway as they can absorb materials in random order. They are also allowed to skip some learning activities and jump to other activities.

Subject Overview Page: This page aims to provide general information about the studied subject. In order to allow global learners to see the 'big picture', a subject overview page was included in to the system. The subject overview can also help global students to relate topics to each other.

3.1.1.5 Other Elements

Some other learning environment elements, which are described below are added into the systems in order to achieve the aims of this study.

Exercise Upload: A system feature that allows submission of the solutions for practical exercises.

Recall Type Assessment Test: In order to complete the learning session the students are asked to answer several multiple-choice questions about the studied subject for assessment purposes.

Student Opinion Survey: At the end, students are requested to evaluate and share their opinions about their experience during this study. Participation into this survey is optional.

3.1.2 Investigated Patterns of Behaviours on Course Elements

In order to detect learning styles of students, it is necessary to find out how they interact with specific learning activities. In this section the behaviour patterns that can provide clues about student learning styles are discussed.

The introduced patterns are selected because of their common usage in TEL environments, and because of their relevance to the learning styles dimensions. Patterns related to content, subject outline, subject overview, examples, self-assessment test, practical exercises, chat, discussion forum, mind mapping and the note-taking tool are determined based on suggestions from literature (Popescu 2009; Graf 2007; Cha et al. 2006). In addition to these, patterns that deal with the navigational behaviours of students are incorporated. Investigating a large number of patterns allows for a precise annotation and provides detailed information about the student behaviours, as stated in Popescu (2009). Therefore, in this study, patterns are determined according to the literature, according to their relevance for identifying learning styles, and for their ease of tracking, in order to make the proposed approach applicable to different learning environments.

With respect to content, subject overview and outline pages, and examples, the number of visits that students make to these kinds of information about the course, and the length of time that students spent viewing them, are used as patterns. Regarding the self-assessment test, the number of visits and the time spent on self-assessment is considered as a pattern. For the practical exercises, the number of visits is used as a pattern. Regarding the chat, discussion forum, mind mapping and note-taking tool patterns, the number of visits, the time students spent, and the number of postings are included. For the navigational behaviour, patterns dealing with how many learning activities students skipped, their random access of learning activities, and the number of visits made to the subject outline and overview pages, are all taken into consideration for the dimension of FSLSM that assesses how information is understood.

3.2 General Design of Learning Environments

This section aims to describe the generic design for adaptive and non-adaptive learning environments. Both learning environments are included exactly the same instructions, learning activities, and both tested the student's learning styles using the Felder and Silverman questionnaire. In order to avoid asking too many questions at once, and to enhance student participation, the FSLSM questions are presented in four stages. Also, after completing the questionnaire and before starting to study the subject, they are provided with a page explaining the goals of the session in both environments.

The first learning design aims to provide an adaptive learning environment based on a student's self- and pre-determined learning styles. The second design provides a free choice of learning activities that allow students to find what they believe is their best way to study the subject. A more detailed explanation about the design of these learning environments is provided in the next section.

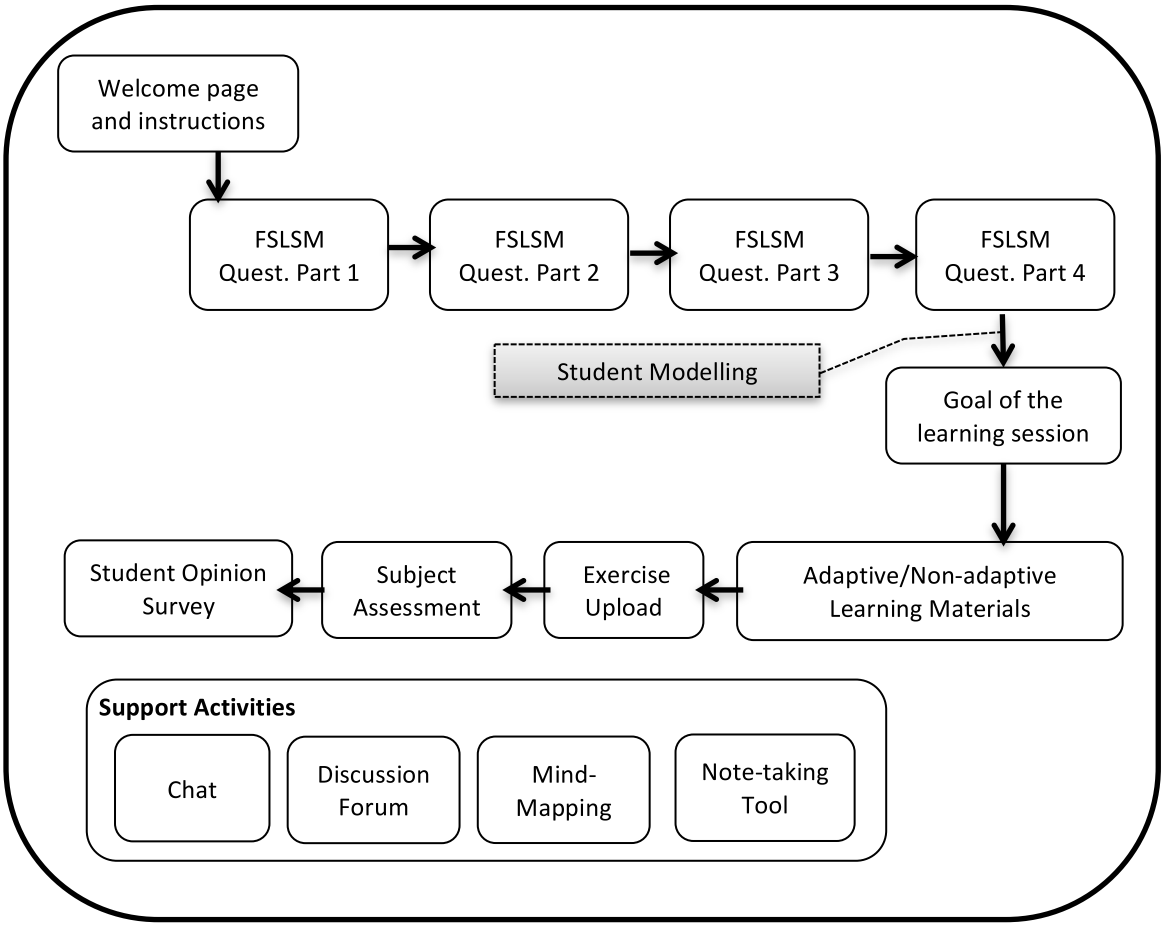

Figure 7: General Design of Learning Environments

3.3 Design of Adaptive Learning Environment

In this study, the adaptive TEL environment is designed based on FSLSM and as discussed earlier, this learning style model characterises students in four dimensions according to their preferred way of processing, perceiving, acquiring and understanding of information.

This design employs the intervention of the system to support students who have been assessed with particular learning styles. At the beginning of the learning 'journey' students are required to complete the FSLSM questionnaire to determine their learning styles before they could start. The student is then automatically presented with an appropriate adaptive learning environment containing the customised learning pathway, a set of learning activities and suggestions for the use of support activity tools according to the results of the questionnaire.

A customised learning pathway for each student is created to help the processing of the presented information. For example, as sequential learners gain understanding by working through the learning materials step by step, with each step followed logically by the previous one, they are provided with a sequential pathway. This design presents the learning content first and then the relevant example. After visiting two contents and relevant examples, the system suggests the use of appropriate support activity tools to reinforce understanding. However, global learners in the adaptive learning environment are allowed to choose their own pathway, as they are able to absorb information in random order. Additionally, in order to help them to see the 'big picture' they are given access to a general subject overview page. In such cases, students may visit the examples first and learning content later. Students that exhibited traits characterising both global and sequential types, thus constituting a balance of the two (balanced type students) are provided with all the features that global and sequential learners could get.

Four different presentation types for contents are used to support visual and verbal type students in order to enhance their way of receiving information. Students who can receive information easily from demonstrations and pictures are provided with learning content presented in picture and audio-visual formats, whereas verbal learners are provided with information contained in audio and text formats, as they are better at learning from spoken or written words. Visual learners could choose video content, picture-driven content, or both: verbal learners students could choose audio content, written content, or both. However, balanced (visual/verbal) type students are allowed to access all available formats of the section.

Two types of examples (i.e. imaginative and practical) for each section are used to support sensing and intuitive type learners. Students in the sensing category are provided with practical-type examples for helping them to find connections between the real world and learnt facts. In addition, supplementary practical examples are made available for these students, since they tend to learn from examples rather than listening to or reading course content. They enjoy solving practical problems. In contrast to sensing learners, imaginative-type examples are provided to intuitive learners to encourage their creativity and discover relationships between concepts. In this environment, sensing learners do not have access to imaginative-type examples and vice versa. In order to support balanced (both sensing and intuitive) type students in this dimension, both types of examples are made accessible to them.

Support activity tools presented to the student are based on the first dimension of FSLSM, which identifies active and reflective students. For example, active learners are encouraged to use chat and discussion forum tools that allow them to discuss the studied materials with their peers, and/or explain it them. In order to allow this type of students to try things out and help their understanding, practical exercises are made available. By contrast, reflective learners are encouraged to take time for thinking and use a note-taking tool for writing summaries. In addition, using a mind-mapping tool, to work alone or for reflecting on the information presented, is an activity that is also suggested to reflective learners. Moreover, self-assessment tests are provided to give them an opportunity to reflect on the materials and check their acquired knowledge. It is recommended to balanced-type students to use any support activity tool.

Towards the end of learning session, students are given a chance to upload and submit their solutions to any of the practical exercises. Afterwards, to complete their learning session they are asked to answer 18 multiple-choice questions about the studied subject for assessment purposes. The assessment test could be attempted only once.

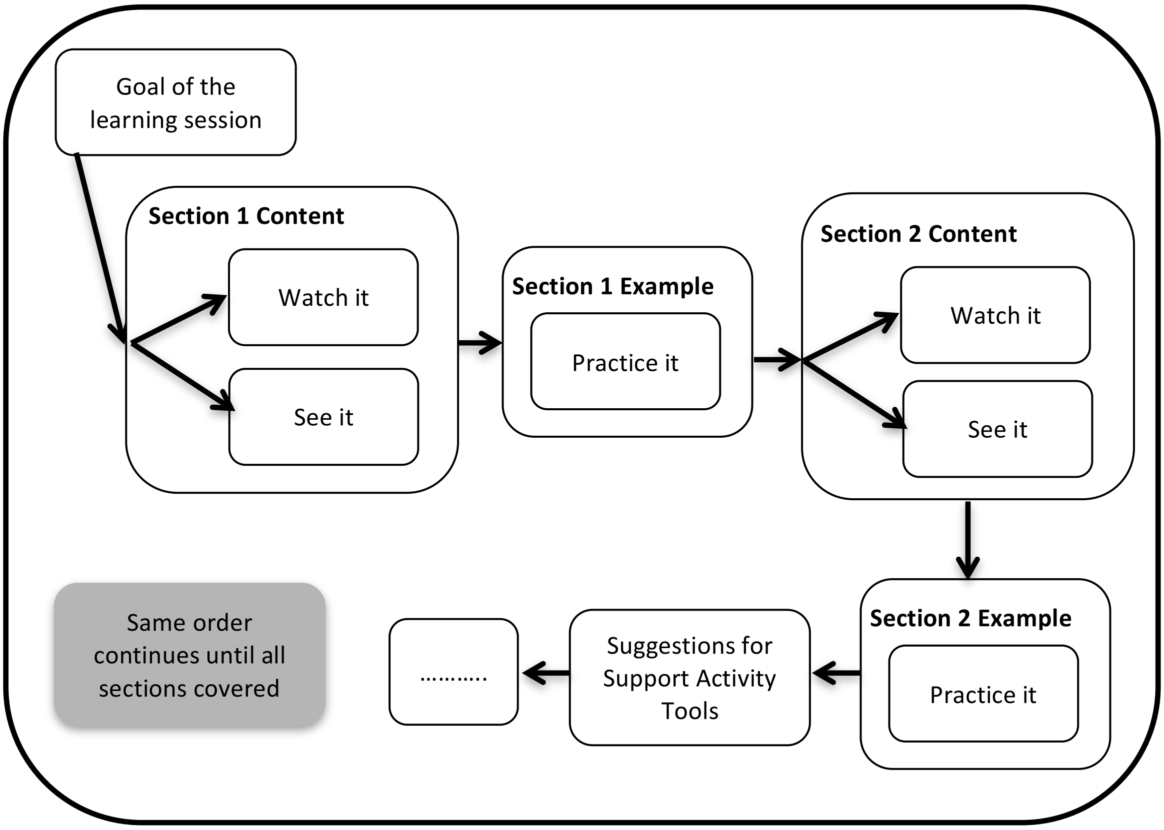

Figure 8: An example of adaptive learning environment user-interface design for Active/Sensing/Visual/Sequential type student

3.4 The Design of the Non-adaptive Learning Environment

The proposed learning design presents a model for supporting students with different learning styles based on FSLSM. The design aims to provide a learning environment in order to support student learning and collect clues about their individual learning styles from their learning behaviours.

In this design, although the TEL environment does not aim to provide any adaptation based on student learning styles, students are required to answer questions about their learning styles before accessing the learning materials and activities. The reason for providing the learning style questionnaire is to detect students who choose a learning method that matches their learning style after they complete their studies. Student learning behaviours are analysed and compared with the questionnaire results in order to find out which students use the system in accordance with their particular style of learning. This helps in answering the second research question.

Students are allowed to choose their own way of learning. Therefore, all learning materials including content and examples, and support activity tools are made freely available to all students. They are allowed to define their own pathway with regard to how they study the subject and are required to take the assessment test at the end.

All available content are presented to the students in four different formats: video, audio, text and pictures. At the same time, they are given access to all existing examples of a subject, which came in two types: practical and imaginative. Discussion forum, chat, note-taking and mind map tools are made freely available in order to enhance student learning. Additionally, students are allowed to access practical exercises. As all learning materials and support tools are available, students are expected to create their own pathways to work through the subject in their preferred way. They are allowed to revisit any material and activity as many times as they wish, however the system does not let them finish the learning session until they work through at least 50% of the learning materials.

As with the adaptive learning environment, at the end of learning session students are given a chance to upload their practical exercises solutions to get some feedback. Then, in order to complete the learning session they are asked to answer 18 multiple-choice questions for the assessment purposes. Students have only one chance to attempt the information recall test.

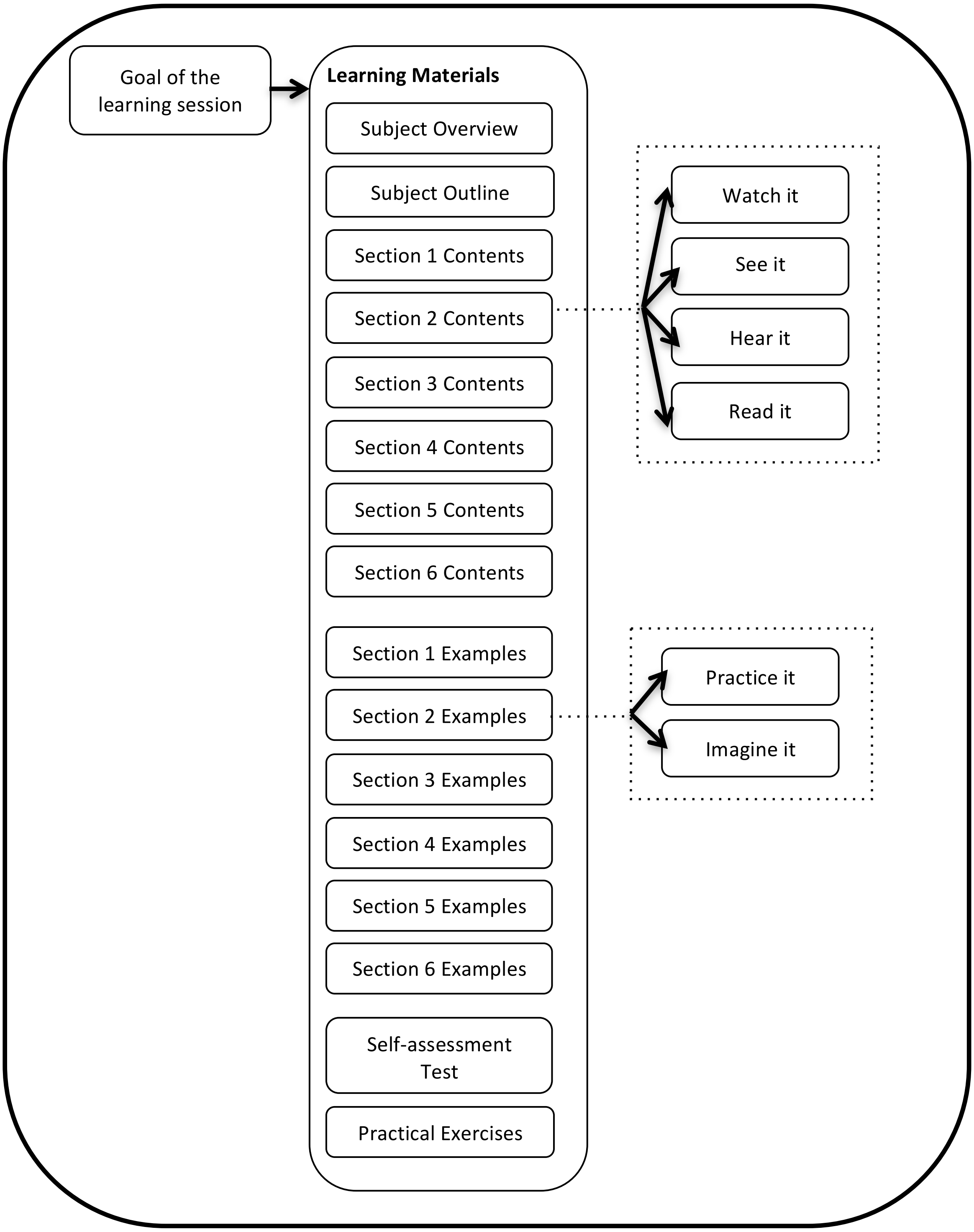

Figure 9: Non-adaptive learning environment user-interface design that each section content presented in four formats and each section example included two types, and students could freely choose to study any of them in any order

3.5 The Implementation of TEL Environments

This section provides an overview of the implementation of the learning systems. The systems are required to be developed based on the introduced learning design approaches and in such a way that student interaction with the environment can be tracked and stored in a database. Therefore, the TEL environments for this study are created with the Learning Activity Management System (LAMS), which is integrated into Moodle Course Management System (CMS). Moodle is selected for its user-friendly interface and LAMS is selected for its ability to provide adaptive learning, and to monitor and track students learning behaviours.

As stated in section 2.5, LAMS possesses all the features required for incorporating different learning activities to support student needs. For example, different content formats can easily be incorporated into the system. Also, LAMS includes necessary support tools such as chat and mind mapping.

Students do not need to self-register with the Moodle, as their accounts had already been created beforehand, in order to accelerate and facilitate their participation. Therefore, when they log in to Moodle they are asked to open up a LAMS lesson in order to enter the learning environment and start answering the FSLSM questionnaire. After completing the questionnaire the system automatically calculates learning styles of students and provides adaptation. The basic idea behind the implementation of the adaptive system is shown in Figure 8. However, the student modelling component is omitted in the non-adaptive learning system.

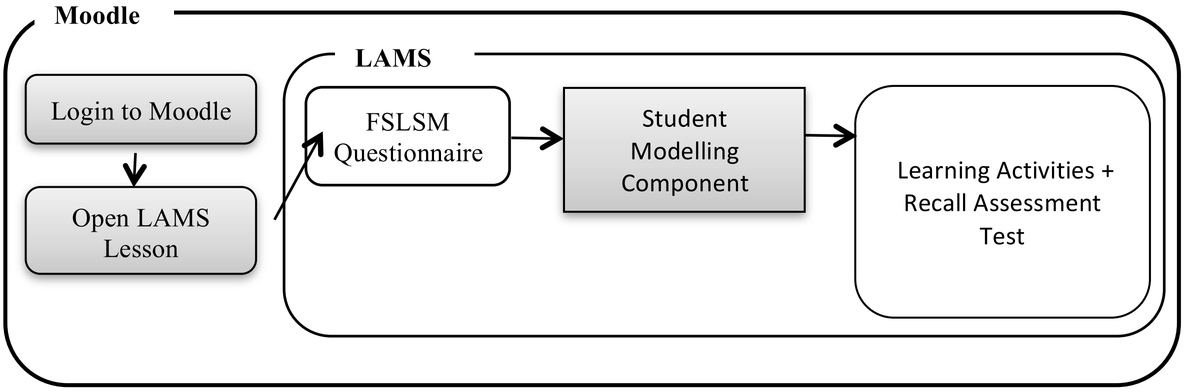

Figure 10: A high-level design of adaptive system

3.6 Conclusion of the Chapter

The design and development of TEL environments that is required to collect student data with the use of various course elements and activity tools are discussed in this chapter. As explained, two different learning environments are designed and implemented with LAMS, which is integrated into Moodle CMS.

In order to answer the research questions, learning styles of students need to be identified from their learning behaviours. Use of each course element provides clues about learning styles of students. As FSLSM is chosen as an assessment method, the elements of the TEL environment are determined based on this learning style model and suggestions from similar studies.

Furthermore, the design of the adaptive TEL environment (aims to adapt based on students learning styles) and the non-adaptive TEL environment (allows free selection of learning activities) are presented in detail in prior sections. These environments are developed in LAMS as it has the ability to provide adaptive learning and track students learning behaviours.

As mentioned earlier, two different experiments are carried out at different times for this study as follows: (1) an exploratory experiment which is conducted before refining the research questions and (2) the main experiment is conducted after refining the research questions based on the exploratory experiment and additional literature review. Therefore, the next chapter aims to describe the design of the experiments and the methodology of data collection with the use of learning environments.

CHAPTER 4 Experimental Design and Methodology of the Study

This chapter presents the methodology of the study, the process of data collection and the design of the experiments of this research study. Selection of the methodology is based on the data required to answer the research questions. The quantitative research method is chosen to eliminate bias issues. This method also provides an objective view so the research can be generalised to a larger population. As this research is based on student data, formal TEL environments are designed and developed in order to collect the required data. The environments are included necessary learning activities that consist of content, examples, assessment tests and support activity tools. The tracked and stored numerical data is used to draw conclusions for this study.

As indicated in the previous chapter, two different scientific experimental models are developed and run at two different times for this research. The following sections explain the design, results and issues related to the experiments. First the exploratory and then the main experiments are described.

In order to test our approach, an exploratory experiment is carried out. The exploratory experiment is designed based on information from the literature and the facilities that e-learning brings with the aid of Internet technologies. This experiment helped this study to test the proposed approach and showed how it can be used to address the research question (explained in section 4.1.1). Also, it allowed to produce a more robust model for the main experiment, thus the main experiment is designed in a different way to how the exploratory experiment is designed. The following sections aim to explain and discuss issues related to the exploratory experiment and the main experiment.

4.1 Exploratory Experiment

The aim of this experiment is to collect the required data to be able to test the proposed approach in answering the initial research questions. In this experiment students are provided with TEL environments to study a given subject, through which their learning behaviours and outcomes are monitored and stored. In order to collect the student data, undergraduate students from two different universities are participated in this experiment. The topic “How to Import Music and Sound in Flash Files, and Publishing a Flash Game”, part of a course entitled “Digital Media”, is taught to 64 level 1 students in the School of Computing and Mathematical Sciences at the University of Greenwich, as well as 43 undergraduate, level 1 students studying Computer Studies and Information Technologies at a university in Cyprus. The courses in both universities are consisted of lectures and a practical component.

The developed TEL environments are introduced and demonstrated to the students during a lecture hour. Also, during the demonstration students are verbally encouraged to use the systems by explaining the benefits of such systems to their learning and how they can help universities to improve. Afterwards, the system manual that is created to support and provide guidance to students is delivered to students via e-mail before they start using the systems, and it is also added to the system.

At the beginning of the experiment students are randomly divided into two groups and they are assigned to two different learning environments to study the same subject with the same learning activities. The difference is that one group worked in an adaptive learning environment and the other group in a non-adaptive learning environment. Students are given two weeks to complete the whole study, at times and in places of their own choosing.

Answering the initial research questions is based on the analysis of student data resulting from two differently designed e-learning systems. In order to be able to use student data to draw meaningful results, students in the adaptive learning environment are required to complete the FSLSM questionnaire at the beginning to help the system to adapt to their learning styles. They are also told to study the subject by following the steps set by the system and complete the recall assessment test at the end. In the non-adaptive learning environment students are also asked to complete the FSLSM questionnaire at the beginning, but the system do not provide any adaptation based on the questionnaire results. Then, students are required to study the subject in their own way by visiting at least 50% of learning materials and complete the recall assessment test to finish their studies.

