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A framework for multiplatform e-learning systems

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Abstract

A multiplatform e-learning system is an e-learning system that can deliver learning content to different accessing devices such as PCs, PDAs and mobile phones. The main objective of the research is to formulate a framework for multiplatform e-learning systems. This thesis focuses on the formulation, competency and constitution of the multiplatform e-learning systems framework and the implementation of a multiplatform e-learning system. In conjunction with the main objective, the research also addresses the factors that influence learner satisfaction during their engagement with a multiplatform e-learning system. In addition, the research investigates the relationships between these factors in influencing learner satisfaction. The research also intends to validate the assertion that multiplatform e-learning systems are better than non-adaptive e-learning systems. A comparative evaluation between a traditional e-learning system and a multiplatform e-learning system from end user (learner) perspective was conducted. The evaluation instrument is based on multiplatform e-learning system questionnaires (MELQ). A total of forty participants took part in the evaluation. Four participants took part in the initial pilot evaluation while thirty six participants took part in the final evaluation. Data analysis and statistical results indicate that there are potential gains in learner satisfaction score in multiplatform e-learning systems over traditional e-learning systems. The results also show that the gain is most significant in mobile devices than in desktop PCs. Statistical analysis reveals that all the factors that influence the learner satisfaction are significant and they have different levels of influence over learner satisfaction. These factors can be further organized into primary factors and secondary factors. These findings and the methodology of evaluation can play an important role for e-learning systems designer to improve the adaptation process and to enhance the level of learner satisfaction in multiplatform e-learning systems.

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Chapter 1 Introduction

1.1 The emergence of multiplatform e-learning systems

E-learning systems have now been adopted by most universities. However, even recently, virtually the only way to access an e-learning system was through a desktop computer in a fixed classroom or laboratory type environment. With the advent of the Internet, the e-learning systems have been transformed into web based learning systems where content can be accessed beyond the conventional classroom and lab boundaries. In recent years, there has been a proliferation of devices capable of accessing the Internet, ranging from tablet PCs to mobile devices including telephones, smart phones and personal digital assistants (PDA), and even appliances such as televisions, microwave ovens and refrigerators in the home. Most of these devices are capable of accessing e-learning systems. However, till now, most popular e-learning systems such as Blackboard and WebCT are not capable of delivering appropriate content to this proliferation of devices. Conventionally these e-learning systems are designed for personal computer usage. With the proliferation of access devices there is a need for these e-learning systems to extend their support to and provide appropriate content for these devices. Such an e-learning system that supports this multitude of devices is called a multiplatform e-learning system in this context. In this new context, many aspects differ from the original context. Firstly most of the mobile devices such as PDAs and smart phones are designed for telecommunication usage. These devices are characterized by a small screen, low memory, low power and distinctly different ways of interaction and navigation compared to desktop computers. When learners use these devices to access and interact with e-learning content instead of making a phone call, how do they feel about the interaction? If the interaction is not as good as with the PC then what are the relevant factors that need to be considered even though the learning content may be identical? Furthermore, in this new context even if the access platform is similar to a desktop computer, other aspects may still differ from the original context. For instance, in most cases the connection bandwidth is likely to be lower than a school's local network. E-learning systems typically do not perform bandwidth estimation to make adjustments to content. The content remains the same irrespective of the changing context. In some cases the bandwidth might be too low for the delivery of multimedia content. Is it possible that some alternate ways of delivering content such as offline or plain text delivery could make learning more satisfying than waiting endlessly for downloads? How might these alternative ways of delivering content influence learners? For instance, the motivational

factor of accessing the e-learning systems might be different at school than on the move. While on the move, urgency may trigger students to explore the e-learning system. As teachers' help is not readily available on the move, a lot of self motivation is required. Would the present of urgency and absence of teachers' help influence learner satisfaction?