Student actions on the systems are regularly monitored during the experiment and they are alerted when required (e.g. in case a student completed the learning styles questionnaire, studied the subject and did not take the assessment test). Finally, in total 46 students out of 107 from two different universities completed the experiment successfully by completing the FSLSM questionnaire, learning session and assessment test. 23 students studied the subject using the adaptive learning environment and 23 students used the non-adaptive learning environment.

4.1.1 Discussion of the Findings

In order to answer the initial research questions, (1) student assessment test results need to be obtained and compared between the two systems and, (2) the learning styles of students who used the non-adaptive learning environment are deduced from their learning behaviours and compared with their learning style questionnaire results to understand which group of students performed better on the assessment test.

While organising the data for the analysis the following issues arose, which showed that meaningful results could not be drawn from this experiment.

The issues that affect the answer of the "Is an adaptive learning environment a more effective means for learning compared to a non-adaptive learning environment?" question are:

Student participation

As taking part into this study was voluntary, a low participation rate was recorded. As mentioned above, the study was resulted in data relating to only 23 students for each e-learning system. This was insufficient to draw meaningful conclusions from this experiment once the students had been broken down into their different learning style groups etc.

Using other sources

Answering this research question was based on student assessment test results that aim to show how well students learned within the provided learning environments. However, when students were allowed to use the systems at anytime and anywhere it has been difficult to understand which sources students actually used to learn the subject. This can be considered as one of the disadvantages of running such experiments in uncontrolled environments.

The issues that affect the answer to the question of "Is a questionnaire-based approach an effective method for determining student learning styles to provide adaptive learning?" are as follows:

Recorded time durations on the system

In this experiment students were allowed to use the systems at their own pace. Therefore, some abnormal time durations (e.g. 300 minutes) were recorded for learning activities and the total system use that did not help calculating student learning styles as time spent on learning activities is considered to be one of the clues about student learning styles. There might have been different reasons for this such as opening the contents page and then visiting other web pages or leaving the computer for a cup of coffee or for meeting a friend. It has been apparent that in uncontrolled environments such factors may have a big impact on experiment results.

Use of support tools

Support tools such as discussion forums and note-taking tools were added to systems in order to support active/reflective type students. Therefore, the use of these tools by students was important for this experiment. However, the collected data showed that the students did not use these tools to a sufficient level to draw meaningful conclusions. Reasons for their lack of use could be that students did not know why and how to use them for learning or that they utilised different tools on the web. In light of this shortcoming it is now understood that providing instructions and documenting how such tools can promote student learning are necessary components of further test systems.

On the one hand, despite the reported issues, results from this experiment showed that student learning styles can be deduced from their learning behaviours while they are interacting with such a non-adaptive learning environment. When some sensible student data was used for the analysis in order to test if learning styles of students can be calculated, the results showed that it is possible to detect learning styles of students from their behaviours with this approach.

On the other hand, reflection on these issues has provided sufficient reason to carry out some more background research on student time management and how they take responsibility for their learning, which then led to a refining of the research questions.

After examining the relevant literature the concept of 'metacognition', namely student self-directed learning abilities, emerged as major theme (discussed in section 2.7).

As stated earlier, taking on board the concept of metacognition enabled the research to become more focused and it has been decided to refine and reduce the number of research questions due to time constraints. Therefore, only a non-adaptive learning environment is considered to be sufficient for answering the refined research questions. Also, the outcomes of the exploratory experiment showed that a more robust experimental model is required to draw meaningful conclusions from the experiment. Therefore, the main experiment is focused on a deliberately constrained set of learning materials within a restricted timescale to provide a scale of experiment that can be managed and controlled by a single researcher.

4.2 Main Experiment

This experiment is focused on testing the learning performance of students within a relatively homogeneous group, on the basis of a free selection of learning activities and comparison of that selection with the learning styles for each individual determined through a standard questionnaire model. In order to reflect on the issues related to the exploratory experiment and answer the refined research question (How do metacognitive skills demonstrated by students influence their learning performance within a formal technology enhanced learning environment?), using only the non-adaptive learning environment with the following changes in this experiment is considered to be sufficient to draw conclusions:

Student participation: In order to increase student participation, it has been decided to distribute book tokens as a prize to 10 students after conducting a draw between students who completed the study successfully.

Recorded time durations on the system: After agreeing with the course lecturer it has been decided to use one practical hour of the lecture to run the experiment in a controlled environment.

Using other sources: Students are observed in a controlled environment and are not allowed to use any other sources related to the subject during the experiment.

Support tools: Written instructions about how to use these tools for learning are prepared and provided for students. In addition, the mind mapping tool and discussion forum are excluded due to the time constraints of the experiment.

The experiment is redesigned and included three distinctive learning events as the duration of the experiment need to be changed as well: (1) an FSLSM questionnaire and pre-knowledge test questions, (2) the learning session and information recall test, and (3) an information retention test and a student opinion survey. For the evaluation of student learning performance, assessment tests are used where students need to answer a set of multiple-choice questions. Recall type assessment test is chosen to test student immediate understanding and retention type assessment test is chosen to test what students are actually retaining over time. Pre-knowledge test results are used to understand if student previous knowledge about the subject had any effect on their learning outcomes. Student opinion survey is provided to tell if there is any relationship between student learning outcomes and opinions.

Students do not need to register with the Moodle system for any of the learning events as their accounts had already been created. Therefore, when they log in to Moodle for the first learning event, they are asked to open a LAMS lesson that included a list of questions. Students are expected to select the answers that suit them best for the questions, which are required to determine their own learning styles. In addition to FSLSM questions, pre-knowledge questions about the subject that are going to be studied during the second learning event are included. This occurs a week before the learning takes place and allows students to become familiar with the system. Students are given the time period of a week to complete this event and their activities are monitored regularly and students are alerted about the issues as they arose.

After completing the first learning event, during a practical part of the course students are asked to login to the TEL environment and study a shorter subject than in the exploratory experiment called “Importing Sound into Flash Movies” which as part of the “Digital Media” course. They are provided with an environment where all available learning activities are presented independent of their learning styles. Students always have the opportunity to access and revisit all available learning activities. The subject is divided into six sections and all required learning activities are included for each of them. Content pages, which explain the relevant sections of the subject, examples for each section, practical exercises, a self-assessment test and support activity tools including note-taking and chat tool are also provided to students. Different to the first experiment, the mind mapping tool, the discussion forum and space for uploading practical exercises are all discarded. During this session, students were not allowed to talk to each other verbally in order to encourage them to use the chat tool for communication purposes. As stated earlier, student communication and collaboration behaviours that allow them to ask questions or explain the studied materials to other parties are important for the process of learning style identification. Similarly, a note-taking tool is presented to support students when they need to take notes or write summaries, instead of using paper and pen or word processing programs.

Two weeks after the second learning event, students were provided with the same assessment test about the subject in order to test how well they retained the learnt information during another practical hour of the lecture. The retention test was provided after two weeks as according to the literature, newly gained knowledge becomes stable in people's long-term memory after six days (Tulving and Craik 2000; Schacter 2009) and the second week after the second learning event was the most convenient time to assess students in a classroom environment. In addition, students also studied other course subjects in between two learning events, which cleared their working short-term memory. At the same time, students were also requested to share their opinions about this study and the design of the TEL environment at the end of this learning event.

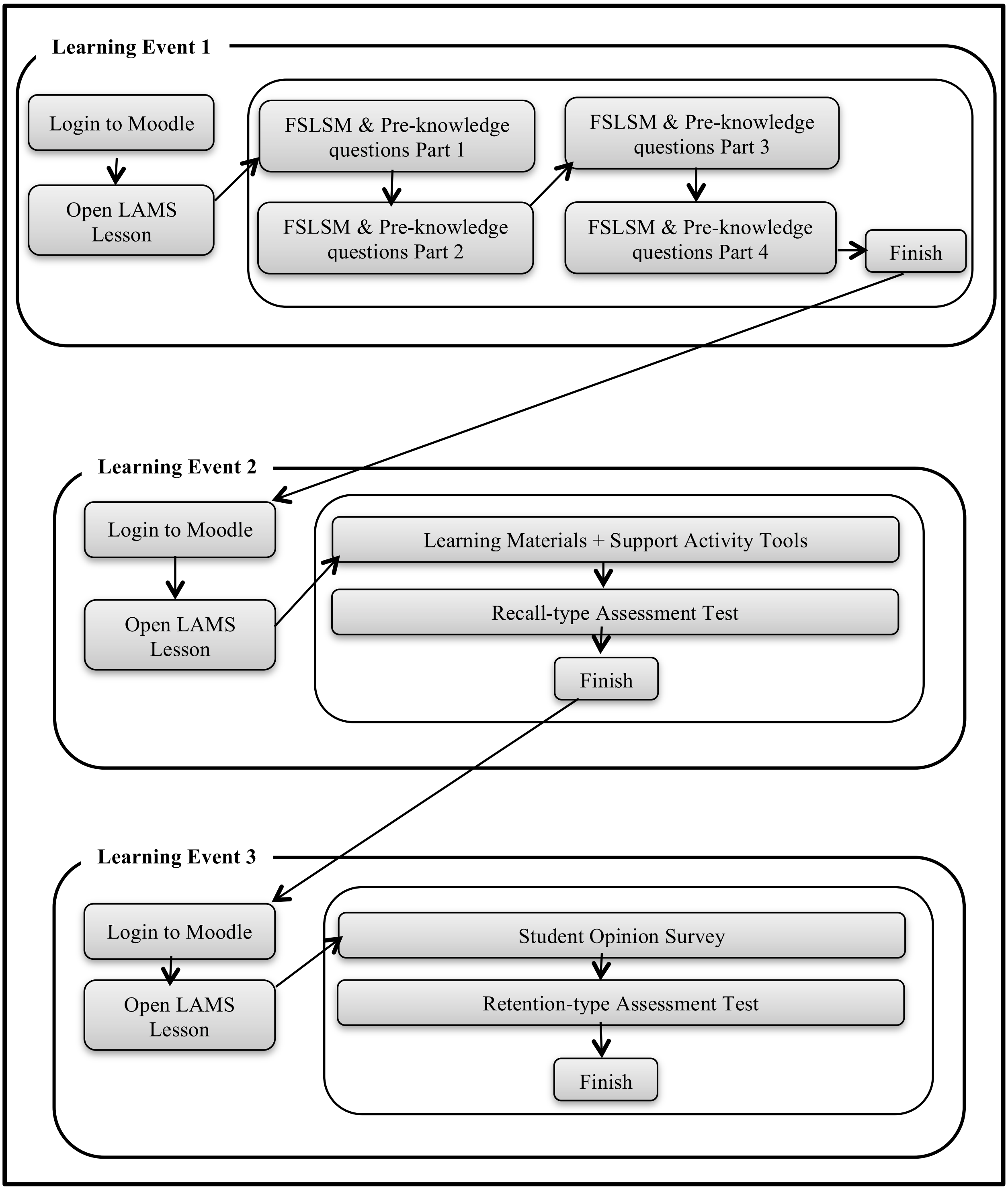

Figure 11: **Distinctive learning events of the main experiment**

In the first learning event, although the TEL environment does not aim to provide any adaptation based on student preferences, students were required to answer 44 questions about their learning styles and six questions about their pre-knowledge about the chosen course subject. In order to eliminate the external factors that may have an impact on student learning outcomes, students are asked to provide information about their pre-knowledge about the subject as their acquired knowledge during this study is important for drawing accurate conclusions.

In the second learning event, all learning activities, including section contents, examples and support activity tools are made freely available to all students. They are allowed to decide their own pathway for studying the subject, with the restrictions of (i) visiting at least 50% of learning materials, (ii) taking the recall type assessment test and (iii) answering ten multiple-choice questions without retaking the test.

In the third learning event, students are initially asked to answer the same set of questions, and are also required to take a recall test to check how well they retained the learnt information during the second learning event. Then they are given the option to evaluate and share their opinions of their experience during this study.

The “Digital Media” course is taught to 323 level 1 students in the School of Computing and Mathematical Sciences at the University of Greenwich in London and 57 undergraduate level 1 students studying Computer Studies and Information Technologies at a university in Cyprus. However, only 287 students from London and 50 students from Cyprus choose to participate in this study. At the end, data from 81 students in total (51 from London and 30 from Cyprus) are used for analysis to draw conclusions as only these students complete all three learning events successfully.

4.3 Method for Detecting Learning Styles

The applied method for detecting learning styles in this study is based on data extracted from student behaviours. Therefore, after the behaviour of students determined and relevant learning environment features added for collecting data about the behaviours, as a second process, the data gathered needed to be organised for the purpose of inferring learning styles. This is usually done by extracting the information about the necessary behavioural patterns from the database, determining the thresholds for data classification and categorising the relevant patterns for each learning style dimension.

In this study, a rule-based modelling method, which is explained and discussed in section 2.6.3.2, is used to calculate learning styles of students. According to the literature, students with a preference for a specific learning style behave in a specific way (Graf, Kinshuk and Liu 2008). Behaviours of students on various learning activities constitute an evidence of their learning styles and the rule-based modelling method can be applied to compute learning styles from the number of matching clues. This method is similar to the method used for calculating learning styles in an FSLSM questionnaire. Also, it can be applied for data collected from any course regardless its design and contents due to the fact that FSLSM is developed for learning in general (Graf, Kinshuk and Liu 2008).

The proposed modelling approach aims to detect learning styles on a 3-item scale (high, average, low) as the FSLSM suggests. Also, it distinguishes different learning styles between, identifying, for example, visual, balanced or verbal learning styles.

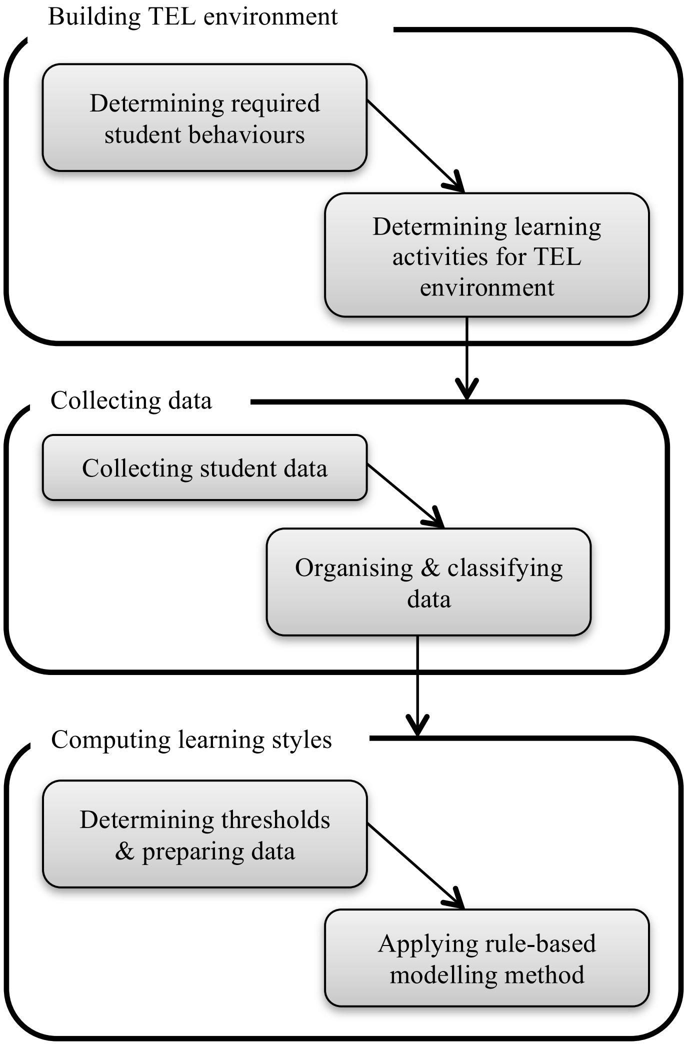

Figure 12: Process of learning styles detection

4.4 Determining Thresholds

The FSLSM categorises occurrences of behaviour for each dimension into three groups: high (strong preference for the respective learning style), average (well balanced between two learning styles) and low (strong negative preference for the respective learning style).

In this study, in order to map student behaviours to patterns, average thresholds that are derived from relative behaviours within the TEL environment are used rather than common thresholds reported in literature. Values of thresholds depend to a certain extent on the course structure and the subject taught. Using common thresholds has the advantage that the identified learning styles are not dependent on the behaviour of other students. However, as stated by Alberer et al. (2003) and Roblyer and Wiencke (2003), common thresholds can vary from course to course, depending on the structure of the course, the subject, and also on the experiences of the students.

Similar studies using common thresholds are designed in a different way (e.g. they include more learning activities as well as assignments), are conducted over a longer time period (e.g. over one term for a whole course), and involve a high number of students. In the following paragraphs, average thresholds for this study are presented and Table 6 summarizes the thresholds for each pattern in percentages, to make them more intelligible.

Features	Pattern	Explanation	Thresholds	
			Low	High
Contents	n_content	Percentage of total number of visited contents based on available contents	20%	29%
	t_content	Percentage of total time spent on contents based on total time spent in TEL environment	56%	73%
	n_video	Percentage of total number of visited video contents based on available video contents	33%	50%
	t_video	Percentage of total time spent on video contents based on total time spent on all video contents	55%	75%
	n_picture	Percentage of total number of visited picture-driven contents based on available picture-driven contents	50%	67%
	t_picture	Percentage of total time spent on picture-driven contents based on total time spent on all picture-driven contents	52%	77%
	n_audio	Percentage of total number of visited audio contents based on available audio contents	17%	33%
	t_audio	Percentage of total time spent on audio contents based on total time spent on all contents	6%	10%
	n_text	Percentage of total number of visited textual contents based on available textual contents	33%	50%
	t_text	Percentage of total time spent on textual contents based on total time spent on all contents	7%	13%
Outline & Overview	n_outline	The number of subject outline page visits	0	1
	t_outline	Total time spent on subject outline page based on total time spent on contents	1%	3%
	n_overview	The number of subject overview page visits	0	1
	t_overview	Total time spent on subject overview page based on total time spent on contents	1%	3%
Self-assessment & Exercise	n_self-assessment	The number of self-assessment test visit	0	1
	t_self-assessment	Total time spent on self-assessment test based on total time spent on contents	13%	22%
	n_excercise	The number of practical exercise visit	0	1
Support activities	n_chatMsg	Total number of chat messages sent	1	3
	t_chat	Total time spent on chat based on total time spent in TEL environment	26%	50%
	n_noteTaking	Total number of note-taking tool visits	0	1
	t_noteTaking	Total time spent on note-taking tool based on total time spent on contents	1%	2%
Navigation	n_skip	Total number of skipped sections	1	2
	n_jumps	Total number of jumps while accessing the learning activities	3	4
	v_overview_beginning	Visiting overview page at the beginning of the learning session	0	1
	v_outline_beginning	Visiting outline page at the beginning of the learning session	0	1

Table 6: Description and values for behavioural pattern thresholds (where prefix n stands for "number", t stands for "time" and v stands for "visit").

As stated earlier in this chapter, threshold values for patterns are determined by taking the average of all values of that specific student behaviour. However, in order to calculate low and high threshold values standard deviation formula is applied for each student behaviour (pattern) within the TEL environment. For example, when average time spent on video content is 267.70 seconds then low and high thresholds are set to 225.52 and 310.08 respectively with 95% confidence. It should be noted that the values of these thresholds depends to a certain extent on the course structure and the subject. The data extracted from system's database are in a quantitative form such as t_content = 225.52 seconds (total time spent on contents), however in order to make the values of thresholds more understandable they are converted to percentages such as t_content = 56% (total time spent on contents based on total time spent in TEL environment). After determining the boundaries of thresholds, the numerical value of the student behaviours is compared and categorised based on threshold values. For example, if a student sends five chat messages (where the low threshold is 1 and high is 3), that is the evidence of high occurrence of this specific behaviour for that student.

The thresholds for the total number of visits to different section contents is set to 20% and 29% of available contents, and the total time spent on contents is set to 56% and 73% of the total time spent within the TEL environment. Students who spend more than 73% of their study time on contents show a high behavioural occurrence and preference for the respective pattern. The total number of visits to different sections' video, picture-driven, audio and text-driven content's thresholds are set to 55% and 75%, 52% and 77%, 17% and 33%, and 33% and 50% respectively, versus available video, picture-driven, audio and text-driven contents in the system. The thresholds for total time spent on video and picture-driven content are accounted for 50% and 67%, 17% and 33% of the total time spent on video content and picture-driven content respectively. However, thresholds for audio and text-driven content are assumed 6% and 10%, and 7% and 13% of total time spent on all contents. It should be noted here that due to the low number of students (n) for audio and text-driven contents, thresholds are calculated based on the total time spent on all available content rather than total time spent on that specific type of content to display the value in percentage.

Subject outline and overview pages contain little information as the study is designed to include only one subject of the course, so students are not required to spend a long time on these learning activities. Therefore, thresholds for total time spent on learning activities are set to 1% and 3% of total time spent on contents. Similarly, 0 and 1 thresholds are set for the number of visits. If the student chooses to visit these objects it is assumed that they show a high preference on relative patterns.

The learning design is included with only one self-assessment test that helps students to reflect on all sections. Therefore, thresholds for visiting this object are set as 0 and 1 and it is assumed that students demonstrate a high preference on this pattern when they prefer to take the test. However, 13% and 22% thresholds are set for total time spent on self-assessment tests, based on total time spent on contents, as it is provided with the learning materials. Due to the fact that practical exercises were only available for download, only the number of visits is accepted as a pattern for this learning object. Therefore, student choice on this is assumed as evidence of high preference for this pattern and thresholds are set to 0 and 1.

Regarding the patterns related to support activity tools, the total number of chat messages sent, total time spent on, and total number of note-taking tool visits are taken into consideration. Due to the low number of visits, thresholds for the total number of note-taking tool visits are set to 0 and 1, while the total time spent on them are set to 1% and 2% of the total time spent on contents as students are expected to use it for note taking while studying the subject. Additionally, values of 1 and 3 thresholds are set for the total number of chat messages sent. 26% and 50% thresholds are set for time spent on the chat tool based, on the total amount of time spent within the TEL environment.

Four different patterns are considered regarding the navigation behaviours of students. Thresholds for visiting the subject overview and outline pages at the beginning of the learning session are set to 0 and 1: more specifically, “yes” is the outcome if they visited these pages, and “no” is the outcome if they did not. Threshold values of 1 and 2 are set for total number of skipped sections as it constitutes important evidence of global learner understanding of the subject. For the total number of jumps while accessing the learning activities 3 and 4, thresholds are assumed by averaging the student behaviours.

4.5 Associating Relevant Patterns to Learning Style Preferences

This section describes the relevant behavioural patterns with their required high or low occurrences for each learning style dimension. In addition, behavioural patterns that are involved in similar studies are discussed in this section. Information about the relevant behavioural patterns and their high or low occurrences are both extracted from literature for this study.

A study (Cha et al. 2006) for learning styles diagnosis based on user interface behaviours for the customisation of learning interfaces is devised based on the learning style model developed by Felder and Silverman. The four dimensions of the learning style model are utilised to reflect on user interfaces while learners are interacting with the system. Behaviours and participation preferences for activities such as quizzes, chats and discussions are considered as patterns for active learners, whereas interests in reviewing other learner and professionals' discussions are considered as patterns for reflective learners. Picture-driven and text-driven contents are targeted at the visual and verbal learners and their preference for content types are used as patterns for this dimension. By considering the sensing learner 'attentiveness to details' characteristic an additional material button for detailed examples is added. Also, the differences in the number of trials and the correctness of the user interface of the quiz section are considered as patterns for sensing and intuitive learners. Section hyperlinks to visit contents, and overview buttons to look through the overview of contents, are added for global learners, and their related behaviours are tracked. On the other hand, next/previous buttons are provided for sequential learners in this experimental study (Cha et al. 2006).

Another similar study is carried out by García et al. (2007). The study is considered only three dimensions of FSLSM, namely perception (sensing/intuitive), processing (active/reflective) and understanding (sequential/global). In order to determine the perception of a student they consider student behaviours while they are taking the exams, the amount of time taken to complete the exam, and the number of visited examples and exercises. To detect whether a student's learning style is active or reflective, they analyse student performances on discussion forums, chats and e-mail systems. Ultimately, they analyse the patterns related to accessing information such as the number of jumps through the course materials to identify student ways of understanding. The thresholds are determined by averaging student behaviours (García et al. 2007).

Research introduced by Graf (2007) considering four dimensions of FSLSM includes similar behavioural patterns for each dimension. Behaviours related to contents, self-assessment tests and discussion forums are used as patterns for the active/reflective dimension. In order to detect whether learning styles of students are sensing or intuitive, actions related to contents, examples and test questions are considered as patterns. Dissimilar to previously discussed studies, Graf (2007) include discussion forum performances and results of graphical and text content related questions as patterns for the visual/verbal dimension. To determine sequential and global learning styles, results of some test questions and student navigational behaviours are accepted as patterns. In this study general thresholds from the literature are used to classify student behaviours.

In another study Popescu (2009) uses a combination of dimensions including visual/ verbal, abstract/ concrete, serial/ holistic, activeExperimentation/ reflectiveObservation, carefulDetails/ notCarefulDetails and individual/team in order to create a model for identifying student learning styles by analysing their behaviours while interacting with the educational system. Patterns for the visual/verbal dimension involve preferred media types for learning contents and time spent on them, as well as performances on chat and discussion forums. Whether a student holds a preference for abstract or a concrete concept, and the amount of time spent on it, are patterns used for the abstract/concrete dimension. Navigational behaviours with previous and next buttons through learning objects are considered as a pattern for the serial/holistic dimension. The activeExperimentation/ reflectiveObservation dimension's patterns include behaviours related to exercises. Preferences about additional information and test performances are chosen as patterns for the carefulDetails/notCarefulDetails dimension. Similar to related studies, actions on chat and discussion forums are used as patterns for individual/team dimension. Thresholds for this study are based on general recommendations from the literature (Popescu 2009).

As discussed in previous paragraphs, behavioural patterns and their classifications based on the occurrences differ with respect to the design of a study. However, it is noticeable that most of the included patterns and the method of threshold determination in the analysed studies are very similar to each other.

As stated earlier, in order to calculate learning styles of students, relevant behavioural patterns need to be determined as well as how often the behaviour occurs. Relevant behavioural patterns of this study for each learning style dimension of FSLSM are summarised in Table 7. High and low occurrences of the respective pattern are represented from the viewpoint of the active, visual and sequential learning style preferences.

The number of patterns of behaviours that are taken into account in similar studies varies: 11 patterns are used in García et al. (2007), 40 in Graf (2007), 58 in Cha et al. (2006) and over 100 are used in Popescu (2009). It is suggested that the higher number of patterns used lead to a greater degree of accuracy in the learning style diagnosis (Popescu 2009).

	Active/Reflective	Visual/Verbal	Sequential/Global
High occurrence	1. Number of practical exercises visits 2. Time spent on chat 3. Number of chat messages / Number of chat tool visit	1. Number of video content visits 2. Time spent on video contents 3. Number of picture-driven content visits 4. Time spent on picture-driven contents	1. Visiting outline page at the beginning 2. Visiting overview page at the beginning
Low Occurrence	1. Number of note-taking tool visits 2. Time spent on note-taking tool 3. Number of visited content objects 4. Spent in general more time on content objects 5. Number of outline page visits 6. Time spent on outline page 7. Number of self-assessment test visits 8. Time spent on self-assessment test	1. Number of audio content visits 2. Time spent on audio contents 3. Number of text-driven content visits 4. Time spent on text-driven contents	1. Time spent on overview page 2. Number of overview page visits 3. Number of skipped learning activities 4. Number of jumps while visiting the learning activities

Table 7: Relevant behavioural patterns for each learning style dimension of FSLSM. The high and low occurrences of the respective patterns are from the viewpoint of the active, visual and sequential learning style preferences.

In this study, the active/reflective dimension has the highest number of patterns, so it provides more detailed information about the relative learning style for each student. Recommended patterns for sensing/intuitive dimension are not listed as this dimension is discarded due to the insufficiency of data. Student interactions with the section examples are considered as patterns that can provide clues about student learning styles related to this dimension, however it is observed that most of the students did not prefer to visit the examples. Therefore, detection of learning styles for this dimension is not possible. In comparison to other investigated studies, visiting the subject overview and outline pages at the beginning of the study is considered as a pattern for sequential learners rather than global learners. When student data is analysed it came into consideration that students who followed the sequential pathway to visit learning activities preferred to visit the overview and outline pages first, due to the fact that in the proposed learning design these pages are located at the beginning of learning activities.

4.6 Computing the Learning Style Preferences

The behavioural patterns related to each FSLSM dimension that is utilised to detect learning styles of students are explained in the previous section. The next step, once the patterns are determined, is to organise the collected data to use as input for the rule-based modelling method. This section explains the process of computing the learning styles of students with the selected modelling method.

The data extracted from the database of the TEL environment is mapped onto a 4-item scale for each pattern. A matrix is created for the data by placing students in rows and patterns in columns. Values from 0 to 3 are assigned to categorise the behaviour of each student for each pattern. Values between 1 and 3 indicate the occurrence of a specific behaviour based on the proposed patterns and the mapping of these values is based on the determined thresholds. 1 represents a low occurrence, 2 an average occurrence and 3 a high occurrence. The fourth scale is 0, and indicates that there is no information available on the pattern in question. For example, if a student does not undertake the self-assessment test, no information about the student's performance in this area is available.

However, the absence of data does not necessarily imply a value of 0 as it depends on the pattern in question. In the case of counting the number of visits to a specific learning object, a lack of data about this pattern means that a student do not wish to visit the learning object. For example, visual learners may prefer to avoid textual content, as expected, which in the process generates no data regarding this particular pattern, thus implying that the number of visits is 0. Therefore, one can also describe this as a low occurrence and hence give it a value of 1 in the matrix. Conversely, if the pattern is about the performance of a specific learning object (e.g. the self-assessment test) no available data about it indicates that no conclusion can be drawn regarding this pattern, and subsequently a value of 0 is assigned in the matrix.

A matrix is built for each FSLSM dimension (Pdim) by including students in rows and all relevant patterns in columns for the dimensions (dim). Consequently, three matrices (Pa/r, Pv/b, Pq/g) are used as input data for calculation of learning styles.

4.6.1 Applying a Rule-based modelling method

This section describes a rule-based modelling method, which is used to infer learning styles based on the idea that each pattern (behaviours of students) for the relevant learning style dimension provides clues about student learning styles. This method is used in similar studies such as Popescu's study (2009) and Graf's research (2008). The following formulas ($ls_{dim} \wedge nls_{dim}$) are used to calculate learning styles for each student.

Formula 1: $ls_{\text{dim}} = \frac{\sum_{i=1}^{p_{dim}} h_{dim,i}}{p_{dim}}$

Formula 2 (Normalised form): $nls_{\text{dim}} = \frac{ls_{dim}-1}{2}$

In the first formula, the total number of matching clues can be calculated with the information about a high, average and low occurrence of the respective student's behaviours, which supports a specific learning style. h_{dim} represents clues gathered for each dimension (i). As stated in formula 1, by summing up all clues of a relevant learning style and dividing them by the total number of patterns that contain information provides a measure for the respective learning style. Then, the Formula 1 is normalised on a range from 0 to 1. 0 represents a strong negative preference and 1 represents a strong preference for the respective learning style. However, conclusions cannot be drawn if patterns do not include any information.

The method aims at detecting learning styles on a 3-item scale, distinguishing, for example, between an active, balanced and reflective learning style. Therefore, the measure nls_{dim} is divided into three groups using values 0.25 and 0.75 as thresholds. These thresholds are based on the literature (Graf 2008), showing that using the first and last quarter to indicate learning style preferences for one or the other extreme of the respective dimension, and using the second and third quarter for indicating balanced learning styles yields better results that dividing the range into 3 equal parts.

4.6.2 Evaluation of the Method

The following precision method proposed by García et al. (2007) is used to compare and show how close the results obtained are using the rule-based modelling method, to the results obtained from the FSLSM questionnaire. The formula is based on the similarity between the obtained results from the rule-based modelling method and the questionnaire results. In order to make the results comparable, three values are considered for each dimension: strong/medium preference, balanced preference and strong/medium negative preference. For example, for the first dimension the values, active (A), balanced (A/R) and reflective (R) are considered.

Precision formula shows the degree of similarity (as a percentage value) between the results obtained from the rule-based method and learning styles questionnaire:

$$\text{Precision} = \frac{\sum_{i=1}^{n} Sim\left(LS_{ruleBased}, LS_{quest}\right)}{n} \, .100$$

Where

$$Sim(LS_{ruleBased}, LS_{quest}) = \begin{cases} 1 \quad if\ LS_{detected} = LS_{quest} \\ 0.5 \quad if\ LS_{ruleBased} \neq LS_{quest}\ and\ \left(LS_{ruleBased} = Balanced\ or\ LS_{quest} = Balanced\right) \\ 0 \quad if\ LS_{ruleBased}\ and\ LS_{quest}\ are\ opposite \end{cases}$$

In the proposed formula, $LS_{ruleBased}$ refers to the learning styles detected by the rule-based modelling method. LS_{quest} represents the learning styles from the FSLSM questionnaire and n is the number of students. The function compares $LS_{ruleBased}$ and LS_{quest} parameters, and returns 1 if they are equal, 0 if they are opposite, and 0.5 if one represents a balanced learning style and the other represents a preference for one of the two poles of the dimension.

Using the formula above a precision rate of 74.51% in the active/reflective dimension, and 75.49% both in the visual/verbal dimension and the sequential/global dimension are obtained.

Active/Reflective	Visual/Verbal	Sequential/Global
74.51%	75.49%	75.49 %

Table 8: Similarities between the rule-base modelling method results and the FSLSM questionnaire results

It can be observed that the proposed rule-based modelling method is yielded good results with a high number of similarities. As a result a precision rate of 74.51% for the active/reflective dimension, and 75.49% for both the visual/verbal and sequential/global dimensions are obtained, which shows how similar the learning styles are, when detected by the questionnaire and rule-based method.

However, compared to results obtained by Cha et al. (2006), García et al. (2007) and Graf (2007) (see Table 5 in Chapter 2), higher results are achieved on active/reflective and sequential/global dimensions.

4.7 Conclusion of the Chapter

This chapter discusses the design of the experiments, which are used to collect data for this study. The exploratory experiment and its results, that are created a basis for the main experiment, are described in detail. Issues related to the main experiment and data collection process are presented. Then the process of determining thresholds and associating student behaviours to their learning styles are explained. Application of the rule-based method to infer the learning styles from data about student behaviours are described and results are reported in this chapter.

Existing research informs the design of the learning environment and the selection of the learning activities. The required learning activities are based on suggestions from similar studies as well as that of Felder and Soloman (1997). The patterns of behaviours that are taken into account for each learning style dimension in this study are also derived from the literature and only the dimension related to student perception is excluded due to insufficient student data.

Time/duration data is one of the key data types for detecting student learning styles: therefore, the second learning event of the main experiment is carried out in a controlled environment. Students used the system and completed their studies during the practical hour of the course. Thus, the time spent within the TEL environment can be considered as reliable data. Also, as student behaviours regarding communication and collaboration tools are important, it can be argued that controlled environments can provide more reliable data due to the fact that student physical interactions can be controlled in such environments.

In this thesis, 'collaborative learning' is defined as a situation in which two or more students interact by asking questions, explain the learned information or share ideas during their learning process. However, 'cooperative learning' is defined as a situation in which a group of students work together to achieve an agreed-upon goal and each group member's success is dependent on the group's success. Collaborative learning is of greater interest than cooperative learning in this study.

In this chapter, the process of data collection and calculation of learning styles of students from their behaviours are explained and results are presented. Therefore, the next chapter aims to demonstrate statistical data analyses that are applied to compare the learning achievements and show the differences between student groups.

CHAPTER 5 Analysis of Data and Discussion of the Results

As described in the previous chapter, learning styles of students are calculated and identified from their behaviours within the TEL environment. In this research study, self-determined learning styles and identified learning styles of students are compared in order to show if there is any difference between students whose behaviours match with their learning styles and students whose behaviours do not match with their learning styles. This comparison specifically refers to learning outcomes for the recall and retention type assessment tests. Comparison of learning styles, and learning achievements of matched and mismatched groups are presented, and findings from statistical data analysis are discussed in this chapter.

5.1 Introduction

This is a two-part data analysis to compare and show differences over matched and mismatched groups regarding their learning achievements. In the first part, several types of data analyses are carried out in order to compare the recall and retention test results of the two groups:

- Students who received a pass mark on the *recall test* (>=50% of the total score) are grouped as matched and mismatched for each dimension of FSLSM, and their achievements on recall and retention tests are compared.

- Students who received a pass mark on the *retention test* (>=50% of the total score) are grouped as matched and mismatched for each dimension of FSLSM, and their achievements on recall and retention tests are compared.

The second part of the analysis includes statistical data analysis to determine if any correlation exists between student learning outcomes and their pre-knowledge, as well correlations between learning outcomes and social-structural factors including gender, age, pre-university qualifications and nationality. In addition, results of the student opinion survey are discussed in relation to student achievements.

5.2 Statistical Data Analysis

In total 81 students are successfully completed the three learning events in this study from two different universities. However, only data from students who received a pass mark from recall and retention tests are included into statistical data analysis as only these groups demonstrate significant differences in the results of analysis. Finally, the data of 55 students who received pass mark from the recall test, as well as the data of 49 students who received a pass mark on the retention test, are used.

The aim of the analysis is to show the differences between the matched and mismatched groups for each dimension of FSLSM regarding their assessment test results, when the students are allowed to freely access all learning activities. Therefore, the student performance and behaviour within the TEL environment are investigated. Since the focus of the analysis is on the effect of learning, the pass mark is set at 50% of the total score. Subsequently, some students are left out, as they did not receive a pass mark.

In order to analyse the differences between the two groups, group comparison methods are applied for test results using the Minitab 16 Statistical Software. A two-tailed t-test is applied for the variables where data are normally distributed and two-tailed Mann-Whitney-U test (u-test) for variables where data are not normally distributed (Shier 2004). Two-tailed t-test and Mann-Whitney tests are suggested by the literature and used in similar research studies (e.g. Graf et al. 2008 and Popescu 2010) for comparing two samples, which comes from the same population. In order to check whether data are normally distributed, the Kolmogorov-Smirnov test is used which is one of the most common tests in statistics to compare the distribution of the values.

In addition, the chi square test is used to distinguish relationships between student recall and retention test results and social-structural factors (e.g. gender, age, nationality, pre-university qualifications) as well as their pre-knowledge of the subject. The chi square test shows whether there is an association between variables. It uses bivariate tables to show the intersections of independent and dependent variables, and finds the relationship between them (if there is any). In order to construct bivariate tables, independent variable values (e.g. gender, nationality, etc.) are arrayed on a vertical axis and dependent variable values are arrayed on the horizontal axis. Each cell on the table shows the total number of combinations of values that is observed in the sample. For concluding a result from the chi square test, the table's chi square value and degrees of freedom (df) of the table must be determined. Degrees of freedom can be calculated with the following formula: df = (number of rows–1)(number of columns–1). However, the probability of the error threshold value (p) needs to be less than 0.05 for the data to present a statistically significant relationship (Lane 2006; Connor-Linton 2006).

5.2.1 Comparison of FSLSM Questionnaire Results and Detected Learning Styles

Table 9 below shows the FSLSM dimensions of the learning styles that are assigned through the rule-based modelling method and the results of the FSLSM questionnaire, which students determined their own learning styles. It includes the results for all students who completed the experimental study successfully. In order to compare and show how close the detected learning style is to the learning style based on the FSLSM questionnaire results, the precision formula proposed by García et al. (2007) is applied. The method is based on the similarity between the obtained results from the rule-based modelling method and the questionnaire results. Using the method, it is demonstrated that the results for the active/reflective dimension have a similarity of 74.51%, and visual/verbal and sequential/global dimensions have a similarity of 75.49%.

Table 9 displays learning styles of students (who completed the whole study successfully) that are identified by results of the learning styles questionnaire and the rule-based method. In this table A/R, V/B and Q/G represent the balanced learning style for the respective FSLSM dimension. It is noticeable that results obtained from two different methods are similar to each other. However, detailed discussion about this data in relevance to the findings of this study is provided in section 5.3.

Student	FSLSM Dimensions					
	Active (A)/Reflective (R)		Visual (V)/Verbal (B)		Sequential (Q)/Global (G)	
	Questionnaire	RB Method	Questionnaire	RB Method	Questionnaire	RB Method
1	A/R	A/R	V/B	V/B	G	G
2	A	A/R	V/B	V/B	Q	Q/G
3	A/R	A/R	V/B	V/B	Q/G	Q
4	A/R	A/R	V/B	V/B	Q/G	Q/G
5	A/R	A/R	V/B	B	Q/G	Q
6	A	A/R	V	V	Q	Q
7	A/R	A/R	V/B	V/B	Q/G	Q
8	A	A	V	V	Q/G	Q
9	A/R	A/R	V	V/B	Q	Q/G
10	R	A/R	V/B	V/B	Q	Q/G
11	A/R	A/R	V/B	V/B	Q/G	G
12	A	A/R	V	V	Q/G	Q
13	A/R	A	V	V/B	Q	Q/G
14	A	A/R	V/B	V/B	Q/G	Q/G
15	A/R	A/R	V	V	Q	Q/G
16	A	A/R	V	V	Q	Q/G
17	A	A/R	V/B	V/B	Q/G	G
18	A	A/R	V	V/B	Q/G	Q/G
19	A/R	A/R	V	V/B	Q/G	Q/G
20	A/R	A/R	V	V	Q/G	Q/G
21	A	A/R	V	V	Q	Q/G
22	A/R	A/R	V	V/B	Q/G	Q
23	A	A/R	V	V	Q	Q/G
24	A	A/R	V	V/B	Q/G	G
25	A/R	A	V	B	Q/G	G
26	R	A/R	V	V	Q/G	Q
27	A/R	A/R	V	V	Q/G	G
28	A	A/R	V/B	V	Q/G	Q/G
29	A/R	A	V	V/B	Q	Q/G
30	A/R	A/R	V/B	V	Q/G	Q
31	R	A/R	V/B	V	Q/G	Q
32	A/R	A/R	V	V/B	Q/G	Q/G
33	R	R	V	V/B	Q/G	Q/G
34	A/R	A/R	V	V/B	Q/G	Q/G
35	A/R	A	V	B	Q	Q/G
36	A/R	A	V/B	V/B	Q	Q
37	A	A/R	V	V/B	Q/G	Q/G
38	A/R	R	V/B	V/B	Q/G	Q
39	A	A	V	V	Q/G	Q
40	A/R	A/R	V	V	G	G
41	R	A	V/B	B	Q/G	Q/G
42	A/R	A/R	V/B	V/B	Q/G	Q
43	A/R	A/R	V	V/B	Q	G
44	A/R	A/R	V	V/B	Q/G	Q/G
45	A	A/R	V	V	Q/G	Q

46	A/R	A/R	V	V/B	Q/G	Q/G
47	A/R	A/R	V	V/B	Q/G	Q
48	R	A	V/B	V	Q	Q
49	A/R	A	V	V/B	Q/G	Q/G
50	A	A/R	V	V	Q/G	Q
51	A/R	A/R	V	V	Q	Q/G
52	A/R	A/R	V	B	Q/G	Q
53	A/R	A/R	V	V	Q/G	Q
54	A/R	A/R	V	V/B	Q/G	Q/G
55	A/R	A/R	V/B	V/B	Q/G	Q/G
56	A/R	A/R	V	V	Q/G	Q
57	A	A/R	V	V/B	Q/G	Q/G
58	A/R	A	V	V/B	Q/G	G
59	A/R	A/R	V	V	Q/G	Q/G
60	A/R	A/R	V	V/B	Q/G	Q/G
61	A/R	A	V	B	Q/G	Q/G
62	R	A/R	V/B	V/B	Q/G	Q/G
63	A/R	A/R	V	V/B	Q/G	G
64	A/R	A/R	V/B	V/B	Q/G	Q/G
65	A/R	A	V/B	B	Q	Q/G
66	A/R	R	V	B	Q/G	Q
67	A/R	A/R	V	V	Q/G	Q
68	A/R	A/R	V	V/B	Q/G	Q/G
69	A/R	R	V/B	V/B	Q	G
70	A/R	A/R	V	V/B	Q/G	Q/G
71	A	A/R	V	V	Q	Q
72	A	A/R	V/B	B	Q/G	G
73	A/R	A/R	V	V/B	Q	Q
74	R	A/R	V	V/B	Q	Q
75	A/R	A/R	V/B	V	Q	Q/G
76	A/R	A/R	V	V	Q	Q
77	A/R	A/R	V	V/B	Q	Q
78	A/R	A	V	B	Q/G	Q/G
79	A/R	A/R	V	V	Q/G	Q
80	R	A/R	V/B	V	Q/G	Q/G
81	A/R	A	V/B	V/B	Q/G	Q/G

Table 9: Comparison of FSLSM questionnaire results with RB method results for all students

In order to make the results comparable three values are considered for each dimension. For example, for the first dimension the values, active (A), balanced (A/R) and reflective (R) are considered.

When the questionnaire results in Table 9 are examined in more detail, it can be observed that very few students categorise themselves as reflective learners (Table 10) and global learners (Table 12). However, the most remarkable result is that none of the students consider themselves as verbal learners, and more than half of the students consider themselves as visual learners (Table 11). Based on student behaviours within the TEL environment some students are characterised as verbal learners with the rule-based method.

Information Processing (Active/Reflective) Dimension		
	FSLSM Questionnaire	RB Method
Active (A)	19	15
Reflective (R)	9	4
Active/Reflective (A/R)	53	62

Table 10: Total number of learning styles of active/reflective dimension based on questionnaire and rule-based method results

Information Receiving (Visual/Verbal) Dimension		
	FSLSM Questionnaire	RB Method
Visual (V)	54	28
Verbal (B)	0	10
Visual/Verbal (V/B)	27	43

Table 11: Total number of learning styles of visual/verbal dimension based on questionnaire and rule-based method results

Understanding Information (Sequential/Global) Dimension		
	FSLSM Questionnaire	RB Method
Sequential (Q)	23	29
Global (G)	2	12
Sequential/Global (Q/G)	56	40

Table 12: Total number of learning styles of sequential/global dimension based on questionnaire and rule-based method results

5.2.2 Comparison of Matched and Mismatched Groups' (who Received a Pass Mark on the Recall Test) Learning Outcomes on Recall and Retention Type Assessment Tests

Students who received a score of 50% or more on the recall type assessment test are used for this statistical test. In total, 55 students received a pass mark on the recall test and these are then divided into two groups, as matched and mismatched, and for each of the three FSLSM dimensions. The groups are compared based on their learning achievements on both the recall and retention type of assessments to determine which group performed better.

Statistical test results as shown in Table 13 indicates that on the recall type assessment test:

- the mismatched group performed better than the matched group in the active/reflective dimension,
- the matched group performed better than the mismatched group in the visual/verbal dimension,
- the groups did not show a significant difference regarding their learning outcomes in the sequential/global dimension.

However in the retention test, the groups do not show significant difference ($p<0.05$) with respect to their learning outcomes in the active/reflective, visual/verbal or the sequential/global dimensions.

Comparison of recall and retention test results between matched and mismatched groups who scored pass mark on the recall test (>=50%)				
Groups based on FSLSM dimensions	**T-test / Mann Whitney**	**Values**		
		T/W	**P**	**N**
A/R matched & A/R mismatched recall test results	T-test	-2.76	**0.008**	30 & 25
A/R matched & A/R mismatched retention test results	Mann Whitney	242.00	0.214	30 & 25
V/B matched & V/B mismatched recall test results	T-test	2.21	**0.030**	28 & 27
V/B matched & V/B mismatched retention test results	T-test	0.55	0.588	28 & 27
Q/G matched & Q/G mismatched recall test results	T-test	0.11	0.914	30 & 25
Q/G matched & Q/G mismatched retention test results	Mann Whitney	0.27	0.791	30 & 25

Table 13: Statistical test results of matched and mismatched groups' learning outcomes on recall and retention type assessment tests

5.2.3 Comparison of Matched and Mismatched Groups' (who Received Pass Mark on the Retention Test) Learning Outcomes on Recall and Retention Type Assessment Tests

Students who received a score of 50% or more on the retention type assessment are used for this statistical test. 49 students received a pass mark on the retention test and they are separated into matched and mismatched groups for each of the three FSLSM dimensions. The groups are compared based on recall and retention test results to determine which group performed better.

Result of this statistical test shows up similar findings as shown in Table 14 to the recall test,

- the mismatched group performed better than the matched group in the active/reflective dimension,
- the matched group performed better than the mismatched group in the visual/verbal dimension,

- the groups did not show a significant difference in the sequential/global dimension.

In the retention test the groups do not show any significant difference ($p<0.05$) in the active/reflective, visual/verbal and sequential/global dimensions regarding their learning outcomes.

Comparison of Recall and Retention test results between Matched and Mismatched Groups who scored pass mark on the retention test (>=50%)				
Groups based on FSLSM dimensions	**T-test / Mann Whitney**	**Values**		
		T or W	**P**	**N**
A/R matched & A/R mismatched recall test results	T-test	-0.1	**0.019**	25 & 24
A/R matched & A/R mismatched retention test results	Mann Whitney	212.5	0.070	25 & 24
V/B matched & V/B mismatched recall test results	T-test	2.5	**0.016**	25 & 24
V/B matched & V/B mismatched retention test results	T-test	0.3	0.700	25 & 24
Q/G matched & Q/G mismatched recall test results	T-test	0.6	0.579	25 & 24
Q/G matched & Q/G mismatched retention test results	Mann Whitney	268.0	0.513	25 & 24

Table 14: Statistical test results of matched and mismatched groups' learning outcomes on recall and retention type assessment tests

5.2.4 Association Between Matched and Mismatched groups' Learning Outcomes and Pre-knowledge about the Subject

In order to find if there is any impact of student pre-knowledge about the subject on their learning outcomes, the relationship between student recall-type assessment test results and their pre-knowledge are investigated. Students who are grouped with respect to their recall and retention assessment test results show significant differences only on recall test results (see Table 13 and 14), therefore correlation tests based on retention test results were not carried out for this group of students.