These examples illustrate some of the basic issues facing a multiplatform e-learning system. A major part of this study is to identify, confirm and explore the factors that influence learners when using a multiplatform e-learning system from a user satisfaction perspective. Figure 1.1 and 1.2 depict a number of possible scenarios and devices where e-learning systems can be used nowadays. In summary, the focus of this research is the formulation, implementation and evaluation of a multiplatform e-learning system framework. The knowledge gained from the research will allow designers to develop a more satisfying multiplatform e-learning system in the future.

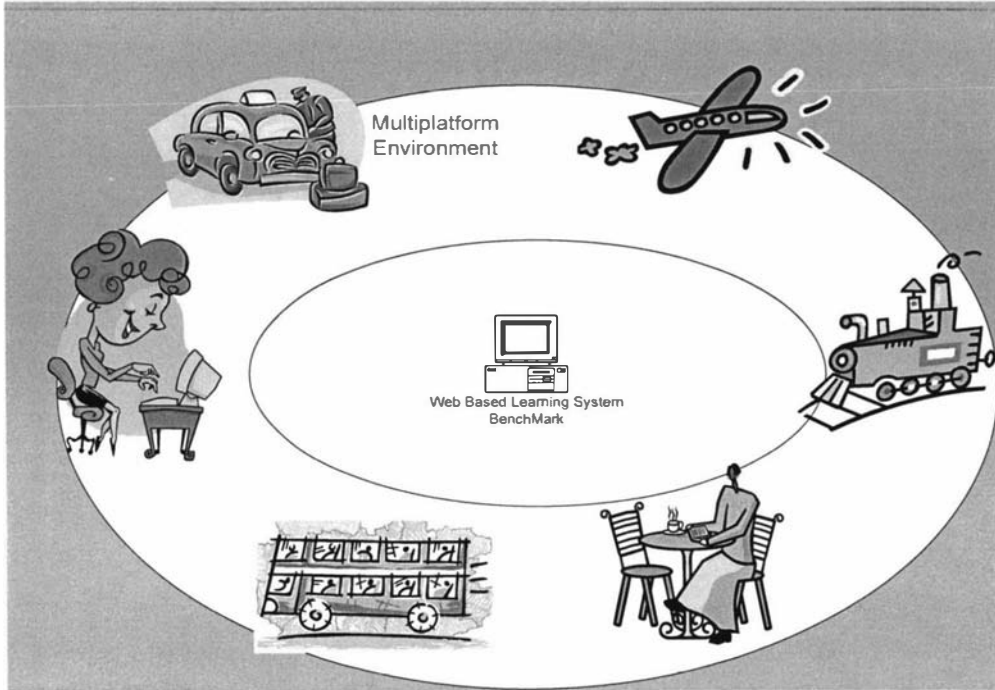


Figure 1.1 Different scenarios for using multiplatform e-learning systems

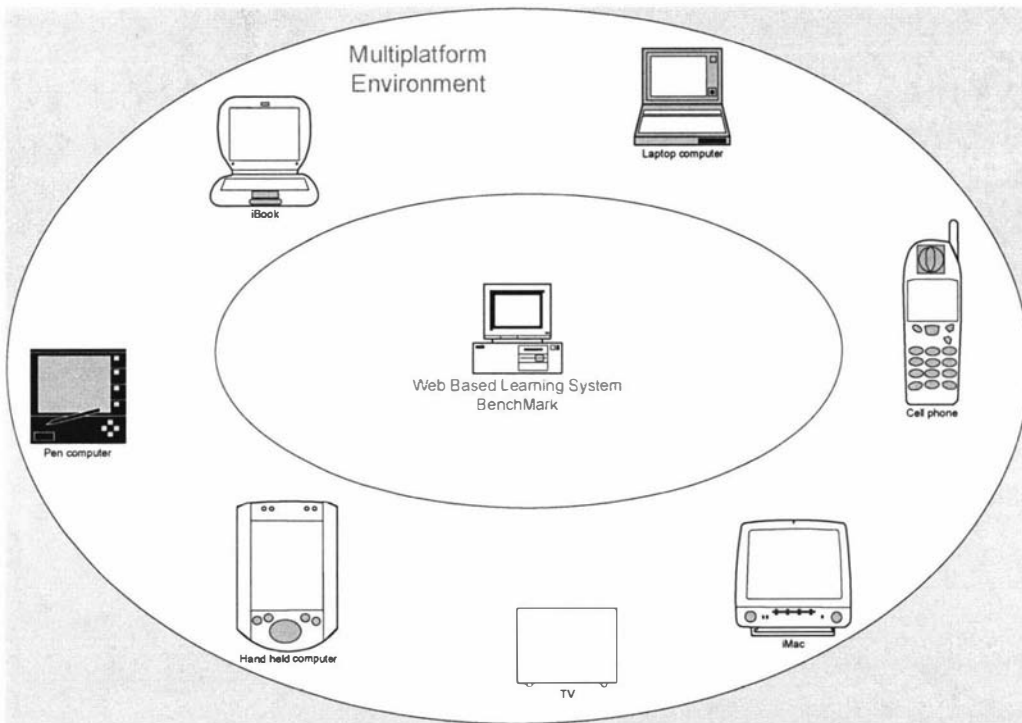


Figure 1.2 Different access platforms

1.2 Research objectives

A multiplatform e-learning system is an e-learning system that is, at the least, capable of adapting content and other aspects such as navigation to different access devices. These devices include PCs, PDAs and mobile phones. With this added capability, e-learning systems can extend their usefulness for anytime and anywhere to any devices. This new channel for accessing e-learning systems is likely to increase the suitability of the content for the needs of the learner and possibly improve learning satisfaction. It may also provide added competitive advantages for institutions that intend to provide innovative delivery approaches. Blackboard and WebCT are the two main e-learning system providers, capturing 83% of the total market share (ESchool, 2005). At the beginning of this study in 2002, they had yet to develop extensions to their systems to facilitate mobile access devices. Currently, an unplugged version of Blackboard is available for offline PC access and some forms of PDA access. While this may not yet be a full-fledged multiplatform e-learning system, it provides an indication of the direction in which these industry leaders are going. While many attempts have been made to develop e-learning systems that can be accessed only through single devices such as desktop computers or certain mobile devices, multiplatform