The answers to pre-knowledge test questions are scored from 1 to 4 based on their degree of importance with regard to student learning outcomes. Therefore, to find the impact of student pre-knowledge on their learning outcomes, the average score that is calculated from student answers is used for this analysis.

The results of chi-square tests demonstrate that there is no relationship (as P value should be less than 0.05) between student recall- and retention-test results, and their pre-knowledge about the subject. The impact of these test results on the findings is discussed at the end of this chapter, section 5.3.

5.2.4.1 Association Between Matched and Mismatched Groups' (who Received Pass Mark on the Recall Test) and Their Pre-knowledge

Pre-knowledge	A/R matched group	A/R mismatched group	Total
>= avg	23	19	42
<= avg	7	6	13
Total	30	25	55
Chi-Square = 0.003, Degrees of Freedom = 1, P-Value = 0.954			

Table 15: Chi-square analysis between A/R matched and mismatched groups who received pass mark on the recall-type assessment test

Outcome: The association between pre-knowledge about the subject and groups' learning outcomes on recall test is not regarded as statistically significant. So, A/R matched and mismatched groups' learning outcomes are not dependent on their pre-knowledge.

Pre-knowledge	V/B matched group	V/B mismatched group	Total
>= avg	24	19	43
<= avg	4	8	12
Total	28	27	55
Chi-Square = 1.897, Degrees of Freedom = 1, P-Value = 0.168			

Table 16: Chi-square analysis between V/B matched and mismatched groups who received pass mark from recall type assessment test

Outcome: The association between pre-knowledge about the subject and groups' learning outcomes on recall test is not regarded as statistically significant. So, V/B matched and mismatched groups' learning outcomes are not dependent on their pre-knowledge.

Pre-knowledge	Q/G matched group	Q/G mismatched group	Total
>= avg	27	15	42
<= avg	3	10	13
Total	30	25	55
Chi-Square = 6.799, Degrees of Freedom = 1, P-Value = 0.009			

Table 17: Chi-square analysis between Q/G matched and mismatched groups who received pass mark on the recall-type assessment test

Outcome: The association between pre-knowledge about the subject and the groups' learning outcomes on recall test is statistically significant. However, this finding is not included in discussions of general findings of this study, as this group of students did not show any significant difference regarding their learning outcomes.

5.2.5 Association Between Matched and Mismatched Groups' (who Received Pass Mark on the Retention test) and Their Pre-knowledge

Pre-knowledge	A/R matched group	A/R mismatched group	Total
>= avg	19	20	39
<= avg	5	5	10
Total	24	25	49
Chi-Square = 0.005, Degrees of Freedom = 1, P-Value = 0.942			

Table 18: Chi-square analysis between A/R matched and mismatched groups who received a pass mark on the recall-type assessment test

Outcome: The association between pre-knowledge about the subject and groups' learning outcomes on the recall test is not regarded as statistically significant. So, A/R matched and mismatched groups' learning outcomes are not dependent on their pre-knowledge.

Pre-knowledge	V/B matched group	V/B mismatched group	Total
>= avg	17	20	37
<= avg	7	5	12
Total	24	25	49
Chi-Square = 0.556, Degrees of Freedom = 1, P-Value = 0.456			

Table 19: Chi-square analysis between V/B matched and mismatched groups who received a pass mark on the recall-type assessment test

Outcome: The association between pre-knowledge about the subject and groups' learning outcomes on recall test is not regarded as statistically significant. So, V/B matched and mismatched groups' learning outcomes are not dependent on their pre-knowledge.

Pre-knowledge	Q/G matched group	Q/G mismatched group	Total
>= avg	15	23	38
<= avg	9	2	11
Total	24	25	49
Chi-Square = 6.121, Degrees of Freedom = 1, P-Value = 0.013			

Table 20: Chi-square analysis between Q/G matched and mismatched groups who received a pass mark on the recall-type assessment test

Outcome: The association between pre-knowledge about the subject and the groups' learning outcomes on recall test is statistically significant. However, this finding is not included in discussions of general findings of this study, as this group of students did not show any significant difference regarding their learning outcomes.

5.2.6 Association Between Matched and Mismatched Groups' Learning Outcomes and Social-structural Factors

In order to find if there is any impact of social-structural factors on student learning outcomes, the relationship between student recall type assessment test results, and their gender, age, nationality and pre-university qualifications are investigated. Students who are grouped with respect to their recall and retention assessment test results show significant differences on recall test results in previous statistical tests, therefore correlation tests based on retention test results were not carried out.

The results of chi-square tests demonstrate that there is no relationship between recall and retention test results, and social-structural factors of students who belong to active/reflective and visual/verbal groups. The impact of these test results on the findings is discussed at the end of this chapter, section 5.3.

5.2.6.1 Association Between Matched and Mismatched Groups' Learning Outcomes (who Received Pass Mark on the Recall Test) and Social-structural Factors

Association between recall test results and gender

Gender	A/R matched group	A/R mismatched group	Total
Female	8	7	15
Male	22	18	40
Total	30	25	55
Chi-Square = 0.012, Degrees of Freedom = 1, P-Value = 0.912			

Table 21: Chi-square analysis between A/R matched and mismatched groups who received pass mark on the recall-type assessment test

Outcome: The association between genders and groups' learning outcomes on recall test is not regarded as statistically significant. So, A/R matched and mismatched groups' learning outcomes are not dependent on their gender.

Gender	V/B matched group	V/B mismatched group	Total
Female	6	9	15
Male	22	18	40
Total	28	27	55
Chi-Square = 0.982, Degrees of Freedom = 1, P-Value = 0.322			

Table 22: Chi-square analysis between V/B matched and mismatched groups who received a pass mark on the recall-type assessment test

Outcome: The association between genders and groups' learning outcomes on recall test is not regarded as statistically significant. So, V/B matched and mismatched groups' learning outcomes are not dependent on their gender.

Gender	Q/G matched group	Q/G mismatched group	Total
Female	9	6	15
Male	21	19	40
Total	30	25	55
Chi-Square = 0.247, Degrees of Freedom = 1, P-Value = 0.619			

Table 23: Chi-square analysis between Q/G matched and mismatched groups who received pass mark on the recall-type assessment test

Outcome: The association between genders and groups' learning outcomes on recall test is not regarded as statistically significant. So, Q/G matched and mismatched groups' learning outcomes are not dependent on their gender.

Association between recall test results and year of birth (YoB)

The year 1990 was chosen to distribute students equally for each group.

YoB	A/R matched group	A/R mismatched group	Total
Before 1990	15	10	25
1990 & after	15	15	30
Total	30	25	55
Chi-Square = 0.550, Degrees of Freedom = 1, P-Value = 0.458			

Table 24: Chi-square analysis between A/R matched and mismatched groups who received pass mark on the recall-type assessment test

Outcome: The association between year of birth and groups' learning outcomes on recall test is not regarded as statistically significant. So, A/R matched and mismatched groups' learning outcomes are not dependent on their YoB.

YoB	V/B matched group	V/B mismatched group	Total
Before 1990	10	15	25
1990 & after	18	12	30
Total	28	27	55
Chi-Square = 2.183, Degrees of Freedom = 1, P-Value = 0.140			

Table 25: Chi-square analysis between V/B matched and mismatched groups who received pass mark on the recall-type assessment test

Outcome: The association between year of birth and the groups' learning outcomes in the recall test is not regarded as statistically significant. So, V/B matched and mismatched groups' learning outcomes are not dependent on their YoB.

YoB	Q/G matched group	Q/G mismatched group	Total
Before 1990	17	8	25
1990 & after	13	17	30
Total	30	25	55
Chi-Square = 3.346, Degrees of Freedom = 1, P-Value = 0.067			

Table 26: Chi-square analysis between Q/G matched and mismatched groups who received pass mark on the recall-type assessment test

Outcome: The association between year of birth and groups' learning outcomes in the recall test is not regarded as statistically significant. So, Q/G matched and mismatched groups' learning outcomes are not dependent on their YoB.

Association between recall test results and nationality

Nationality	A/R matched group	A/R mismatched group	Total
British	17	17	34
Others	13	8	21
Total	30	25	55
Chi-Square = 0.742, Degrees of Freedom = 1, P-Value = 0.389			

Table 27: Chi-square analysis between A/R matched and mismatched groups who received pass mark on the recall-type assessment test

Outcome: The association between nationalities and groups' learning outcomes on recall test is not regarded as statistically significant. So, A/R matched and mismatched groups' learning outcomes are not dependent on their nationality.

Nationality	V/B matched group	V/B mismatched group	Total
British	16	18	34
Others	12	9	21
Total	28	27	55
Chi-Square = 0.528, Degrees of Freedom = 1, P-Value = 0.467			

Table 28: Chi-square analysis between V/B matched and mismatched groups who received pass mark on the recall-type assessment test

Outcome: The association between nationalities and groups' learning outcomes on recall test is not regarded as statistically significant. So, V/B matched and mismatched groups' learning outcomes are not dependent on their nationality.

Nationality	Q/G matched group	Q/G mismatched group	Total
British	19	15	34
Others	11	10	21
Total	30	25	55
Chi-Square = 0.064, Degrees of Freedom = 1, P-Value = 0.800			

Table 29: Chi-square analysis between Q/G matched and mismatched groups who received pass mark on the recall-type assessment test

Outcome: The association between nationalities and groups' learning outcomes on recall test is not regarded as statistically significant. So, Q/G matched and mismatched groups' learning outcomes are not dependent on their nationality.

Association between recall test results and pre-university qualifications

UCAS and access qualifications are chosen as the majority of the students gained places at the universities with these qualifications.

Qualification	A/R matched group	A/R mismatched group	Total
UCAS	10	13	23
Access	5	4	9
Others	15	8	23
Total	30	25	55
Chi-Square = 2.196, Degrees of Freedom = 2, P-Value = 0.333			

Table 30: Chi-square analysis between A/R matched and mismatched groups who received pass mark on the recall-type assessment test

Outcome: The association between pre-university qualifications and groups' learning outcomes on recall test is not regarded as statistically significant. So, A/R matched and mismatched groups' learning outcomes are not dependent on their pre-university qualifications.

Qualification	V/B matched group	V/B mismatched group	Total
Ucas	13	10	23
Access	3	6	9
Others	12	11	23
Total	28	27	55
Chi-Square = 1.417, Degrees of Freedom = 2, P-Value = 0.492			

Table 31: Chi-square analysis between V/B matched and mismatched groups who received pass mark on the recall-type assessment test

Outcome: The association between pre-university qualifications and groups' learning outcomes on recall test is not regarded as statistically significant. So, V/B matched and mismatched groups' learning outcomes are not dependent on their pre-university qualifications.

Qualification	Q/G matched group	Q/G mismatched group	Total
Ucas	11	12	23
Access	4	5	9
Others	15	8	23
Total	30	25	55
Chi-Square = 1.846, Degrees of Freedom = 2, P-Value = 0.397			

Table 32: Chi-square analysis between Q/G matched and mismatched groups who received pass mark on the recall-type assessment test

Outcome: The association between pre-university qualifications and groups' learning outcomes on recall test is not regarded as statistically significant. So, Q/G matched and mismatched groups' learning outcomes are not dependent on their pre-university qualifications.

5.2.6.2 Association Between Matched and Mismatched Groups' Learning Outcomes (who Received Pass Mark on the Retention Test) and Social-structural Factors

Association between retention test results and gender

Gender	A/R matched group	A/R mismatched group	Total
Female	8	7	15
Male	17	17	34
Total	25	24	49
Chi-Square = 0.046, Degrees of Freedom = 1, P-Value = 0.830			

Table 33: Chi-square analysis between A/R matched and mismatched groups who received pass mark on the retention-type assessment test

Outcome: The association between genders and groups' learning outcomes on recall test is not regarded as statistically significant. So, A/R matched and mismatched groups' learning outcomes are not dependent on their gender.

Gender	V/B matched group	V/B mismatched group	Total
Female	6	9	15
Male	19	15	34
Total	25	24	49
Chi-Square = 1.051, Degrees of Freedom = 1, P-Value = 0.305			

Table 34: Chi-square analysis between V/B matched and mismatched groups who received pass mark on the retention-type assessment test

Outcome: The association between genders and groups' learning outcomes on recall test is not regarded as statistically significant. So, V/B matched and mismatched groups' learning outcomes are not dependent on their gender.

Gender	Q/G matched group	Q/G mismatched group	Total
Female	9	6	15
Male	16	18	34
Total	25	24	49
Chi-Square = 0.698, Degrees of Freedom = 1, P-Value = 0.404			

Table 35: Chi-square analysis between Q/G matched and mismatched groups who received pass mark on the retention-type assessment test

Outcome: The association between genders and groups' learning outcomes on recall test is not regarded as statistically significant. So, Q/G matched and mismatched groups' learning outcomes are not dependent on their gender.

Association between retention test results and year of birth (YoB)

Year 1990 was chosen to separate students equally for each group.

YoB	A/R matched group	A/R mismatched group	Total
Before 1990	10	9	19
1990 & after	15	15	30
Total	25	24	49
Chi-Square = 0.032, Degrees of Freedom = 1, P-Value = 0.858			

Table 36: Chi-square analysis between A/R matched and mismatched groups who received pass mark on the retention-type assessment test

Outcome: The association between year of birth and groups' learning outcomes on recall test is not regarded as statistically significant. So, A/R matched and mismatched groups' learning outcomes are not dependent on their YoB.

YoB	V/B matched group	V/B mismatched group	Total
Before 1990	7	12	19
1990 & after	18	12	30
Total	25	24	49
Chi-Square = 2.496, Degrees of Freedom = 1, P-Value = 0.114			

Table 37: Chi-square analysis between V/B matched and mismatched groups who received pass mark on the retention-type assessment test

Outcome: The association between year of birth and groups' learning outcomes on recall test is not regarded as statistically significant. So, V/B matched and mismatched groups' learning outcomes are not dependent on their YoB.

YoB	Q/G matched group	Q/G mismatched group	Total
Before 1990	13	17	30
1990 & after	12	7	19
Total	25	24	49
Chi-Square = 1.829, Degrees of Freedom = 1, P-Value = 0.176			

Table 38: Chi-square analysis between Q/G matched and mismatched groups who received pass mark on the retention-type assessment test

Outcome: The association between year of birth and groups' learning outcomes on recall test is not regarded as statistically significant. So, Q/G matched and mismatched groups' learning outcomes are not dependent on their YoB.

Association between retention test results and nationality

Nationality	A/R matched group	A/R mismatched group	Total
British	17	17	34
Others	8	7	15
Total	25	24	49
Chi-Square = 0.046, Degrees of Freedom = 1, P-Value = 0.830			

Table 39: Chi-square analysis between A/R matched and mismatched groups who received pass mark on the retention-type assessment test

Outcome: The association between nationalities and groups' learning outcomes on recall test is not regarded as statistically significant. So, A/R matched and mismatched groups' learning outcomes are not dependent on their nationality.

Nationality	V/B matched group	V/B mismatched group	Total
British	16	18	34
Others	9	6	15
Total	25	24	49
Chi-Square = 0.698, Degrees of Freedom = 1, P-Value = 0.404			

Table 40: Chi-square analysis between V/B matched and mismatched groups who received pass mark on the retention-type assessment test

Outcome: The association between nationalities and groups' learning outcomes on recall test is not regarded as statistically significant. So, V/B matched and mismatched groups' learning outcomes are not dependent on their nationality.

Nationality	Q/G matched group	Q/G mismatched group	Total
British	19	14	33
Others	6	10	16
Total	25	24	49
Chi-Square = 1.738, Degrees of Freedom = 1, P-Value = 0.187			

Table 41: Chi-square analysis between Q/G matched and mismatched groups who received pass mark on the retention-type assessment test

Outcome: The association between nationalities and groups' learning outcomes on recall test is not regarded as statistically significant. So, Q/G matched and mismatched groups' learning outcomes are not dependent on their nationality.

Association between retention test results and pre-university qualifications

UCAS and access qualifications are chosen as the majority of the students gained places at the universities with these qualifications.

Qualification	A/R matched group	A/R mismatched group	Total
Ucas	10	13	23
Access	5	4	9
Others	10	7	17
Total	25	24	49
Chi-Square = 1.012, Degrees of Freedom = 2, P-Value = 0.603			

Table 42: Chi-square analysis between A/R matched and mismatched groups who received pass mark on the recall-type assessment test

Outcome: The association between pre-university qualifications and groups' learning outcomes on recall test is not regarded as statistically significant. So, A/R matched and mismatched groups' learning outcomes are not dependent on their pre-university qualifications.

Qualification	V/B matched group	V/B mismatched group	Total
Ucas	13	10	23
Access	3	7	10
Others	9	7	16
Total	25	24	49
Chi-Square = 2.222, Degrees of Freedom = 2, P-Value = 0.329			

Table 43: Chi-square analysis between V/B matched and mismatched groups who received pass mark on the recall-type assessment test

Outcome: The association between pre-university qualifications and groups' learning outcomes on recall test is not regarded as statistically significant. So, V/B matched and mismatched groups' learning outcomes are not dependent on their pre-university qualifications.

Qualification	Q/G matched group	Q/G mismatched group	Total
Ucas	11	12	23
Access	4	5	9
Others	10	7	17
Total	25	24	49
Chi-Square = 0.664, Degrees of Freedom = 2, P-Value = 0.718			

Table 44: Chi-square analysis between Q/G matched and mismatched groups who received pass mark on the recall-type assessment test

Outcome: The association between pre-university qualifications and groups' learning outcomes on recall test is not regarded as statistically significant. So, Q/G matched and mismatched groups' learning outcomes are not dependent on their pre-university qualifications.

Student Groups	Social-structural Factors			
	Gender	Age	Nationality	Pre-university qualification
A/R matched and mismatched	0.912	0.458	0.389	0.333
V/B matched and mismatched	0.322	0.140	0.467	0.492
Q/G matched and mismatched	0.619	0.067	0.800	0.397

Table 45: Summary of the correlation analyses test results (P values) between matched and mismatched groups' learning outcomes (who received pass mark on the recall test) and social-structural factors

Table 45 summarises the results of correlation analyses tests that are conducted to find out if there is any relationship between student learning outcomes and social-structural factors.

Statistical analysis using the chi-square test reveals that there is no significant effect of any social-structural factors including gender, age, nationality and pre-university qualifications on student learning achievements. However, the impact of these analyses results on the findings is discussed at the end of this chapter, section 5.3.

5.2.7 Analysis of Student Opinions Regarding Their Studies Within the TEL Environment

At the end of the experimental study, students are asked to share their opinion of their experience of the formal TEL environment. The student opinion survey includes five questions and student participation is optional. The questions are selected to explore learning experiences and opinions of students relating to the learning environment and activities, and the survey is provided in the appendices of this thesis.

In total, 47 out of 55 students who received a pass mark from the recall type assessment test participated in this survey.

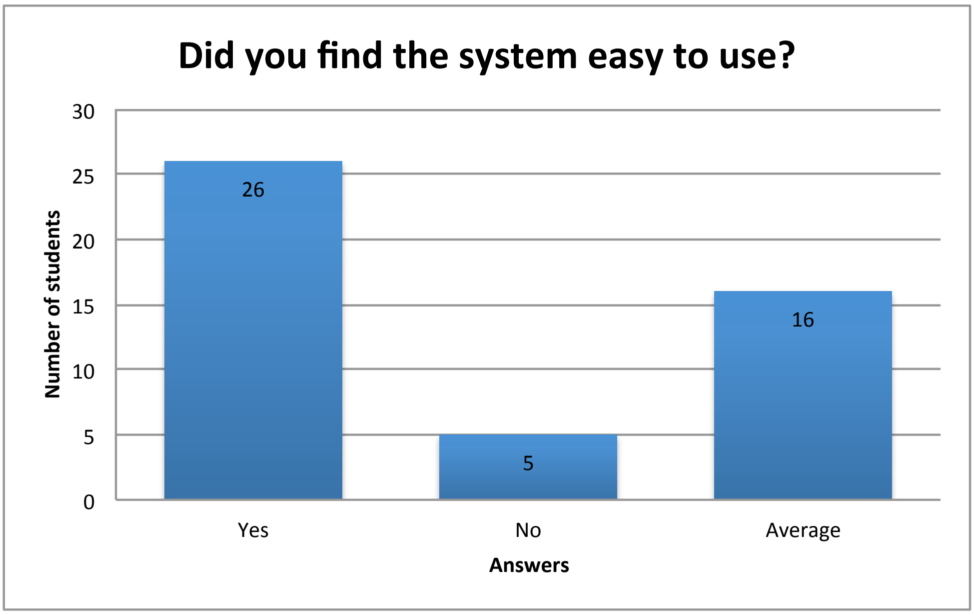

Figure 13: Distribution of students with respect to their answers for question 1 in student opinion survey

Majority of the students (55%) found the system easy to use, 34% of students are neutral and 11% found the system not easy to use.

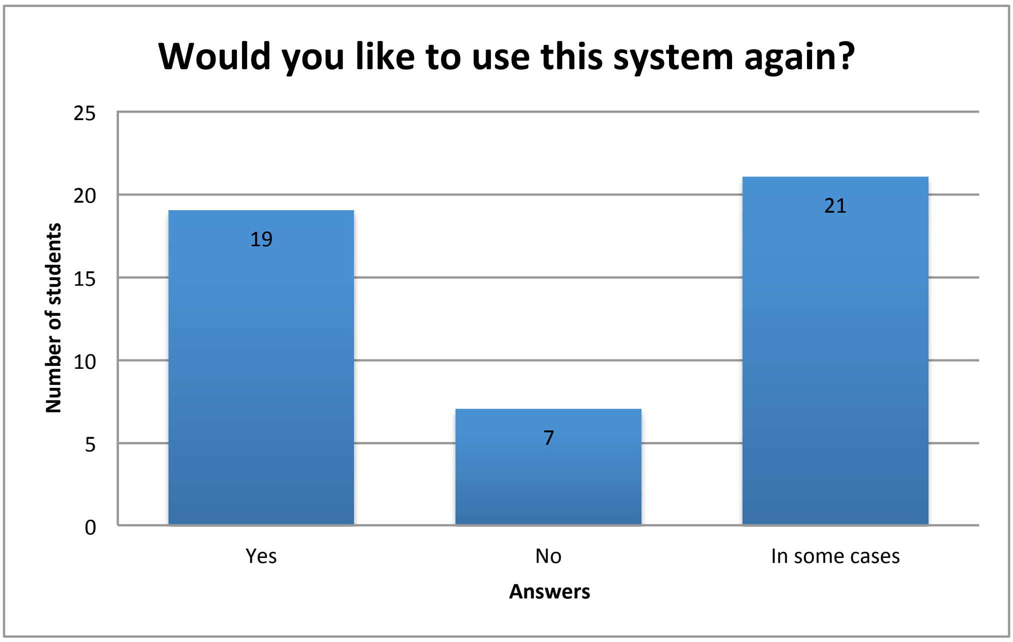

Figure 14: Distribution of students with respect to their answers for question 2 in student opinion survey

Most of the students (45%) agreed to use this system again in some cases, and 40% of the students would like to use this system again, whereas 15% of students did not want to use it again.

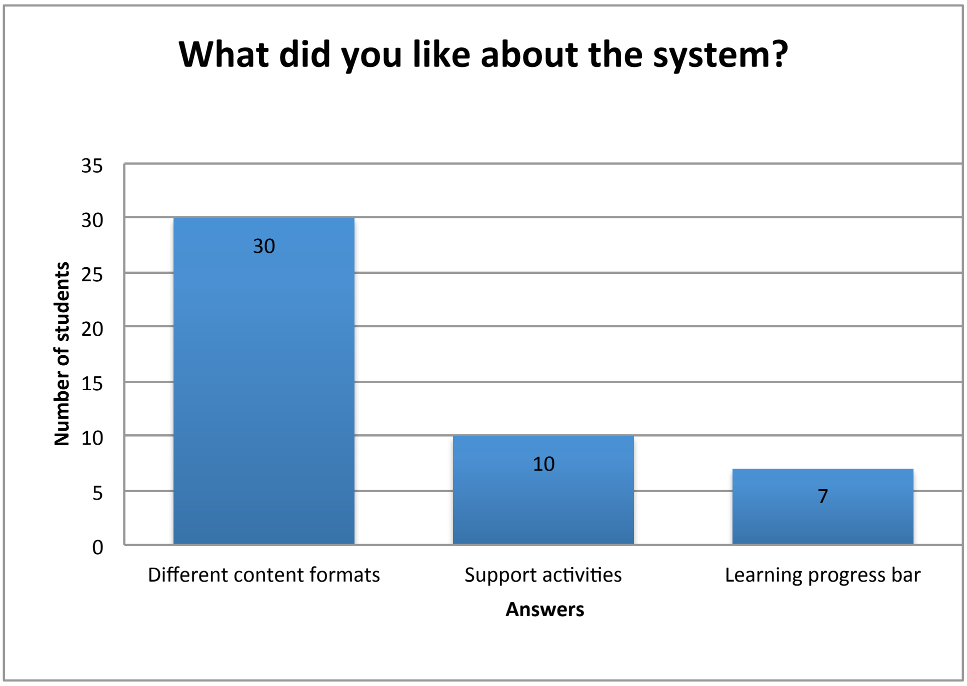

Figure 15: Distribution of students with respect to their answers for question 3 in student opinion survey

As can be seen from Figure 13 a high number (64%) of students enjoyed receiving course contents in different formats. However, a low number of students enjoyed using support activity tools (21%) and having a learning progress bar (15%) displaying the order of activities within the course, as well as their progress.

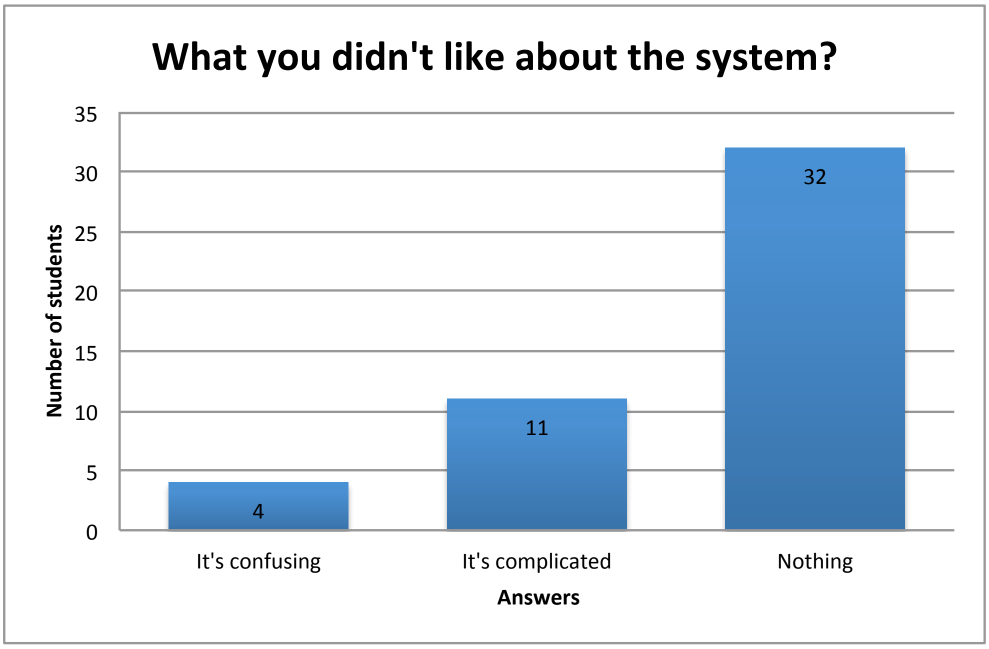

Figure 16: Distribution of students with respect to their answers for question 4 in student opinion survey

When students are asked to share their opinion about what they did not like about the system the majority of the students (68%) reported that there is nothing that they did not like: however, 23% of them found the system complicated.

Overall, students seem satisfied with the TEL environment and agreed to use it again in some cases.

5.2.8 Student Opinion Survey Results of Matched and Mismatched Groups

In this section, the opinions of matched and mismatched groups' who received pass marks on the recall-type assessment test are investigated and compared for each question in the student opinion survey.

Active/Reflective matched and mismatched groups

In this dimension of FSLSM, 27 students from matched group and 20 students from mismatched group participated in the survey.

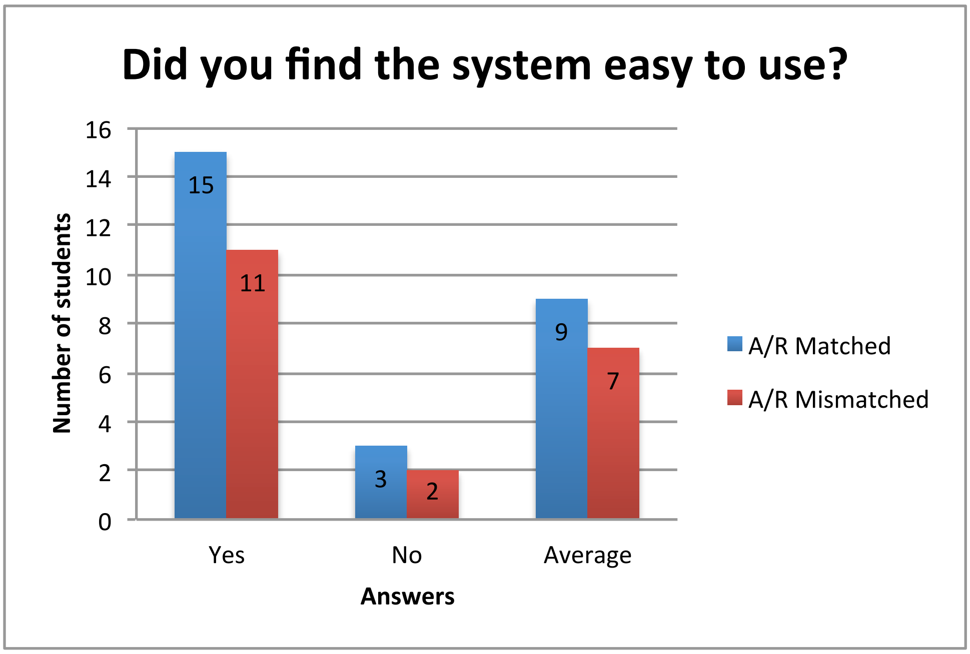

Figure 17: Distribution of matched and mismatched groups in A/R dimension with respect to their answers for question 1 in student opinion survey

The groups share similar opinions about system use, i.e. they both (56% of matched group and 55% of mismatched group) found the system easy to use, or neither easy nor difficult.

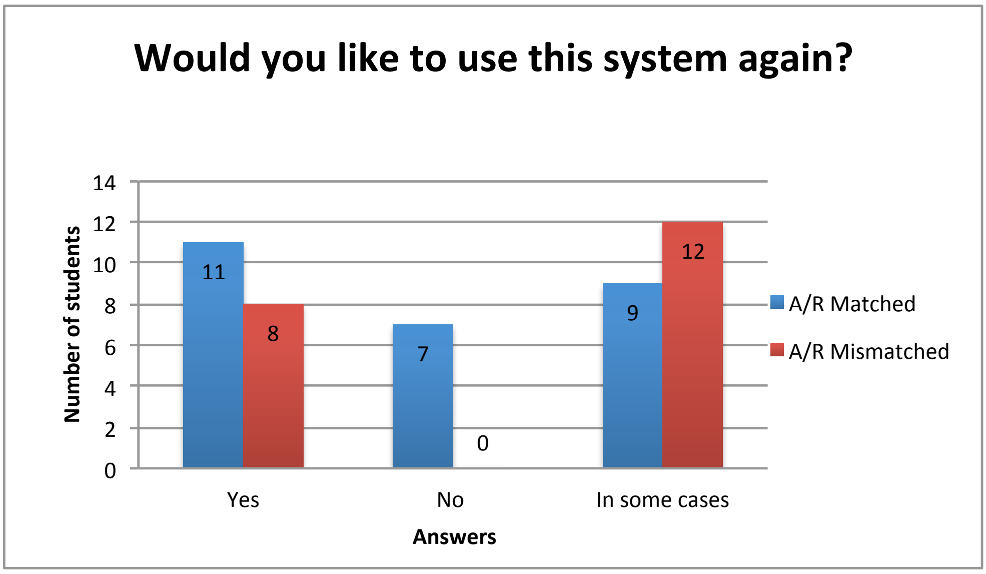

Figure 18: Distribution of matched and mismatched groups in A/R dimension with respect to their answers for question 2 in student opinion survey

41% of students in the matched group said they would like to use the system again, 33% students said they would like to use the system in some cases, and 26% said they do not want to use the system again. However, all students in the mismatched group agreed (60% said in some cases, 40% said yes) to use the system again and none of them said that they do not want to use the system again.

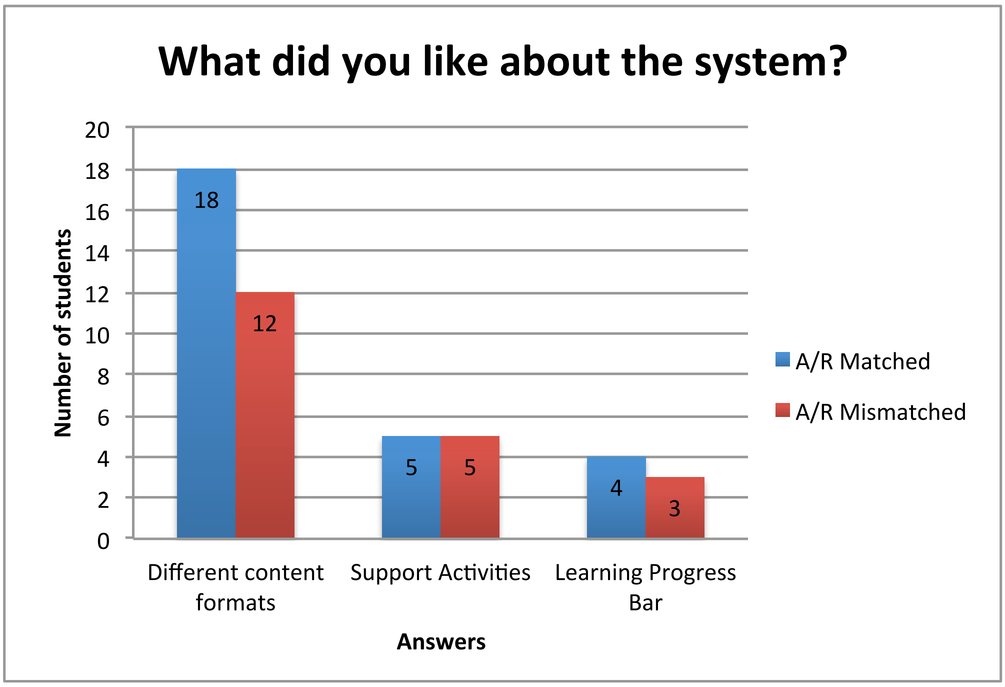

Figure 19: Distribution of matched and mismatched groups in A/R dimension with respect to their answers for question 3 in student opinion survey

The majority of students in the matched (67%) and mismatched (60%) groups liked having course content presented in different formats. However, a low number of students enjoyed using the support activities.

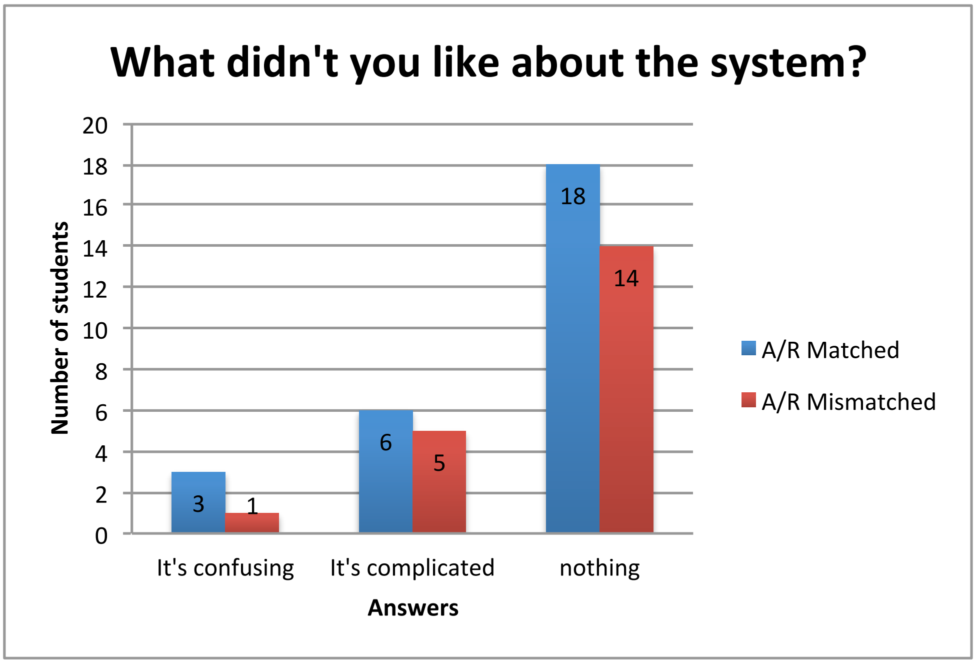

Figure 20: Distribution of matched and mismatched groups in A/R dimension with respect to their answers for question 4 in student opinion survey

Most of the students in both groups (67% for the matched group and 70% for the mismatched group) recorded that there is nothing they did not like about the system.

Visual/Verbal matched and mismatched groups

In this dimension of FSLSM, 22 students from the matched group and 25 students from the mismatched group are participated in the survey.

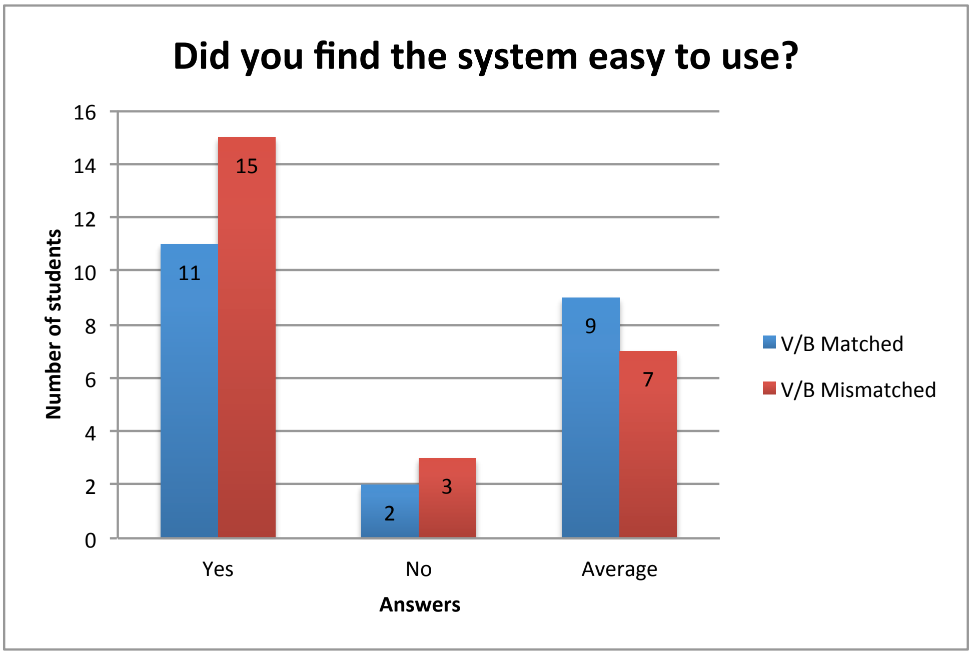

Figure 21: Distribution of matched and mismatched groups in V/B dimension with respect to their answers for question 1 in student opinion survey

50% of students in the matched group and 60% in the mismatched group found the system easy to use. 41% of the matched group and 28% of the mismatched group said the system is neither easy nor difficult to use. In both groups a very low number of students said that the system is not easy to use.

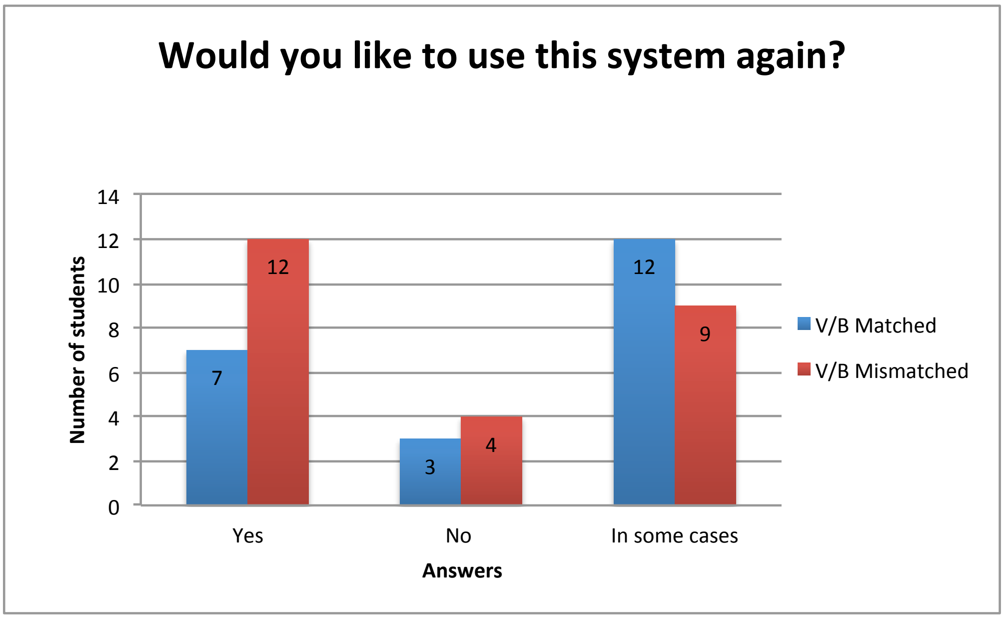

Figure 22: Distribution of matched and mismatched groups in V/B dimension with respect to their answers for question 2 in student opinion survey

The results of this question shows that 55% of the matched group preferred to use the system in some cases, whereas 48% of the mismatched group would like to use the system again. A low number of students said they do not want to use the system again.

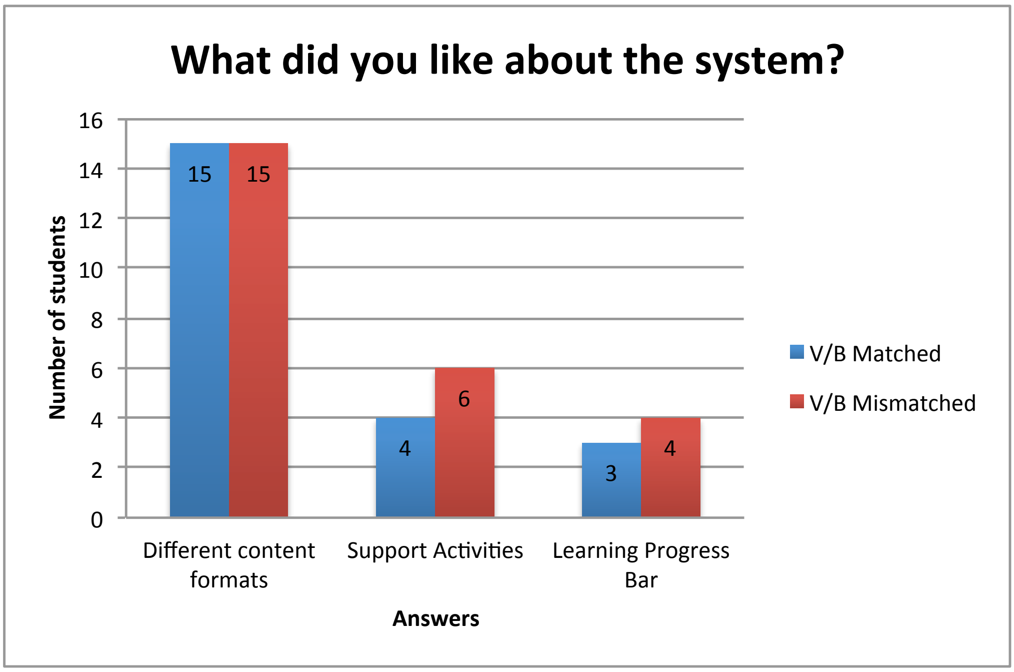

Figure 23: Distribution of matched and mismatched groups in V/B dimension with respect to their answers for question 3 in student opinion survey

As with the A/R groups, 68% of the V/B matched group and 60% of V/B mismatched group liked receiving course contents in different formats. However, the number of students who enjoyed having support activity tools is not high (18% of the matched group and 24% of the mismatched group).

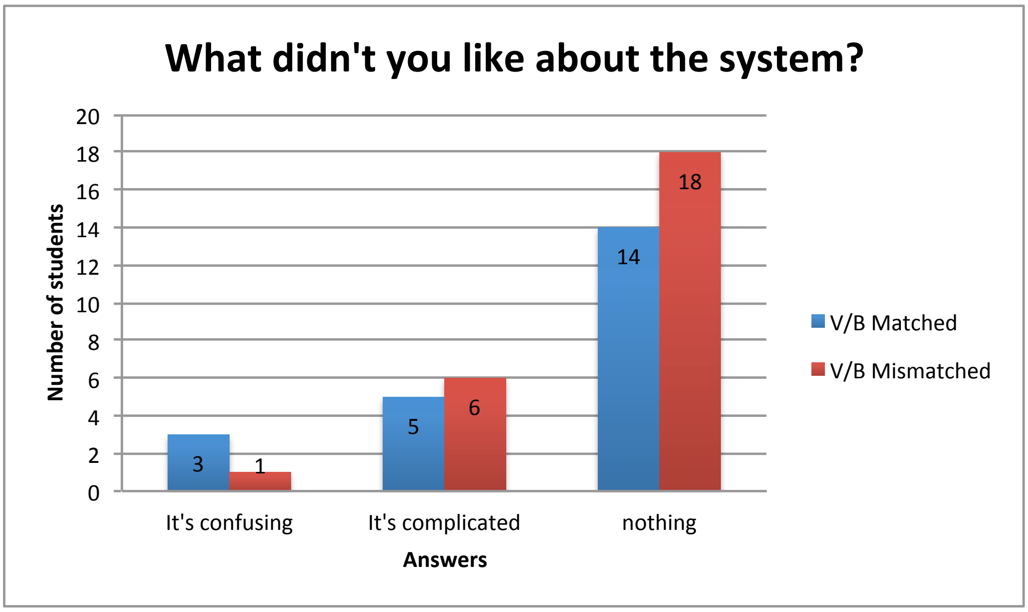

Figure 24: Distribution of matched and mismatched groups in V/B dimension with respect to their answers for question 4 in student opinion survey

A high number of students in both groups (64% of the matched group and 72% of the mismatched group) note that there is nothing that they did not like about the system.

Sequential/Global matched and mismatched groups

In this dimension of FSLSM, 28 students from the matched group and 19 students from the mismatched group are participated in the survey.

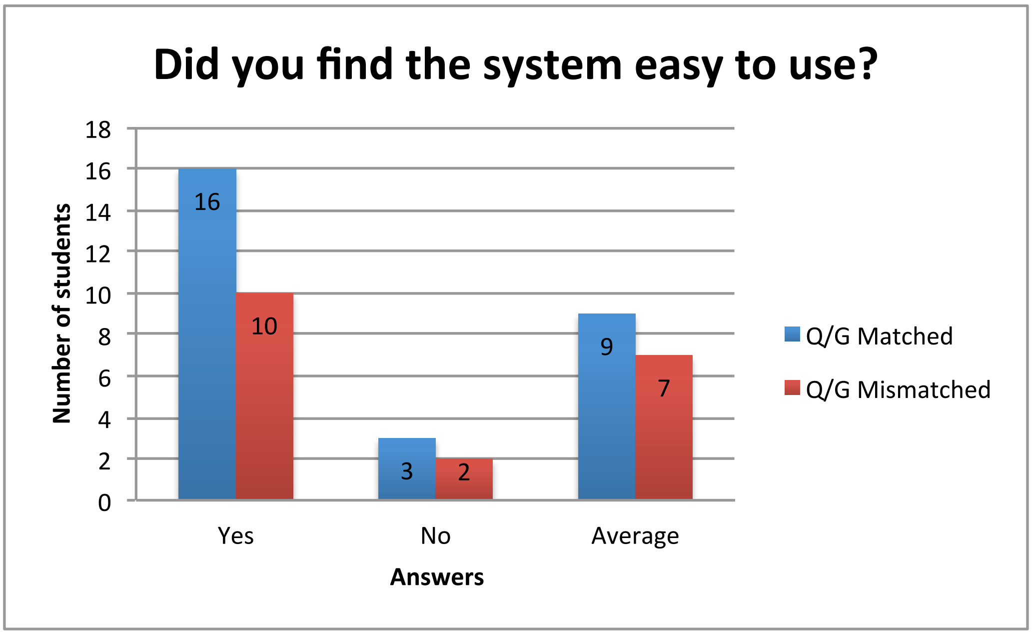

Figure 25: Distribution of matched and mismatched groups in Q/G dimension with respect to their answers for question 1 in student opinion survey

57% of the matched group and 53% of the mismatched group found the system easy to use. However, 11% of students from both groups noted that the system is not easy to use.