e-learning systems have not been well researched. With the escalating speed at which new mobile devices are being launched and wireless infrastructure is being developed, there is an ever-increasing need to acquire an understanding of the characteristics and interactive experiences of multiplatform e-learning systems from a learner perspective. Thus in this study the first step is to discover which factors constitute a multiplatform e-learning systems framework. Subsequently, the aim is to validate the usefulness of the proposed framework through an implementation of a prototype multiplatform e-learning system and finally to explore and validate the degree of relationships among factors that influence learners' satisfaction based on an empirical usability evaluation.

1.3 Statement of the problems and research questions

A multiplatform e-learning system is an extension of a typical e-learning system. It can be seen as a new era of educational technology innovation which is still in its infancy. The literature review suggests that there is limited research and few established frameworks addressing such a system and specifically, on the factors influencing learner satisfaction during the process of learner/system interactions. Without an established framework, it would be difficult to implement a baseline multiplatform e-learning system

and to evaluate its performance with respect to learner satisfaction. Therefore based on an extensive literature review, systematic research and requirements identification, the objective of this research is to first construct a framework that allows a multiplatform e-learning system to be implemented and then use it as a test bed to investigate the factors influencing learners' satisfaction during the process of learner/system interaction. As the multiplatform e-learning system needs to be able to adapt its content and other aspects such as navigation to various access devices, one can expect the system to be more satisfying for learners than the traditional e-learning system. Thus the main research question (RQ1) in this study focuses on the constitution of a multiplatform framework and its immediate goal, which can be summarized as follows:

What factors constitute a multiplatform e-learning system framework that will adapt to each learner's context and improve learner satisfaction? (RQ1)

In order to improve learner satisfaction, logically one should first understand the factors that affect learner satisfaction while using a multiplatform e-learning system. Once these factors have been identified, they can be categorized and organized into various dimensions. These organized dimensions can be utilized to address the main research question. Thus to provide an answer to the main research question, the following research question two (RQ2) should be addressed:

What are the factors influencing learner satisfaction in a multiplatform e-learning system? (RQ2)

Through identifying the potential influencing factors, one can organize these factors to construct a framework for multiplatform e-learning systems. Subsequently based on the framework multiplatform e-learning systems can be implemented to validate the usefulness of the framework and the factors within the framework. However it is likely that these factors will not be equally influential; some may be perceived as more influential than others. One of the benefits of knowing which factors are perceived as more influential is to allow system developers to prioritize the adaptation process in the design of a multiplatform e-learning system. Hence this leads to the following sub research questions one and two (SQ1 & SQ2) with respect to learner/system interaction and the relationships among these factors:

How significant are the various factors in influencing learner satisfaction with respect to the multiplatform e-learning system? (SQ1)

And,

What are the groupings (relationships) among the factors that influence learner satisfaction with respect to the multiplatform e-learning system? (SQ2)

Finally, the main research question emphasizes that the multiplatform e-learning system should increase learner satisfaction compared to the traditional approach. As in many adaptive systems, this objective is important as it provides a specific goal for the multiplatform e-learning system. The multiplatform e-learning system not only provides access and adapted content and other aspects to different access devices: it must also perform in such a way that the learner can feel a sense of satisfaction while interacting with it. Thus this issue is addressed through the following research question three (RQ3):

Is the multiplatform e-learning system actually achieving its goal of improving learner satisfaction? (RQ3)

In summary, this set of research questions provides an integrated means for investigating the characteristics of multiplatform e-learning systems and permits researchers to explore the factors perceived by learners to be influencing their level of satisfaction during the interaction process.

1.4 Research methodology

Determining the phenomena underlying the interaction between users and multiplatform e-learning systems is one of the objectives in the current research. Using a qualitative approach alone might not reveal the true nature of the situation. Jackson et al. (2003) in their Internet research stressed the importance of gathering both quantitative and qualitative data to uncover hidden information. Similarly, Lucas and Spitler (2000) pointed out that using a single research approach such as a quantitative method may not lead to accurate measurements during the evaluation process. They suggested a combination of quantitative methods such as variance analysis and qualitative methods such as interviews to gain a better understanding. In order to capture more reliable and

accurate data during the evaluation process, a mixed method combining qualitative and quantitative methods were adopted. The qualitative techniques include written feedback and face-to-face interviews while the quantitative approach comprises questionnaires given during the usability test. Table 1.1 gives an overview of the research methodology in this study.

1.5 Significance of the study

One of the main contributions of this research is to draw attention to multiplatform e-learning systems. This type of systems is currently not common but it can have great impact on e-learning as learners equipped with mobile devices such as mobile phones become more common. Scaffolding on current e-learning systems, the multiplatform e-learning systems provide integrated access and are capable of adapting content to many Internet ready devices. This encompasses and in some ways extends mobile learning. While many researchers have examined mobile learning itself, the current research looks at more generic and fundamental issues of multiplatform e-learning systems. As the multiplatform e-learning systems belong to emerging technologies, guidelines and a framework are needed to formulate and develop such systems. Therefore, another contribution of this study is to devise and formulate a framework that supports the development of multiplatform e-learning systems. The framework benefits e-learning developers and adopters with generic guidelines to systematically capture relevant requirements for the construction or acquisition of multiplatform e-learning systems. The framework also permits extensions to cater for new technologies, access devices and context of use. These guidelines are likely to lead to successful implementation. Through scenario-based usability experiments and several data analysis techniques such as correlation and structure equation modeling, this research is able to identify each factor, its relationships with other factors and its level of influence over learner satisfaction. The research also validates the assertion that adaptive systems can provide better learner satisfaction than non-adaptive systems in the context of multiplatform e-learning systems. Thus another contribution of this study is to devise an evaluation method and instrument to measure the relationships and validate the multiplatform e-learning systems. These findings will benefit developers and institutions intending to develop or acquire multiplatform e-learning systems by enabling them to investigate, verify, enhance and invest in factors that have significant impact on learner satisfaction. This understanding will help institutions and educators to make the right investment decision in the eventual