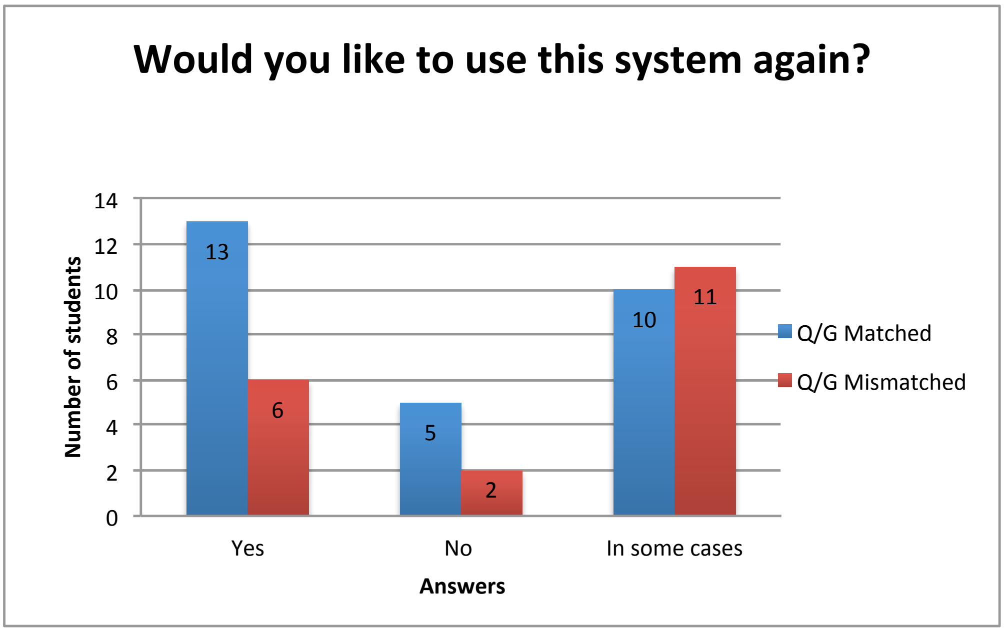

Figure 26: Distribution of matched and mismatched groups in Q/G dimension with respect to their answers for question 2 in student opinion survey

A high number of students (46%) from the matched group, and 58% from the mismatched group preferred to use the system again. A low number of students from both groups did not want to use the system again.

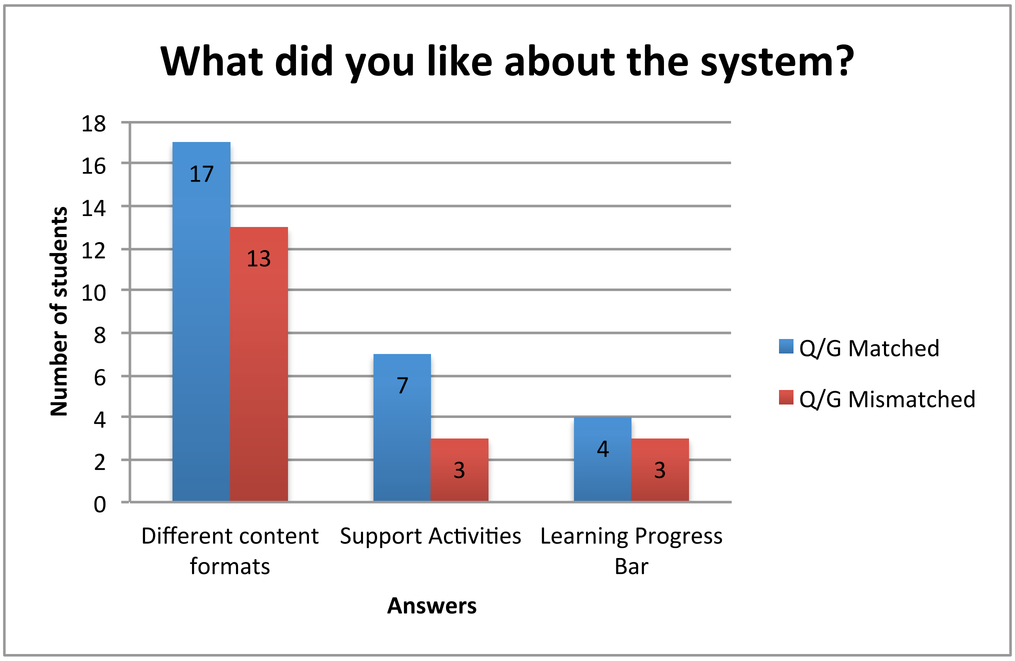

Figure 27: Distribution of matched and mismatched groups in Q/G dimension with respect to their answers for question 3 in student opinion survey

Similar to student choices in other dimensions, while the majority of students (61% of the matched and 68% of the mismatched group) enjoyed having different content formats, a low number of students enjoyed the support activities.

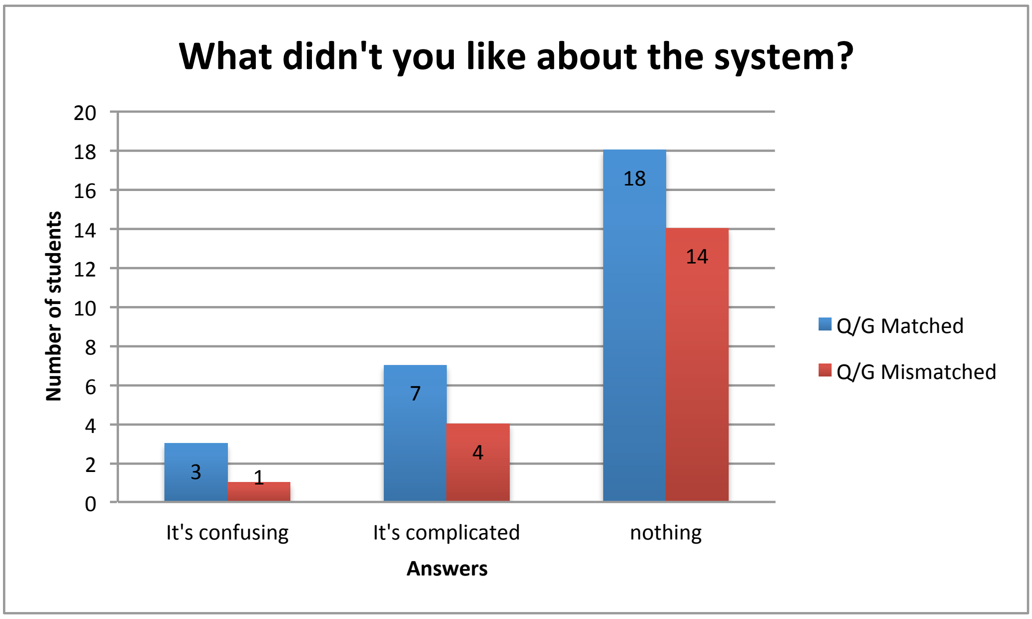

Figure 28: Distribution of matched and mismatched groups in Q/G dimension with respect to their answers for question 4 in student opinion survey

Most of the students from both groups (64% of the matched group and 74% of the mismatched group) recorded that there is nothing that they did not like about the system.

5.3 Discussion of the Findings

This study aims to investigate the impact of metacognitive skills demonstrated by students on their learning performances. As discussed earlier, the 'metacognition' is defined as students awareness of their own way of learning, and use of the TEL environment, which provides a free selection on learning activities and support activity tools, accordingly to study the course subject.

According to Stel and Veenman (2010) people develop monotonically in metacognitive skills and show a continuous growth of metacognitive skills with age, paralleling their intellectual growth. The development of metacognition starts at the age of 3 to 5, when children show both verbal and non-verbal metacognitive behaviours during problem solving, and develop what has been termed Theory-of-Mind (Flavell 2004; Veenman, Hout-Wolters and Afflerbach 2006). However, it is widely accepted that in formal learning cases the development of academic metacognitive skills emerges at the age of 8 to 10 years and continues to develop during the following years (Veenman 2012; Lai 2011). In addition, particular metacognitive skills (e.g. monitoring) become more advanced than others (e.g. planning). The ability to regulate cognition with improvements in monitoring appears at 10 to 14 years of age (Lai 2011). It has been reported that metacognitive skills develop on a very basic level during early school years, however they become more sophisticated and academically oriented when students find it necessary to use explicit metacognition in formal education (Veenman, Hout-Wolters and Afflerbach 2006).

By taking account of the continuous development and improvement of metacognitive skills over time, and with age, it should be mentioned that in this study the simple act of choosing one learning activity over another involves the use of metacognitive skills: however, achieving positive learning outcomes through the selection of learning activities suggests the use of metacognitive skills at an effective and advanced level on the part of the students.

Taking into account the statistical test results in the previous section, matched and mismatched groups' learning achievements in relation to their use of metacognitive skills are discussed in the following subsections. In order to avoid bias in those results, scientific experimental models and the quantitative research method were applied, as described earlier.

5.3.1 Active/Reflective Mismatched Group Performed Better on the Recall Test than Active/Reflective Matched Group

The results of the analysis show that students who selected a way of learning that does not match their learning style (the mismatched group) in the active/reflective dimension perform better than the matched group on the recall-type assessment test, when students are grouped based on recall- and retention-test results. Results of the statistical analysis also confirm that pre-knowledge of students about the subject and social-structural factors do not have any impact on their learning outcomes. In addition, with respect to the student opinion survey results, most of the students in this group find the system easy to use and they do not encounter any problems. The remarkable result from the survey is that all of the students agreed to use the system again as none of them answers “No” to the question “Would you like to use this system again?”.

This finding can be interpreted to mean that, as in a case of mismatch between student learning styles and the learning environment, students are able to find their own way of learning in such formal education situations. This interpretation is discussed in greater depth below.

When the learning environment cannot meet the learning needs of this specific group of students, they need to find their own way to study the subject. This may be an indication of a type of metacognition that students demonstrate to achieve positive learning outcomes. As stated before the definition of metacognition in the literature includes student learning and awareness of their way of learning, how they control their strategy selection, and change plans when needed. Students who are aware of their motives, responsibilities and personal cognitive processes, and have control over their learning strategies, use metacognition (Phelps et al. 2002). Therefore, it is possible to argue that students may have used/developed learning strategies that help them to be successful within this learning environment. The selected strategy was successful not in the sense of knowing explicitly their own learning styles, but knowing their own way of learning. Riding and Rayner’s (1998) observation that, in the case of mismatch, individuals can develop learning strategies to deal with learning environments that are not suitable to their learning styles, helps to explain this finding. They also claim that learning strategies can be developed and modified to meet the demands of an environment, as opposed to learning styles with relatively fixed characteristics.

Free text comments from student opinion survey are analysed using the Wordle tool and the words “good”, “system”, “different” and “idea” are extracted from student comments. This indicates that students in this group enjoy using the system that they like the idea of studying the subject in this way with different content formats. Therefore, it can be argued that when students enjoy using such a system for acquiring knowledge it encourages them to find a way to study the subject in a state of a mismatch between the learning environment and their learning style.

5.3.2 Visual/Verbal Matched Group Performed Better on the Recall Test than Visual/Verbal Mismatched Group

Statistical analysis show that students who select a way of learning that matches their learning style (the matched group) in the visual/verbal dimension perform better than the mismatched group on the recall-type assessment test when students are grouped based on their recall- and retention-test results. Results of the statistical tests also confirm that pre-knowledge of students about the subject and social-structural factors do not have any impact on their learning outcomes. Moreover, the student opinion survey results show that most of the students in this group find the system easy to use and that they do not have any complains. Another prominent result from the survey is that the majority of students in this group like having course contents presented in different formats.

This specific group of students demonstrate an effective use of metacognitive skills to select a way of learning in agreement with their learning styles. Students receive a pass mark when they use the environment with respect to their learning styles. As a conclusion it is possible to state that students produce positive learning outcomes when they use advanced metacognitive skills.

As can be seen in the Appendix, the free text comments in opinion survey of visual/verbal matched group student the words “good”, “different” and “learn” are emphasised on Wordle. This show that this group of students thinks the system is good and they like the different content formats. Making the right selections on different learning content formats is important for these students as the idea to add different content formats is to support the visual/verbal type of students.

5.3.3 Sequential/Global Matched and Mismatched Groups did not Show Significant Difference on Learning Outcomes

The test results demonstrate that students in the sequential/global matched and mismatched groups do not perform with any significant difference on either the recall and retention type of assessment tests, when they are grouped based on their recall- and retention-type assessment test results. Therefore, it can be argued that students who do not show significant differences at the metacognition level also do not display differences in learning outcomes within this context. These groups do not show any evidence of the use of effective metacognitive skills leading to a positive impact on their learning outcomes.

5.4 General Discussion of Findings

As discussed in previous chapters of this thesis, there appears to be a comparatively small body of literature specifically addressing the impact of student metacognition on their learning outcomes in TEL environments by using a learning style model as an assessment method. Most of the research focuses on identifying student learning styles and providing adaptive learning in order to compare matched and mismatched student groups' performances. In addition, as stated in section 2.7, some researchers (for example, Kirsh 2005) suggest that the use of metacognition can be supported by the visual design of the TEL environment. Alternatively, Azevedo and Cromley (2004) tested student ability to regulate their learning by allowing them to establish their goals in order to improve their learning. In another study carried out by Zimmerman (2008), pre- and post-questionnaires are included to determine whether motivation and learning strategies are used in order to measure student self-regulation. Stel and Veenman (2010) investigate student development of metacognitive skills, as well as the generality- versus domain-specificity of developing metacognitive skilfulness, through analysing Thinking-aloud protocols. They divide metacognitive skilfulness into four subscales: Orientation (O), Planning and Systematic orderliness (P), Evaluation (Ev), and Elaboration (El).

Metacognition is recognised by many researchers (Flavell 1976; Phelps et al. 2002; Barak, 2010) to be significant for learning. Metacognitive skills are understood to be an important predictor of learning performance (Stel and Veenman 2010). The purpose of the present study is to determine the impact of metacognition on student learning performances, and on the basis of it, to generate recommendations for designing TEL environments. The results of the analysis and the comparison of student achievements on the recall test show that the use of metacognitive skills at an effective level is important for their learning.

Effective metacognitive skills, which are expressed while studying the course within the formally designed TEL environment are crucial for student success. Those students who used effective metacognitive skills can successfully recall the learned information. However, students who fail to use metacognitive skills at an effective level did not show any difference in learning achievements. Therefore, when a student uses metacognitive skills effectively there is a high possibility that the student can achieve success in their learning.

Students, who demonstrate an understanding of their own way of learning and make selections that meet their learning needs, are more likely to achieve positive learning outcomes. Making selections among the alternatives that enable them to undertake the academic work provides evidence of understanding what works best for them. In the TEL environment, the success of students can be a reflection of the effective use of their metacognitive skills. Recognising what enables them to be successful in their learning is the result of using metacognitive skills effectively.

The findings of this study confirm the importance of metacognition in TEL and suggest that metacognition needs to be encouraged as a central component of instruction, as it became apparent that the effective use of metacognitive skills produces positive impacts on student learning outcomes.

The outcomes of the main experiment are inconclusive as far as the use of learning styles as a design arbiter for learning environments is concerned, as the results that show statistically significant achievements in learning performance are associated with both matched and mismatched groups. The matched group that performed better show evidence of an effective use of metacognitive skills, thus confirming the original premise of the research. However, some of the findings provide us with an alternative outcome in relation to metacognition, namely that some other mechanism was at work in enabling the mismatched group to perform better, which can be described as a learning strategy. Therefore, the argument can be made that learning strategies were applied, which is evidence of the use of enhanced metacognitive abilities. In addition, this shows that learning styles are not an effective arbiter for designing learning environments on their own.

Some students perform well in contrast to their learning styles and others perform well consistent with their learning styles however, all of them show evidence of the effective use of metacognitive skills as they manage to find a way to be successful. It is reasonable to make an argument that the selection of learning activities is not only a reflection of learning styles but in fact it may have also resulted from applying a learning strategy. Selecting appropriate learning activities is fundamentally based on metacognition. So, students in the mismatched group may have figured out what works for them and developed their own learning strategies.

It is a reasonable to conjecture that, where students achieve positive learning outcomes by selecting learning activities that do not match their learning style, they appear to be applying learning strategies successfully and hence effective metacognitive skills. Students may have used or developed learning strategies to overcome mismatches between their learning style and learning environment provided to them. This finding takes the debate one step further to address the question of whether learning strategies are responsible for improving performance. It has been discussed in the literature review chapter that a number of researchers, e.g. Riding and Rayner (1998), Matthews (1996), and Kolb (1984), claim that students tend to be creative and grow personally when confronted with learning materials that do not suit their learning styles. Also, learning strategies are reported to be developed and modified to meet the demands of the environment, a quality which contrasts them to the relatively fixed nature of learning styles. The findings of this study agree with these statements but not with the statements by Felder (1993) and Felder and Soloman (1997), which claim that it is difficult for students to learn when educators fail to present material in their preferred way. However, Felder and Spurlin (2005) argue that student previous learning experiences and environmental factors may create preferences and strategies rather than styles, which can be supported with the findings of this study. Barak (2010) reported that metacognition involves the use of strategies to control cognitive activities in order to meet a particular goal.

The outcomes of this study need to be considered with regard to the extent to which they could potentially improve the design of adaptive learning environments. The research aimed to use learning styles as a means of discriminating between learners, and thereby designing a learning environment that provides learning activities to learners based on their learning style. The main reason behind the idea of providing adaptive learning is to help students to learn better while working within a learning system that understands their learning needs and offers an environment that suits multiple approaches to learning. Existing learning style theories can be used to profile students through a questionnaire. When designing an adaptive TEL environment that supports learning styles and allows students to freely select their learning activities, examining the behaviours of students in terms of immediate understanding and information retention and determining the consistency with their learning styles, can be described as metacognition. However, students who made inconsistent selections with regard to their learning styles appear to be applying different learning techniques, which also helped them to be successful. This can be further enhanced by examining the behaviours of students, with regard to how they absorb information, in order to further improve the adaptability of the system. The results of the study demonstrate that some students utilised the provided learning activities and environment in a different way than their learning style profile in order to achieve their goals. In light of these findings, future studies would do well to focus more on how learning strategies are developed and executed.

A further question that arises from the findings is whether students adopted learning strategies consciously, and based on knowledge of how they learn, or intuitively. This opens up another debate based on the nature versus nurture paradigm.

The nature versus nurture paradigm deals with issues of individual differences in metacognitive abilities, posing the question of whether these are caused by biological differences or differences arising from learning experiences (Woolfolk and Margetts 2007). In the literature it has been reported that students can develop metacognitive strategies as part of their usual learning or students can be trained to prepare for future learning. Although information about student background (pre-university education, nationality, etc.) is collected in this study, it is not enough to draw conclusions from this information alone. Therefore, reasons underpinning differences in metacognition remain somewhat elusive and they are beyond the scope of this study.

A number of statistical analyses were carried out for this research and results are presented in this chapter. Furthermore, an extensive discussion of the findings relating to student learning achievements is provided. Therefore, the next chapter aims to summarise this study and provide concluding remarks as well as some future directions that can help extend this research.

CHAPTER 6 Conclusion and Future Work

In this chapter a summary of the work conducted during this research is provided. The first section summarises the performed research and highlights its contributions. The second section goes on to present the limitations of this study and offers a variety of ways of expanding its scope into different areas.

6.1 Summary

The main aim of the research is to investigate the impact of adaptive TEL environments on student learning. Taking this into consideration, the research is started by posing two central research questions and the goals of the study are articulated in Chapter 1. However, the contents and aims of the research is evolved as it progressed, shifting its focus to the impact of metacognition on student learning outcomes: this amended focus is developed following a review of the existing literature and following the execution of exploratory experiments. The evolution of the research is explained more fully in the following paragraphs.

Chapter 2 examines the main issues regarding the concepts of TEL environments, adaptation and metacognition. A review of the research to date in the field confirms the positive effects of ICT and internet technologies on student learning. It is also shown that adaptation with regard to individual learning needs is one of the most important topics for scholars working in the field of information technology (IT) and e-learning today. In light of these findings, the field of adaptation regarding existing adaptive e-learning systems is explored in greater detail, which let the study to uncover instances of the use of learning styles for providing adaptation, a common approach to understanding student preferences. Furthermore, the methods to identify learning styles of students and create a student model are examined. At this stage of the research two TEL environments (adaptive and non-adaptive) were designed based on, and informed by, the extensive research is carried out in the field, with a view to fulfilling the original research objectives (explained in chapter 3). Then, an exploratory experiment is conducted. Key findings from this experiment showed that in order to collect the required student data to achieve the aims of this study, the design of the experiment needs greater development in terms of monitoring, supporting and encouraging the students. It is also revealed that it is possible to deduce learning styles of students when they are given the opportunity to freely select learning activities. Having recognised the number of issues regarding the student learning behaviours, it is also became apparent that the research required a greater focus, which led to a redefinition of the research questions and the development of an amended research question: "How do metacognitive skills demonstrated by students influence their learning performance within a formal technology enhanced learning environment?". Accordingly, an additional literature review is carried out focusing on the impact of metacognition on student learning, in which metacognition is considered as consistent with the selection of learning activities with the learning style ascribed to the individual via learning styles questionnaire. In order to investigate the relationship between metacognitive skills demonstrated by students and their learning performance in terms of information recall and retention, the non-adaptive TEL environment that is used in the exploratory experiment is improved and used in the main experiment to track student learning behaviours. In this environment students are provided with all available learning activities to give them an opportunity to decide how to study the subject and take control of their learning. The learning outcomes are assessed with a recall-type assessment test immediately after they are finished with their studies and a retention test took place two weeks after they had completed the learning session (explained in chapter 4). The collected student data, including questionnaire results pertaining to learning styles, actions on each learning activity and assessment test results are analysed, and the contributions of this study are presented in the following paragraphs.

The general findings show improvements in learning outcomes by those students who used effective metacognitive skills and could recall the information better than those who did not. In order to eliminate the external factors that might have had an impact on students learning outcomes, additional data about pre-knowledge of students and social-structural factors are considered while drawing conclusions from this study.

Analysis of the data from the main experiment which is presented in chapter 5 demonstrate statistically significant results in a number of cases, and these suggest positive learning outcomes for students whose selection of learning activities is consistent with their learning style, as well as evidence of positive learning outcomes for those whose selection of learning activities is inconsistent with their learning style. This suggests that learning style would not be a good arbiter of learning performance on its own in TEL. Results also suggest that the designed TEL environment can be utilised as a precursor to providing adaptation in TEL, and as a support for developing metacognitive skills, by identifying both consistency with learning style and learning performance on free-selected learning activities. Potentially, it can be used to measure levels of metacognition to support adaptation and personalisation of TEL.

6.2 Contributions

In general, findings from this research can contribute to the body of knowledge on adaptive learning in terms of their usefulness for designing an adaptive TEL environment, as well as their contribution to an understanding of the concept of metacognition, specifically regarding the promotion of metacognitive skills in TEL environments.

This research has provided some clear evidence for instructors and instructional designers who wish to design a TEL environment that supports students in their attempts to use and develop effective metacognitive skills in order to take more responsibility for their own learning. Results from the analysis revealed that successful students used effective metacognitive skills in order to complete their studies and achieve their learning goals. Therefore, in this study it is clear that metacognition play a critical role in successful learning in this TEL environment and this argument can be extended to suggest that this may true for all TEL environments as it has also been demonstrated in non-TEL environments (e.g. Flavell 1976). This research can assist educationalists in understanding the importance of metacognition in learning, and in considering how technology can be used to better allow students to develop their metacognitive skills and thereby develop and apply cognitive strategies.

The work in designing and developing a TEL environment that supports students in using their metacognitive skills, based on the Felder and Silverman Learning Style Theory, is novel due to the fact that no such approach had been previously taken when this research began. The consideration of the impact of metacognition on student information recall and retention, in particular the relationship of this process to FSLSM, is also novel and represents the first attempt to establish a relationship between metacognition and FSLSM. The combination of these outcomes can form the basis of a design model for future adaptive TEL environments where learning materials, especially the four different formats of learning contents, and activity selection based on a learner's learning style, can be applied to generate more effective learning. The applied learning design approach, including the learning activities, can inspire future researchers and instructional designers to encourage student use of metacognitive skills. Also, this approach can be used as a basis for designing an adaptive and personalised TEL environment.

In addition, the findings regarding student ability to use or develop effective metacognitive skills in the event of a mismatch between their needs and the learning environment can guide educationalists in building learning environments that encourage students to learn how to learn. Shen and Liu (2011) argue that, in light of a diverse range of e-learning environments in existence, and today's information technologies, "how students can choose useful information and monitor their self-learning process is an issue that educators should pay attention to" (Shen and Liu 2011:140). Vogel-Walcut and Fiore (2010) also suggest that in order to facilitate student overall retention and use of knowledge, a major goal of education must be to assist students in monitoring their learning. It has been proven that the level of applied metacognitive skills within the TEL environment has a positive impact on student achievements. Therefore, it is essential that students use strategies such as identifying the main points in a given task or dealing with a task from start to finish (Barak 2010), and be motivated to use developed or newly acquired, self-regulatory strategies effectively (Matuga 2009).

Another finding of the study suggests that instructional designers need to be mindful that students have the capacity, and may need to be monitored and encouraged to use, metacognitive skills. This suggestion is in agreement with Flavell (1976) who drew attention to the possibility of metacognitive-skill acquisition through instruction and learning. Hartman (2001) argued that metacognition is not a fixed trait and, can be learnt and improved by practice, which leads to successful learning with other learning skills, including reflection. Therefore, these findings will be beneficial for designing TEL environments to promote metacognitive skill development, leading to an improvement in student learning.

Furthermore, the experimental model developed in this study could be adopted to provide both a design mechanism for an adaptive learning environment and, potentially, a learning environment explicitly supporting the development of metacognitive skills. The experimental model can be described as a methodological approach to capture the adaptive requirements and the level of metacognitive ability of individual learners, through the use of a learning style analysis, free selection of learning materials within an appropriately constrained subject choice, and recall and retention tests. The information captured from this methodological approach could then be used to adapt a learning environment to support a learner, and to provide feedback and support in the development of metacognitive skills.

In terms of practical implications, the approach and the system used in this study can be utilised to help students develop their metacognitive skills. The TEL environment developed for the main experiment explicitly promotes metacognitive skills. Based on student learning activity selections, it is possible to determine the level of metacognitive skills by showing how effective they are and help students improve their skills by making better selections. Experimental data collected through the TEL environment shows the learning behaviours of students thus it is possible to determine learning strategies of students. For example, skills and strategies that students in mismatched group used can help other students to develop learning strategies. Therefore, advice can be provided to students on the basis of what works for them by using this experimental model with different course materials. In addition, individual feedback can be given to those who do not perform well by analysing their learning behaviours.

The literature suggests (Wagster et al. (2007) and Hartman (2001)), metacognitive skills can be gained or developed through training and the experimental model used in this study can be used as a training model for metacognitive skills. The model makes it possible to find out how students can make appropriate selections for their learning and can be used for different courses. This research demonstrates a model for learner development focused on helping them to develop metacognitive skills for future learner-centric learning TEL environments.

A key point is that students need to have effective metacognitive skills to take control of their learning, as the whole principle of TEL is to move towards student-centred learning. Furthermore, this approach allows educators to decide if there is a need for adaptive learning as when students use their metacognitive skills effectively, all available learning materials can be provided to them to allow them to choose their own route.

MOOCs have become popular and expected to grow quickly. According to NMC Horizon report (2013), one of the most appealing promises of MOOCs is that they allow students, life-long learners, and professionals to acquire new skills and improve their knowledge. The report also draws attention to the need of determining how to best support collaboration, interaction and assessment of students (Johnson et al. 2013). “The notion of thousands and even tens of thousands of students participating in a single course, working at their own pace, relying on their own style of learning, and assessing each other’s progress has changed the landscape of online learning” (Johnson et al. 2013:11). Considering these recent developments in online learning and discussions about MOOCs, this study may inform educators to support their learners by determining their metacognitive skills. Most of the time students need to work alone and at their own pace in MOOCs therefore, helping students with the experimental model used in this study to understand their own way of learning may improve their learning achievements. As students are provided with free selection of learning materials in MOOCs, this experimental model can be used to advise students on accessing the learning materials in an effective order or way, depending on the type of MOOC. When experimental model of this research used to collect information about learning behaviours of students, it is possible to detect whether students accessed learning materials in a way that made them to achieve positive learning outcomes.

This research contributes to the literature by showing that learning styles may not be good arbiter to design TEL environments, generating some evidence for the use of cognitive strategies, demonstrating the importance of metacognition on students selections on learning materials, and defining the methodological approach to design a TEL environment that could be used to help students to develop metacognitive skills and thereby cognitive strategy.

6.3 Limitations

The time and resources available for the experiment was limited to one practical hour and one subject of the course. The approach presented in this study is tested with a specific course and involving students from computing departments. Therefore, it might be interesting to confirm the results by applying the test to different courses and by using students from other departments. The approach taken to detect students who use effective metacognitive skills can be applied to different courses by developing appropriate learning materials. A high number of students participated in this study and because of the break down of the learning styles the data from a small number of students is used for each analysis, which provided statistically significant results. It would be useful to conduct further analysis with data from other, potentially larger groups of students.

The Rule-based Method was utilised as it was considered the most suitable way of detecting student learning styles in this context and the results can be confirmed utilising other methods (e.g. Bayesian Networks) to provide further confirmation.

Specific scientific experimental model is used to collect numerical data in order to answer the research questions and the quantitative research method is used to draw conclusions for this study. However, different methods and experimental models could be used to reproduce this experiment to confirm the conclusions.

6.4 Future Work

In this section, possible future directions for the research and appropriate areas for further study are presented. The findings and prototypes developed in this research can be developed further with regard to providing adaptive learning and encouraging student use of metacognition.

During the undertaking of this research, a number of fields are investigated in the literature review chapter for the purpose of designing and developing an online learning environment. The investigated areas include: the impact of TEL Environments on learning, how a TEL environment can be designed to support student learning needs, and metacognitive skills. In addition, the investigation of student learning behaviours contributes to the field of adaptive learning environment design.

One aspect of understanding student's learning needs, and designing a TEL environment accordingly by including various learning activities, is considered in this thesis. A TEL environment with a particular learning design approach is developed as a result of investigations into various areas. However, this constitutes a single and limited approach, and future research might wish to expand the scope of this study by using different learning design approaches.

The research could be improved by incorporating different types of learning activities that recent Internet technologies offer. For example, Wiki and concept-mapping tools, that promote knowledge construction and critical thinking, could be added to the learning environment in order to support students with specific types of learning styles. Clariana and Wallace (2007) suggest that concept maps can be used to promote the development of metacognitive skills and that, by drawing concept maps, students can identify and contemplate relationships between multiple concepts. Thus, concept maps are considered as one of the effective metacognitive tools for promoting metacognition. Also, it has been noted that visualising course contents and interpreting diagrams are important metacognitive skills for learning transfer (Shen and Liu 2011). Future researchers might wish to investigate the application of these tools to explore how to use the advantages and limitations of each tool, in terms of supporting the development of student metacognition.

Future work in the research field might wish to investigate the relationship between metacognition and learning strategies, discussed earlier in this chapter, as one of the findings of this study showed that there might be a higher degree of association between metacognitive skills of students and learning strategies rather than between metacognitive skills and learning styles.

Furthermore, as stated earlier, and in reference to the nature-versus-nurture debate, students may use or develop metacognitive skills as part of their usual learning or they can be trained to learn how to develop metacognitive skills. Therefore, it might be exciting to investigate the development of tools and environments to support the development of metacognitive skills.

The development of TEL is now predominantly focused on more formal student-centric and less formal learner-centric environments, distributed and distance learning, and massive on-line participation. All of these require the student to take far greater control of their own learning experience, and require to be achieved without the effective application of metacognitive skills by the student. There is, therefore, a need to explicitly encourage and develop metacognitive skills in students and if it is accepted that this is possible, this research provides both evidence in support of that argument and a route forward to achieving it.

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Appendices

Appendix 1 Pre-knowledge Test Questions

1. At what level do you consider your computer skills?
    a. Basic
    b. Intermediate
    c. Advanced

2. Have you used Flash before?
    a. Yes
    b. No
    c. Very little

3. Have you used Sound in Flash before?
    a. Yes
    b. No
    c. Very little

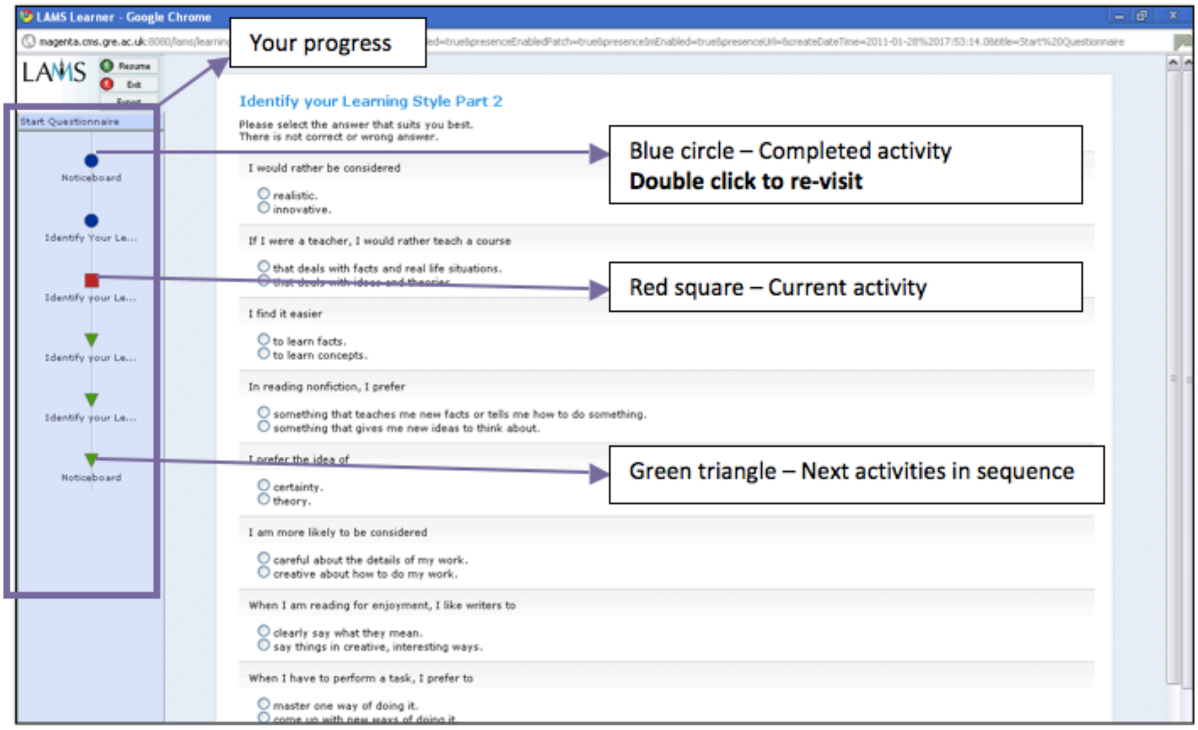
4. Do you have experience of using Sound in another program?
    a. Yes
    b. No
    c. Very little

5. Do you have experience of using any other animation program (i.e. Scratch)?
    a. Yes
    b. No
    c. Very little

6. If yes, at what level do you consider yourself?
    a. Basic
    b. Intermediate
    c. Advanced
    d. No, I haven't

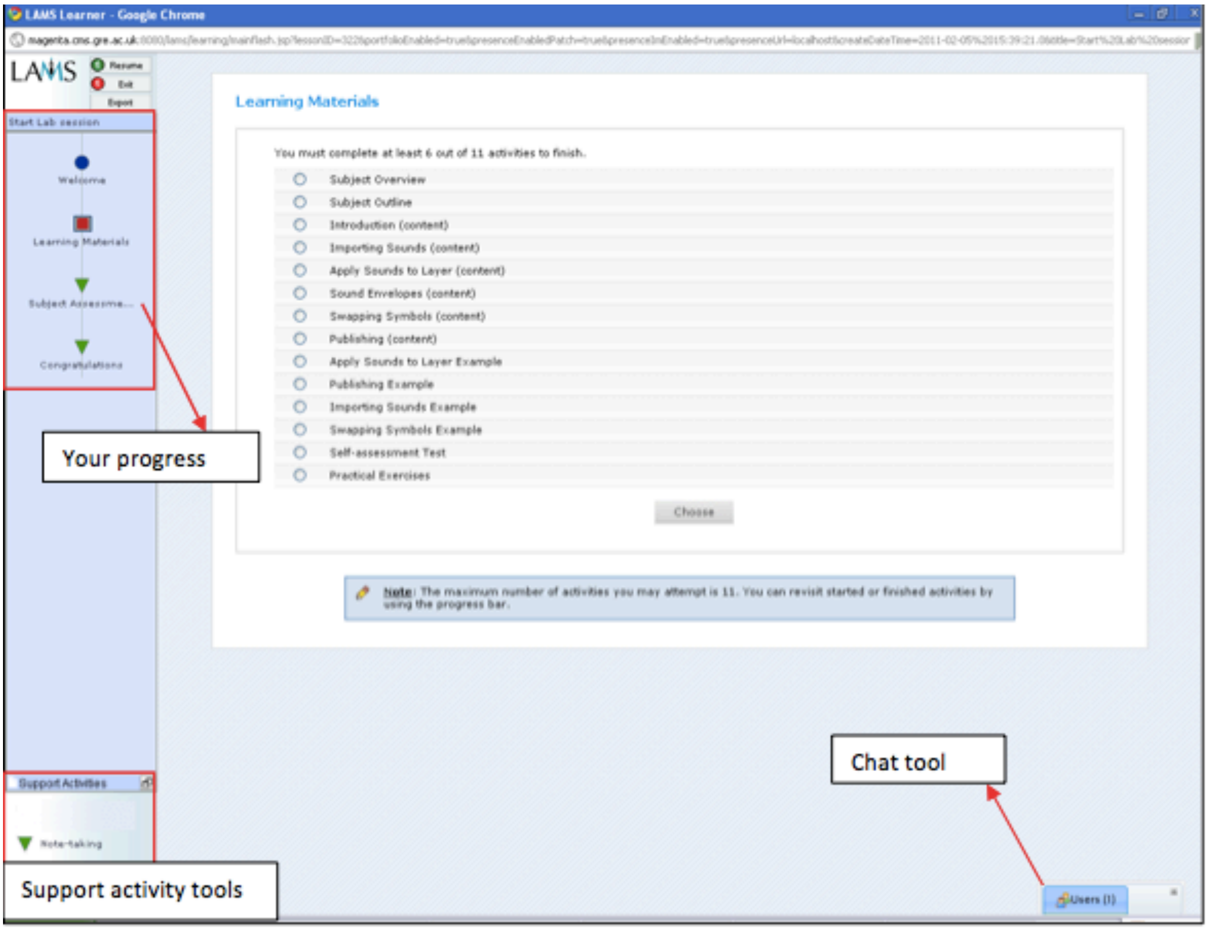
Appendix 2 Non-adaptive Learning Environment User Interfaces

Learning Event 1 and Instructions to Students - Learning Styles Questionnaire

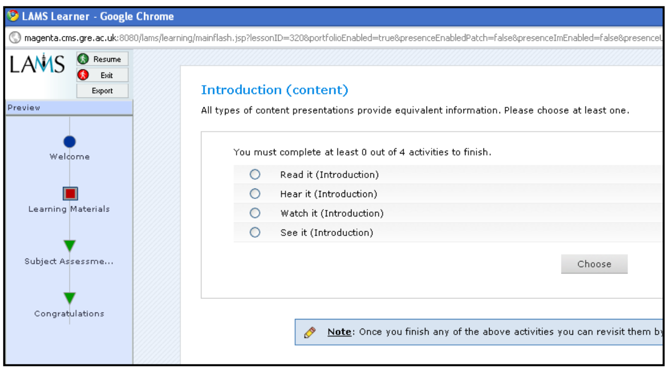


Learning Event 2 and Instructions to Students

After clicking "Lab Session - Session Two" link you will see the following screen after welcome page:



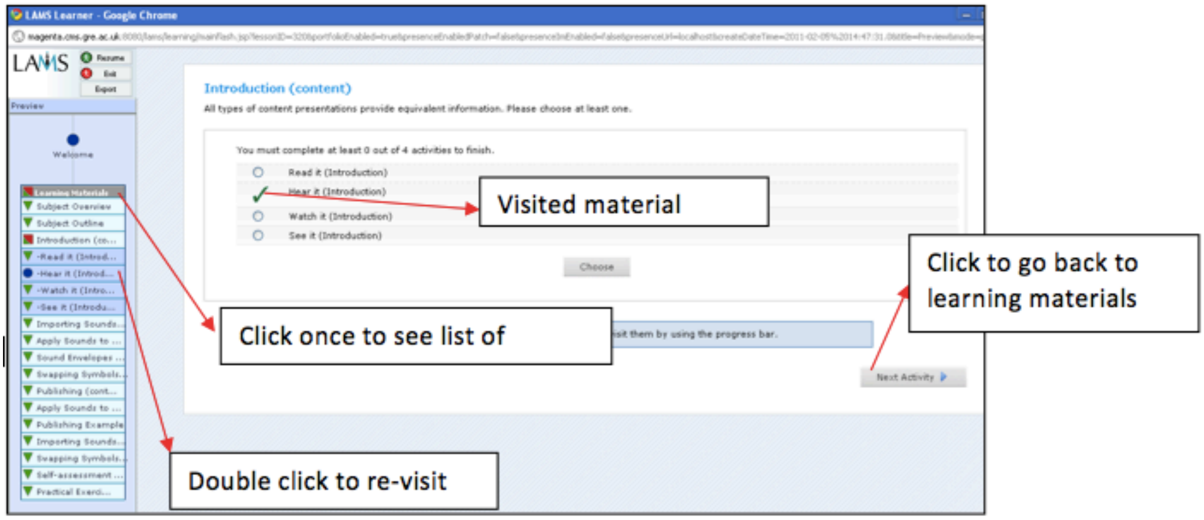
When you select any of the contents you will see 4 options:



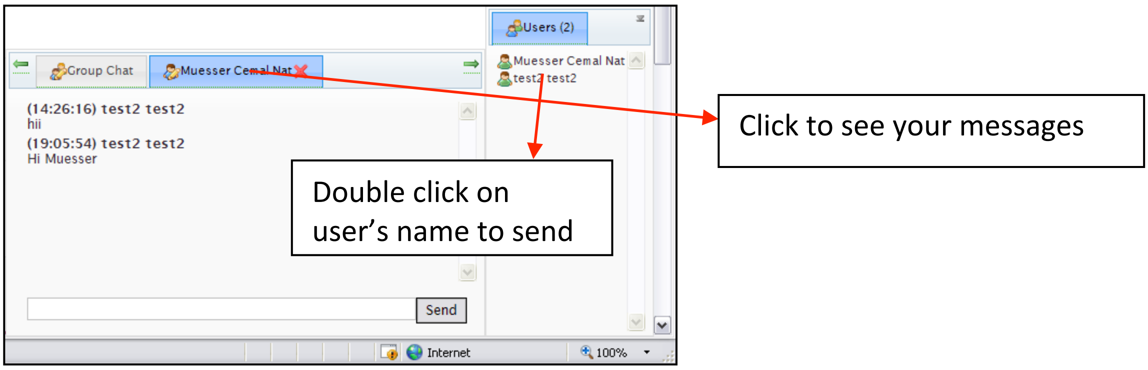
Each sub-subject has presented in 4 different formats
(All of them provide exactly the same information)

1. **Read it (Text)**
2. **Hear it (Audio)**
3. **Watch it (video)**
4. **See it (picture)**

After visiting the specific content you will see the following screen:



At the bottom right there is a chat tool that you can have 1-1 or group chat. You need to click on “Users” to start.



Appendix 3 Student Opinion Survey

Your comments will not affect your mark or assessment results. Feel free to answer questions.

1. Did you find the system easy to use?
    a. Yes
    b. No
    c. Average

2. Would you like to use this system for your studies again?
    a. Yes
    b. No
    c. In some cases

3. What did you like about this system?
    a. Different content formats
    b. Support activities (chat, discussion forum, etc.)
    c. Learning progress bar

Other - please specify

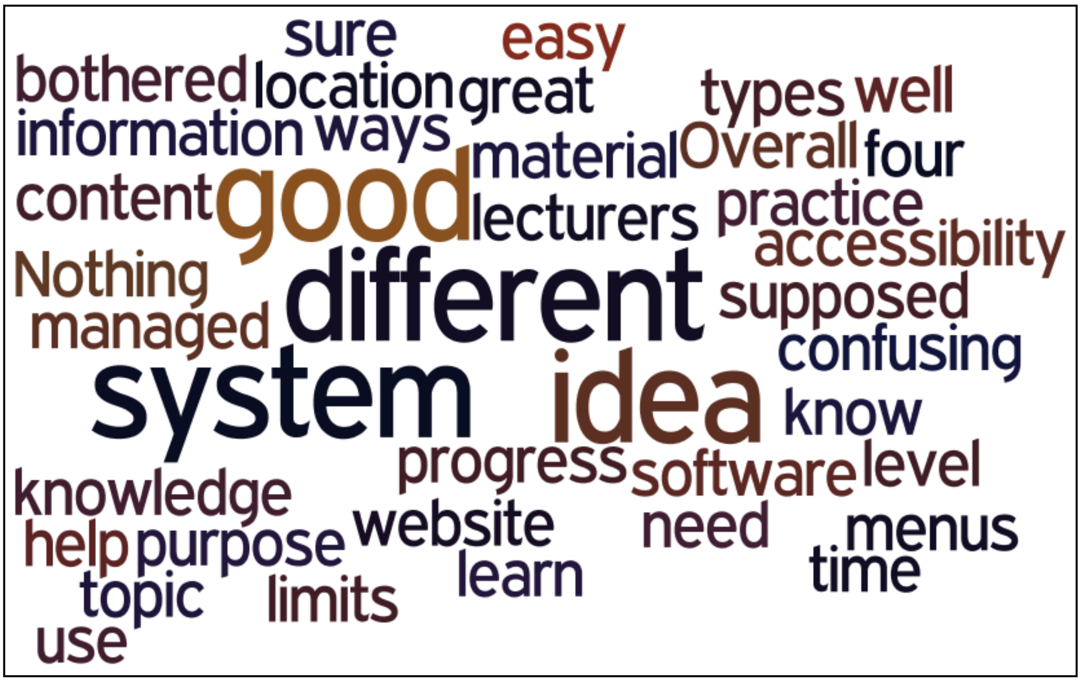
4. What didn't you like about this system?
    a. It is too complicated
    b. It is confusing
    c. It is hard to use

Other - please specify

5. Any other comments or suggestions?

Appendix 4 Wordle Outputs

A/R Mismatched Group



V/B Matched Group

Appendix 5 HCI Conference Paper 2011

Impact of Metacognitive Awareness on Learning in Technology Enhanced Learning Environments

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Abstract
With the advent of internet technologies and the closer integration of mobile and ubiquitous devices, learning and teaching has changed the way we view the learning process. Indisputably, there are many ways of using technology to support students' learning which enables them to manage the pace, time and place of their learning. Technology enhanced learning (TEL) can place students at the centre of the learning process, but this means that students need to take more responsibility for their learning. The literature refers to this as self-directed and self-regulated learning (Liu, Gomez, Khan and Yen, 2007; Nicol, 2006). Students can take more control over their learning and develop leadership of their own 'learning curve'. Self-directed learning includes management of the learning materials, monitoring learning progress and regulating cognitive learning styles. However, this requires students to develop metacognitive strategies so they can identify their own learning styles in the appropriate formal and informal learning situations. This paper aims to investigate the impact of students' metacognitive awareness on their learning outcomes within technology enhanced learning environments and concludes that the design of a TEL environment and the development of students' metacognitive skills have a direct bearing on learning performance.

Keywords
Technology enhanced learning, self-regulated learning, metacognition, learning strategies.

Introduction
The emergence of the internet and latest Information and Communication Technologies (ICT) have brought a whole new dimension to almost every aspect of society and in particular, to higher education. Learning and teaching in many disciplines now occurs within technology enhanced environments. ICT is used as a means for engaging in such activities as communication, socialisation, networking and researching but its unique affordances provide new approaches to the design of interactive learning environments. In such environments, there are many factors that can influence learning. A learning environment has a variety of elements including pedagogical approach, learning materials and activities as well as addressing students' learning needs. Motivation and students' learning styles are additional important factors that influence learning (Mulwa, Lawless, Sharp, Wade &

Sanchez, 2010). In this paper the authors discuss how the design of a TEL environment and students' metacognitive skills can affect learning performance.
In most TEL environments students have the freedom to navigate through a wide range of resources, represented as text, graphics, animation, audio, and video, which are commonly presented in a non-linear way (Azevedo, Cromley, & Seibert, 2004; Mulwa et al, 2010). Learning in TEL environments require students to regulate their learning by making decisions about what and how to learn, how much time to spend on the material, and determining whether the material has been understood or not (Azevedo et al, 2004). TEL allows students to take more control over their learning i.e. it provides a more heutagogic, as opposed to pedagogic/andragogic, model of learning and therefore works best for students who are motivated, self-directed, well organised and strategic. The current approaches used in TEL are less effective for those who require more support and direction for their learning (Flynn, Concannon & Bheachain, 2005). Corliss and Spitulnik (2008) state that "many students lack the self-regulated learning strategies needed to be successful in these types of learning activities".
Self-regulated learning is a form of metacognitive guided learning whereby students set learning goals for themselves, monitor their progress, regulate and control their cognition (Azevedo & Cromley, 2004). Self-regulation is the ability to develop knowledge, skills and attitudes that can be transferred from one learning environment to another as well as to a leisure and work environment (Boekaerts, 1999). Students who are aware of their learning strengths and weaknesses are self-regulated students (Benmimoun & Trigano, 2009). Self-regulated students can organise, manage and adapt their thoughts into skills that are required for learning (Shannon, 2008). They continuously monitor their progress towards a goal or outcome and redirect efforts when necessary (Shannon, 2008). Students need to be aware of their own thought processes and monitor the effectiveness of their learning strategies to develop an ability to self-regulate (Zimmerman, 2008). Furthermore, it is essential that students attain strategies such as identifying the main points in a given task, asking questions or dealing with a task from start to finish (Barak, 2010), and be motivated to use developed or newly acquired self-regulatory strategies effectively (Matuga, 2009).