adoption of multiplatform e-learning systems and to a greater extent provide sound technology for students to embark on lifelong learning anytime, anywhere and through a variety of devices. Such evaluation over a period of time can also help to identify factors that are still not accepted by learners.

1.6 Thesis organisation

The organisation of the thesis mainly follows the sequence of the research questions. Every chapter represents an incremental understanding of the multiplatform e-learning systems and represents the progression of the research. In Chapter 1 the multiplatform e-learning systems have been introduced. The deficiency of current e-learning systems in supporting a proliferation of mobile devices were highlighted. In particular the discussion focussed on situations that are likely to make the learner/system interaction less satisfying. Subsequently this chapter gave an overview of the problems and the research questions that to be investigated. The main research question focuses on the formulation, competency and constitution of the multiplatform e-learning systems framework. In conjunction with the main research question, the research also addresses the factors that influence learner satisfaction. In addition, the research also intends to discover the relationships between these factors in influencing learner satisfaction. The assertion that adaptive systems are better than non-adaptive systems is also targeted for investigation.

Chapter 2 provides a literature review of the works that are relevant to the current study. As the multiplatform e-learning systems belong to emerging technologies, there are very few studies that are directly applicable. However by breaking down each component of the research questions one can identify several research areas that are helpful and useful in the formulation and implementation of multiplatform e-learning systems. Thus the review covers multidisciplinary areas which include existing e-learning frameworks and architecture, various content adaptation techniques, various device detection and identification techniques, state of the art mobile learning research, and W3C device independent access (DIA) recommendations.

In chapter 3, the focus is on the formulation of the framework for multiplatform e-learning systems. The formulation of the framework is derived from an extensive literature review. Because of the nature of the system and its problems, the literature review covered multidisciplinary areas. These include e-learning systems framework and e-learning architecture, content adaptation techniques in the general Web domain, device identification techniques, mobile learning systems, context awareness systems, the

resource descriptive framework (RDF), Composite Capabilities/Preference Profiles (CC/PP), UAProf, MIDF-Mobile information device profile, W3C device independent access, information systems architecture theory, agent-oriented systems, ITS systems, and Web service coordination theory. Based on this review, a multiplatform e-learning systems framework is proposed that provides guiding principles and a mechanism for understanding the underlying research issues. Further development of a multiplatform e-learning system eventually provides a test bed for evaluation.

In chapter 4, the implementation of a multiplatform e-learning prototype system will be discussed. The development of the prototype system is based on the framework described in chapter 3. The framework provides adequate competencies and requirement guidelines to build a prototype system. The development of the prototype system aims to validate the usefulness of the framework and to demonstrate that the framework is workable. The prototype provides a means by which the designer can attempt to validate requirements. To construct the prototype system, a conceptual mapping between the framework and the system architecture was performed. This step involves developing various components of the multiplatform e-learning system with different functionalities. Through this mapping, one can identify how the components relate to each other from framework to architecture. By mapping the relationships of the system components to the required objectives, the risk of missing functionalities or creating redundant functionalities in the system can be minimised. Chapter 4 also considers issues related to content and quality. Finally chapter 4 discusses relevant technologies such as XML, XSLT, DOM, Flash technologies, mobile device technologies, bandwidth estimation, off-line learning techniques, learning with interactive multimedia design, and usability pertaining to the implementation. In summary this chapter addresses and clarifies various issues arising from mapping the framework to the system architecture.