Within TEL environments, students' achievement is influenced by the level and effectiveness of applied self-regulation techniques, or the ability to plan, monitor and evaluate their own behaviour and learning strategies (Matuga, 2009). A study by Azevedo et al. (2004) investigated whether undergraduate students could regulate their own learning about the circulatory system using a hypermedia environment. Results demonstrated that students who regulated their learning by using effective strategies, monitored their understanding, and adapted their time and effort, showed a significant improvement in their learning. By contrast, those who used less effective learning strategies limited their ability to manage their metacognitive monitoring activities and failed to show a significant improvement in their learning (Azevedo et al, 2004).

Azevedo & Cromley (2004) provide evidence to show that not all students have the ability to regulate and deploy certain key strategies during their learning. However, the presence of a tutor who assisted them in establishing goals and using effective strategies for regulating their learning, created a significant improvement in learning. Students who were given a list of goals to guide their learning were less effective at regulating their own learning (Azevedo & Cromley, 2004).
A study to measure students' self-regulation was carried out by Zimmerman (2008) who employed learning diaries, which were collected at the end of each week, to structure a series of questions regarding events during a study session. Students were asked to complete a questionnaire that included items about motivation and learning strategies at the outset and at the end of the study. The control group of students were asked to complete a pre-test and a post-test but did not receive self-regulatory training or use the diaries. Zimmerman (2008) reported that students who received self-regulatory training displayed significant improvements in intrinsic motivation, self-efficacy, effort, attention and self-motivation areas whereas those in the control group showed only increases in self-motivation.

Metacognition

The engine that drives self-regulated and self-directed learning is metacognition. Shannon (2008) suggests that students use metacognition to identify suitable learning strategies in the appropriate learning situations. The term of metacognition was introduced by Flavell to describe people's own thinking processes and how they gain control over them. The concept of metacognition is the "knowledge and cognition about cognitive phenomena" (Flavell, 1976:906) It includes students' learning and awareness of their learning, how they control their strategy selection and change plans when needed (Phelps et al, 2002). Students who are aware of their motives, responsibilities, personal cognitive processes and have control over their learning strategies use metacognition (Phelps et al, 2002). Barak (2010) takes the concept further by suggesting that metacognition involves the use of strategies to control cognitive activities in order to meet a particular goal.

Phelps (2002) suggests that metacognitive awareness "empowers learners to become more independent in their approach to learning with, and about, computers in the future" (Phelps et al, 2002:481). Metacognitive skills of students may provide distinct advantages in contexts of rapid change, such as keeping up-to-date in the field of Information Technology where knowledge in using a particular piece of software is likely to become out-of-date over a short period of time (Phelps et al, 2002).

Students with strong metacognitive skills can foresee problems that may arise during a learning experience, and they are able to better allocate their cognitive resources for learning to cope. Furthermore, they are better able to monitor their learning experience and determine the information they understand or the information they need to investigate more (Vogel-Walcut & Fiore, 2010).

Metacognition in TEL environments

Zimmerman (2008) argues that TEL environments have the potential for improving learning, but they require skills including goal setting, monitoring, controlling cognition and motivation. Moreover, he argues that the improvement of high-tech learning environments can assist students in using self-regulated learning strategies (Zimmerman, 2008). Azevedo and colleagues have indicated that learning in a TEL environment requires self-regulatory skills to organise, navigate, and combine information into feasible mental models but, students experience particular difficulty in using metacognitive skills in TEL environments. They cannot appropriately plan, set goals and reflect on their progress (Azevedo et al, 2004). Several research studies have confirmed that students, who do not have the ability to regulate their learning in a TEL environment, learn little and the use of such environments for these types of students rarely provides them with a deep understanding of complicated subjects (Azevedo & Cromley, 2004). Commonly, regulating cognitive systems, organisation of, and access to, different representations of information and determination of an adequate instructional sequence, are seen as challenging for students (Azevedo & Cromley, 2004).

Vogel-Walcut & Fiore (2010) suggest that in order to facilitate students' overall retention and use of knowledge, a major goal of education must be to assist students in monitoring their learning. Metacognition has proven to be a particularly useful strategy for such settings that involves awareness and regulation of cognitive processes. Promoting the development of metacognitive skills encourages students to anticipate, monitor and reflect upon their own cognition and can lead to better engagement with learning materials. It can support students in developing their metacognitive skills in further learning or performance situations and in monitoring activity that takes place during critical performance events. Additionally, in the literature it's reported that despite the different characteristics of students, metacognitive support can improve learning (Vogel-Walcut & Fiore, 2010).

An understanding of learning styles, such as being aware of one's own learning processes and operating control over learning strategies, can be used to support or increase metacognitive awareness (Siadaty, 2007). Students can use different learning styles to select different learning pathway through materials, accessing and processing information that influence the quality of learning process (Ulieru, Draghicescu, Petrescu, & Stancescu, 2008). For instance, some students may understand information better by watching or listening, others by reading, and others by doing and moving or through practical work in a hands-on environment (Cemal Nat, Dastbaz & Bacon, 2008).

Visual cues structure the design of the interaction in a TEL environment and have the potential to make a significant difference in the effectiveness of metacognitive development. Kirsh (2005) notes that the interface design of an environment which helps students to manage the resources provides tools, supports and advice. The success of a TEL environment "depends as much on the details of how tools, content and support are implemented and visually presented as on the simple fact of their presence" (Kirsh, 2005:01). For example, discussion forums and chat rooms will not be used if students do not notice them. Content will not be visited if the links which identify them are not well marked. Students need to actually notice the information first, and then to recognise that it is important (Kirsh, 2005).

Currently, the authors are running experiments in a formal learning design environment with undergraduate students to investigate their actions and evaluate their levels of metacognition related to their learning performance. The learning environment includes learner heuristics such as discussion forum, chat tools, mind-mapping and note-taking tools. It also provides additional metacognitive development activies. For example, students are asked to complete a pre-knowledge test, an information recall test and an information retention test during the experiment. While studying the subject within the TEL environment students have freedom to navigate through the learning materials which are presented in text, audio, image and video formats, and find a way of learning that suits them best.

Conclusion

In this paper we have discussed the factors that are required to help students gain the full benefits of learning within TEL environments. On the one hand, students need to use metacognitive strategies to manage their learning, particularly when they are given freedom to determine how they access and use a variety of on-line resources. On the other hand, TEL environments must include relevant metacognitive and support activities by considering students' differences in skills, preferences and metacognitive needs. Finding effective ways of learning depends on two key factors: the design of a TEL environment and students' metacognitive skills. Although, most students having difficulty in regulating their learning process and strategies, there are different learning activities (i.e. wiki, concept-mapping and discussion forums) that can be utilised to encourage skills development. Future work involves the discussion of students' behaviours within a formal learning design environment where students have full control of their learning.

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Appendix 6 Publication in The Journal of Teaching English with Technology (TEwT) 2011

LEARNING DESIGN APPROACHES FOR PERSONALISED AND NON-PERSONALISED E-LEARNING SYSTEMS

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Abstract

Recognizing the powerful role that technology plays in the lives of people, researchers are increasingly focusing on the most effective uses of technology to support learning and teaching. Technology enhanced learning (TEL) has the potential to support and transform students' learning and allows them to choose when, where and how to learn. This paper describes two different approaches for the design of personalised and non-personalised online learning environments, which have been developed to investigate whether personalised e-learning is more efficient than non-personalised e-learning, and discuss some of the student's experiences and assessment test results based on experiments conducted so far.

1. Introduction

The ubiquitous availability of information and communication technologies (ICT) and multimedia tools have altered the landscape of learning and teaching. In this digital age, traditional learning habits have been reshaped; students demand learning environments that can be accessed via their personal choice of tools as wireless technologies and high-tech devices become widely available (JISC, 2009) and easy to use. The benefits of e-learning include 24/7 connectivity to information sources and people, use of multimedia resources and activity tools. These enhancements have made many educational institutions wish to integrate technology into their educational practices.

At the same time, e-learning promises to be a very efficient and effective educational method (Wei & Yan, 2009) and one of the hottest topics in technology enhanced learning is providing real personalisation (Mylonas, Tzouveli, & Kollias, 2004). Future plans of the British Government include teaching strategies to support personalised learning, utilising new technologies to realise personalised learning, and finding methods to use the curriculum flexibly for increasing personalised learning opportunities (Baker, 2008). Today, with the ability of advanced technologies to capture, store and use individual data to deliver personalised learning based on students' preferences, it is possible to address this agenda (Mylonas, Tzouveli, & Kollias, 2004). Existing learning style models in the literature are widely utilised to achieve different levels of personalisation in learning materials and provide a pathway through a set of learning materials (Cemal Nat, Bacon, & Dastbaz, 2009).

Different pedagogical approaches can be applied to the design of an online course (Teo & Gay, 2006), however, "technology does not in itself bring about successful learning" (JISC, 2009), and students will still need support and guidance. The designs of a course needs particular consideration if, for example, it is to improve retention rates and enable successful progression and completion. Technology facilitates students' learning by allowing them to find a better way of learning, however, it does not guarantee that they will learn (Cemal Nat, 2010).

In traditional classroom instruction, teachers use various strategies and activities to create their learning designs as part of their lesson plan. In any learning design, sequencing and organizing of course contents and the selection of support activities are key concerns. In contrast to a focus on the organization of content, support activities need special attention (Dalsgaard, 2005). Various online support activities that can be included in the learning design of a course can help students to reinforce their understanding of contents and, acquire knowledge and skills (JISC, 2009).

“Learning Design is a descriptive framework for activity structures that can describe many different pedagogical methods.” (Dalziel, 2009) and every learning practice has its own underlying learning design (Koper, 2005). It is possible to develop hundreds of different learning practices depending on the course objectives (Koper, 2005). Different perspectives and associated pedagogies or combination of perspectives can be involved in a learning design. According to JISC (2009), it could also be argued that successful learning may depends on integrating different approaches.

In this paper we describe two different learning designs which have been designed to investigate whether personalised e-learning systems are more efficient than non-personalised e-learning systems in the context of assessing particular outcomes (e.g. recalling). The Felder & Silverman Learning Style Model (FSLSM) (1988) was selected as the preferred model to profile students and create personalised e-learning environment. The model was formulated by Richard Felder and Linda Silverman in 1988, and an instrument of the model was developed by Richard Felder and Barbara Soloman in 1997. Approaches for providing personalised learning through a process of profiling students using FSLSM and free-use of e-learning environment will be discussed.

In both designs, individual student’s learning styles are tested. The first design aims to provide a personalised learning environment based on a student’s predetermined learning styles. In this case their learning ‘journey’ is predetermined. The student, therefore, needs to answer a list of questions before accessing the learning materials and activities. The second design, non-personalised e-learning system, provides a free choice of learning materials and activities that allow students to find what they believe is their best way to study the subject. Both of them include exactly the same instructions, learning materials and activities, and both aim to test the student’s learning style using the Felder and Solomon questionnaire (Felder and Soloman 1997). During the experiment, students were provided with e-mail support regarding the learning materials and technical problems as needed.

These two learning designs have evolved as two different e-learning systems, which aim to provide complete, and classroom independent, e-learning environments. The Learning Activity Management System (LAMS), which was integrated into the Moodle VLE, was used to develop the e-learning systems. For the experiment a group of university students from 'Multimedia Games Design and Development' course were randomly divided into two groups and invited to use one of the two e-learning systems to study the subject of "how to import music and sound in flash files, and publishing a flash game" which was divided into six sub-sections in both systems.

2. A concept for identifying learning styles and providing personalised learning

Owing to the rapid development of internet technologies and the shortcomings of traditional classroom learning, the way of learning is continuing to shift from the physical classroom to online supported learning although the vast majority of students themselves still value face to face teaching environments (JISC, 2006). Providing effective learning in an online environment has become a significant issue (Lin & Chen, 2008). Personalisation in e-learning is the process of tailoring the learning environment according to students' learning styles, profile, interest, previous knowledge level, goals and pedagogical method in order to maximize the effectiveness of learning (Jing & Quan, 2008). Students' individual differences such as prior knowledge, learning goals and styles have been considered as the principal elements of personalisation. Notably, learning style is seen as one of the most significant factors to support personalisation (Liu, 2007). It is widely accepted and reported that the learning preferences of each student tend to be different (Liu, Gomez, Khan and Yen, 2007; Uden and Damiani, 2007); some students may learn best by watching and listening, other by reading, and others by doing (Zapalska and Brozik, 2006; Cantoni, Cellario and Oliveira 2004).

In our study, a personalised e-learning system was designed based on FSLSM which is considered as the most appropriate and feasible learning style theory with respect to web-based learning system design and development (Carver, Howard, and Lane, 1999). The main aim of this learning style model is to describe the most significant learning styles of engineering students and help instructors to match their teaching strategies with students' learning needs (Felder and Silverman 1988). It characterises students in four dimensions according to their preferred way of processing, perceiving, getting and understanding of information. In parallel, it classifies instructional methods to address proposed learning styles and distinguishes preferences in four dimensions.

Active/Reflective dimension

This dimension categorises learners according to their way of processing information. *Active learners* are categorised as retaining and understanding information better by doing something with the learned material such as; discussing, applying or explaining it to others. By contrast, *reflective learners* tend to think about the concepts quietly first and they like work alone. Also, in order to retain the material more effectively they prefer to stop periodically to review and think what they have read, and write short summaries of their reading. In our system different types of learning support tools were included for the provision of pedagogical support and encouraging students' information processing.

Sensing/Intuitive dimension

Learners in this group are distinguished according to their perceptions of the learning materials. *Sensing learners* prefer to learn facts and study concrete learning materials, whereas *intuitive learners* are more comfortable with abstract materials. Moreover, in order to learn from concrete material *sensing learners* tend to like solving problems with standard approaches and dislike complicated problems. They also remember and understand information best if they see how it connects to the real world and they tend to be more practical.

Intuitive learners like discovering possibilities and relationships. Moreover, learners in this category tend to be more innovative and like challenges than *sensing learners*. Imaginative and practical types of examples were used for each section of the subject being studied in order to facilitate students' perception on learning materials in our system.

Visual/Verbal dimension

In this dimension learners differentiate according to the way that they prefer to get the information. While *visual learners* remember best what they see, such as pictures, diagrams and movies, *verbal learners* learn better from written and spoken explanations. Furthermore, *visual learners* may use techniques such as highlighting to colour-code their notes to remember better. Video, audio, picture-based and text-based content presentations of each section were provided to facilitate the students' in learning the information.

Sequential/Global dimension

Learners are characterised according to their understanding of information in this dimension. *Sequential learners* prefer to learn in a linear way and in order to find solutions they tend to follow logical stepwise learning paths. By contrast, *global learners* tend to learn in large jumps and absorbing learning materials randomly. They can put things together once they see the 'big picture'. They are interested in overviews and find connections between different areas, whereas *sequential learners* are more interested in the details. In order to encourage understanding of the subject, a sequential or free selection of learning path was developed for these learners.

Table 1. Felder and Silverman Learning Style Model.

Felder and Silverman Learning Style Model								
Dimension	*Processing*		*Perception*		*Input*		*Understanding*	
Learning Style Preference	**Active**	**Reflective**	**Sensing**	**Intuitive**	**Visual**	**Verbal**	**Sequential**	**Global**
Description	Discussing, applying, explaining	Thinking, taking notes	Facts, concrete materials	Creative, abstract materials	Pictures, diagrams, movies	Written spoken	Linear steps	Large jumps, random steps

Corresponding teaching styles of instructors in a classroom with the learning styles of students have also been suggested by Felder and Silverman (1988). However, as e-learning was not common in 1988, corresponding e-learning system features with the learning style preferences have been constructed by the authors and are summarized in Table 2.

Table 2. Reflections of the FSLSM in classroom and on the system.

Learning style preference		***Corresponding teaching styles in a classroom***		***Corresponding e-learning system features***
Active	**Processing**	Active	**Student Participation**	**Learning Support Tools** (discussion forum, chat, mind map, note taking)
Reflective		Passive		
Sensing	**Perception**	Concrete	**Content**	**Subject Examples** (imaginative, practical)
Intuitive		Abstract		
Visual	**Input**	Visual	**Presentation**	**Content Presentation** (text, audio, picture, video)
Verbal		Verbal		
Sequential	**Understanding**	Sequential	**Perspective**	**Learning pathway** (sequential, random)
Global		Global		

Significant elements such as learning goals, expected outcomes, learning activities, learning pathways and/or learning materials are considered by instructional designers in learning designs used to develop contextual and domain knowledge (Jing & Quan, 2008). However, in traditional classroom education, it is difficult for instructors to use multiple design experiences due to time, material and environmental constraints (Vattam & Kolodne, 2006).

3. Personalised learning design

This design employs the intervention of the system to support students who have been assessed with particular learning styles and needs. At the beginning of the learning 'journey' students were required to complete the FSLSM questionnaire to identify their learning styles before they could start. In order to avoid asking too many questions at once and to enhance students' participation, questions were presented in four stages. The student was then automatically presented with an appropriate personalised e-learning environment containing the individualised learning pathway, a set of learning materials and learning support tools according to the results of the questionnaire. Before starting to study the subject in order to prepare the students, they were provided with a page explaining the goals of the session.

A personalised learning pathway for each student was created to help the processing of the presented information. For example, as *sequential learners* gain understanding by working through the learning materials step by step, with each step following logically from the previous one, they are provided with a sequential pathway. This design presents appropriate learning content and then provides examples for each section. After completing these two steps, the system suggests the use of particular learning support tools to reinforce understanding. However, *global learners* in a personalized system are allowed to choose their path freely as they can absorb materials with random steps. Additionally, in order to help them to see the 'big picture' they are given access to general subject overview page. In such case, students could visit examples first and learn contents later or directly use support tools.

Four different presentation types for content were used to support visual and verbal type students in order to enhance their way of receiving information. Students who can receive information easily from demonstrations and pictures were provided with learning content, which are explained using video and pictures, whereas *verbal learners* are provided with audio and text contents, as they are better at learning from spoken or written words. *Visual learners* could choose video content, picture-based content, or both: *verbal learners* students could choose audio content, written content, or both.

Two types of examples (i.e. imaginative and practical) for each section were used to support *sensing and intuitive learners.* Students in the sensing category were provided with practical-type examples for helping them find connections with the real world and learnt facts. In addition, supplementary practical examples were made available for these students, since they tend to learn from examples rather than listening or reading course content. They enjoy solving practical problems. In contrast to *sensing learners*, imaginative-type examples are provided to *intuitive learners* to encourage their creativity and discover relationships between concepts. In this system, *sensing learners* did not have access to imaginative-type examples and vice versa.

Learning activities that were presented to the student were based on the first dimension of FSLSM, which identifies active and reflective students. For example, *active learners* were encouraged to use chat and discussion forum tools that allow them to discuss and/or explain the studied materials with their peers. Furthermore, multi-user mind mapping tools were also provided for this type of students to support their information processing. In order to allow this type of students to try things out and help their understanding, additional exercises and code samples were made available. By contrast, *reflective learners* were encouraged to take time for thinking and use a note-taking tool for writing summaries. In addition, generating a single user mind map tool to work alone or for reflecting on the information presented was also made available for *reflective learners*. Moreover, self-assessment tests were provided to give them an opportunity to reflect on the materials and check their acquired knowledge.

Towards to the end of learning session, students were given a chance to upload and submit their solutions to any of the practical exercises. Afterwards, to finish their learning session they were asked to answer several multiple-choice questions about the studied subject for assessment purposes. The assessment test could be attempted only once.

4. Non-personalised learning design

In this design, our aim was to create a learning environment that does not provide any personalisation. Therefore, all learning materials including contents and examples, and support tools were made freely available to all students. They were allowed to choose their pathway to study the subject with the restriction of visiting at least six learning materials as the subject has six sections. To provide additional data on learning styles, students were still required to answer the FSLSM questionnaire at the start of the learning session and take the assessment test at the end.

The students were presented with all available contents in four different formats: video, audio, text and picture-based. At the same time, they had access to all existing examples of the subject in two different formats including practical and imaginative. Discussion forum, chat, note-taking and mind map tools were freely available in order to enhance students' learning. Moreover, students were allowed to use all supplementary materials such as extra practical examples and more information sections. As all learning materials and activities are available, students created their own pathways to work through the subject in their preferred way. They were allowed to revisit any material and activity as many times as they wished, however the system would not let them finish the learning session until they have tackled some learning materials. For example, students may prefer to visit examples first and then contents or only examples.

As in the personalised learning design, towards to the end of learning session, students in this group were also given a chance to upload their solutions and finish their learning session by answering multiple-choice questions about the studied subject without retaking the assessment test.

5. Results and discussion

This study was designed to investigate if personalised e-learning systems are more efficient than non-personalised systems in the context of assessing particular outcomes (e.g. recalling). Students were expected to study the subject and answer an 18-item multiple-choice assessment measuring their knowledge at the end of their learning session. Each question was worth 1 point and the system calculated the final grade for each student. In total 46 students from two different universities used the systems and successfully completed the learning sessions. 23 students studied the subject using the personalised e-learning environment and 23 students used the non-personalised e-learning environment.

Table 3. Subject assessment test results.

University	*Learning environment*	*Average of total grades*
University A	Personalised	9.7
	Non-personalised	9.1
University B	Personalised	6.9
	Non-personalised	7.6

As the results of the assessment test indicate, students from University A performed better in the personalised e-learning environment and achieved higher marks than students from university B. Most of them answered half of the questions correctly. Students made positive and constructive comments about the systems after completing their learning. A student from university A made the following comment about the personalised learning environment:

> This was a very useful insight into the future of E-learning. Truth be told, I didn't try my hardest to complete all the tasks but I believe, if this system was fully

integrated into our learning schedule, it would be very useful particularly because it offers tailored learning.

On the other hand, about the non-personalised learning environment they said:

- It's very easy to use, pretty fun. I wouldn't mind using it again. Videos were awesome.
- It is very educational. Please implement this in the future course.

The comments above show that students are willing to use an integrated e-learning system in their course. In particular, they liked the idea of having course content presented in different formats. As students are now quite familiar with technology, they did not have problems using the systems. Nevertheless, user manuals for each system were provided in order to minimise any difficulties.

In contrast to University A students, University B students performed better in the environment that they had free access to all learning materials and support tools. Although, they got lower marks than University A students, they made optimistic and encouraging comments. Their opinions about personalised system are:

- I found it easy to use. I would like to use it again also there are good tutorials and I could get helpful information. It's a very good system which will help our generation and future generation.
- The system is good and distinct. I want to use it again because I want to improve my flash knowledge. I like the videos which are explaining every steps. I think some 'action scripts' are long. Thank you for this thing, I hope we will use it again.

Similarly, positive comments were expressed by students using the non-personalised system:

- "Well, I have learned some useful things in this session because of there was things which I haven't seen before and then I tried to figure my experience by practicing step by step to get the right result and I'm so so thankful to who the set this e-learing session up for us :)."
- "If given chance and opportunity I might use this system again. It was user-friendly plus convenient as we can do it while sitting at home."
- "I found it easy to use and would like to use it again. I liked the tutorial part where I was able to learn and I liked the assessment part as well. There is no part of the system I did not like. A good point of the system is the ability to track my progress."

- "At first I found the e-learning hard to use but later on I was conversant with it. I would like to use the system again. I liked the chat application and profile pages."

Students from University B provided opinions from different perspectives. In addition to system usage and accessibility, they shared ideas about their learning. They reported learning different techniques and improved of their knowledge about the subject. Moreover, they were able to analyse the content. For example, comments such as "I think some 'action scripts' are long", demonstrates the ability of this student to evaluate how to improve the system. Others remarked that it is good to be able to track their progress and use chat application.

In general, results and comments indicates that Learning Activity Management System (LAMS) as a standalone learning environment is accepted positively by students and that they would like to have it integrated into their usual learning programme.

6. Conclusion

The current study was intended as a preliminary study exploring the efficacy of personalised e-learning systems. The proposed learning designs are applicable to LAMS and students appreciated using the e-learning systems. However, the findings do not definitively support the conclusion that personalized e-learning systems are more efficient than non-personalised e-learning systems or vice versa. These findings warrant further research, particularly with larger sample sizes and in-depth analysis of students' data such as, time spent on contents and assessment test, number of content visits etc.

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