Chapter 5A presents the usability evaluation methodology of the multiplatform e-learning system. The aim is to measure the significance of the factors influencing learner satisfaction. It also intends to answer the research sub-questions by identifying the interrelationships and groupings among the factors that influence learner satisfaction. This part of the evaluation involves both qualitative and quantitative data collection through interviews, observations, and questionnaires after a series of usability experiments. This is the phase in which the functionalities of the system are verified and it also provides the means to answer the research sub-questions. Chapter 5B continues with a thorough data analysis. The data analysis approaches are selected through a review

of descriptive statistics, correlation analysis, ANOVA, and structure equation modelling. Data analysis involves descriptive statistics to provide an overview of learner satisfaction scores. ANOVA tests are used to determine the effectiveness of adaptive systems compared to non-adaptive systems. To reveal the interrelationships among factors correlation analysis and structure equation modeling techniques are used. Each method provides different insight into the relationship. The outcome of the data analysis is useful for future developments and enhancements of multiplatform e-learning systems. Limitations of the evaluation and fundamental framework are also addressed for future improvement.

Chapter 6 provides a discussion on implications and limitations of the research. Finally Chapter 7 concludes the research by summarizing the findings. This chapter also provides a direction for future studies in this area.

The appendixes include the ethics approval forms, the usability test procedures for participants, the Multiplatform E-learning System Questionnaires (MELQ) and scripts examples. A list of publications which includes international conference presentations, workshops and international journal articles generated from this research is also provided.

Table 1.1 Research Overview

Research Methodology				
Research Questions	Formulation of Framework	Implementation Based on Framework	Evaluation Based on Framework	Data Analysis
<p>Multiplatform e-learning systems framework:</p> <ul style="list-style-type: none"> ▪ Formulation of framework? ▪ Factors influencing learner satisfaction in multiplatform environment? ▪ Adaptive system works? ▪ Relationships between factors? ▪ Grouping of factors? 	<p>Grounded by literature review on:</p> <ul style="list-style-type: none"> ▪ Content adaptation ▪ Device identification ▪ E-learning framework ▪ Mobile learning system ▪ Context awareness system ▪ RDF ▪ CC/PP /UAProf ▪ W3C accessibility ▪ MIDF-Mobile information device profile ▪ IS theory in information system architecture ▪ Device Independent Access 	<p>Supported by literature review on:</p> <ul style="list-style-type: none"> ▪ W3C ▪ XML ▪ XSLT ▪ DOM ▪ Flash ▪ Server page ▪ Bandwidth estimation ▪ Off-line learning ▪ Learning with interactive multimedia ▪ Usability 	<p>Supported by literature review on:</p> <ul style="list-style-type: none"> ▪ Evaluating adaptive systems ▪ Usability ▪ Mobile usability ▪ Evaluating e-learning systems ▪ HCI ▪ QUIS ▪ Scenario based evaluation ▪ Emotion stimulation ▪ Multitasking environment 	<p>Based on:</p> <ul style="list-style-type: none"> ▪ Descriptive Statistics ▪ Correlation Analysis ▪ ANOVA ▪ Structure equation modeling

Chapter 2 Literature review

2.1 Review of e-learning frameworks

In order to answer the main research question concerning the constitution of a multiplatform e-learning framework, it is important to understand the terms ‘framework’ and ‘architecture’ which are commonly found in the e-learning domain. These terms are used by different communities in different ways and they typically carry different meanings. Often they describe a high-level overview of the range of functions, concepts, theories or services of an e-learning system. The term ‘framework’ in general is used more often from a social science perspective and is normally theoretical in nature. The term ‘architecture’ is commonly used from a computer science perspective and is normally technical in nature. These two perspectives are not mutually exclusive: they are interdependent because technical capabilities determine the possible implementation of the theoretical framework. In this regard, the proposed multiplatform e-learning system framework will take these perspectives into consideration.

In general, the purpose of an e-learning framework is to understand the concept of a system, its components, and its interactions within itself and to external systems and users (LTSA, 2001). This is precisely what the multiplatform e-learning system framework is intended to achieve, by providing an implementation guideline to facilitate understanding of its relationships. A framework would normally not address specific details of implementation technologies such as the platform, programming languages, protocols, authoring tools, or operating systems necessary to implement the e-learning system (LTSA, 2001). Nor should the management systems such as learning content lifecycle management, quality and auditing assurance, access and security control, or user administration necessary to manage an e-learning system be specified in a framework (LTSA, 2001). An e-learning framework generally facilitates and provides conceptual design guidelines, principles, objectives and goals for the e-learning system under consideration (LTSA, 2001). Similarly, in the multiplatform e-learning system framework (please refer chapter 3) there are no restrictions on the implementation technologies; rather it focuses on facilitating design guidelines, competency principles and the objective of achieving better learner satisfaction. The logical first step is to look at various e-learning frameworks and architectures and examine how they could possibly aid in identifying the elements that constitute the multiplatform e-learning system framework. By examining both

perspectives and identifying relevant contributing factors, a better foundation for the multiplatform e-learning systems framework can be built.

2.1.1 Learning technology systems architecture

One of the most comprehensive e-learning system architectures is the IEEE Learning Technology Systems Architecture (LTSA, 2001). LTSA aims to be neutral in terms of pedagogy, content, culture, and platform. While some of these objectives are similar to the multiplatform e-learning system framework, other design issues may not. For example, delivery of multimedia across networks of varying capabilities and presenting multimedia on devices with varying capabilities are the main concerns of the multiplatform e-learning system framework; these are not the main focus of LTSA (LTSA, 2001).

The LTSA prescribes processes, storage areas, and information flows for an e-learning system (O'Droma, Ganchev, and McDonnell, 2003; LTSA, 2001). Figure 2.1 (layer 3) shows the relationships between these elements. The solid arrows represent data flows while the dashed arrows represent control flows. The overall operation is as follows: Learning Preferences, including the learning styles, strategies, and methods are initially passed from the learner entity to the Coach process. The Coach reviews the set of incoming information, such as performance history, future objectives and searches Learning Resources, via Query, for appropriate learning content. The Coach extracts Locators for the content from the Catalog Info and passes them to Delivery, which uses them to retrieve the content for delivery to the learner as multimedia. Multimedia represents learning content, to which the learner exhibits a certain behaviour; this behaviour is evaluated and results in an Assessment and/or Learner Information such as performance. Learner Information is stored in Learner Records and Interaction Context provides the context used to interpret the learner's behaviour. It is clear that the LTSA structure and flow depict the common operations of an e-learning system. The Learning Preferences represent the learner model well in most systems. The Coach can be treated as a decision engine to determine and coordinate the appropriate content based on the Learner model. In the multiplatform e-learning system framework, emphasis is placed on the delivery of content and transformation of content which conveys similar meanings and organises appropriate structure when it is delivered to the learner through different accessing devices in different environments. It is the learner's overall satisfaction through interacting with

the multiplatform e-learning system compounded by the use of different accessing devices such as mobile phones and PDAs that is of primary concern in the current research. The LTSA architecture recognises the importance of interactions between the learner and their environment. Thus there is a specific layer in the LTSA architecture concerned with the acquisition, transfer, exchange, formulation, discovery, etc. of knowledge and/or information by the learner through interaction with the environment. To some extent, a multiplatform e-learning system needs to perform such activities and this is reflected in the communication dimension of the framework. More significantly, to be able to apply this information effectively there is a need to know at a fundamental level how these elements of information influence learners.

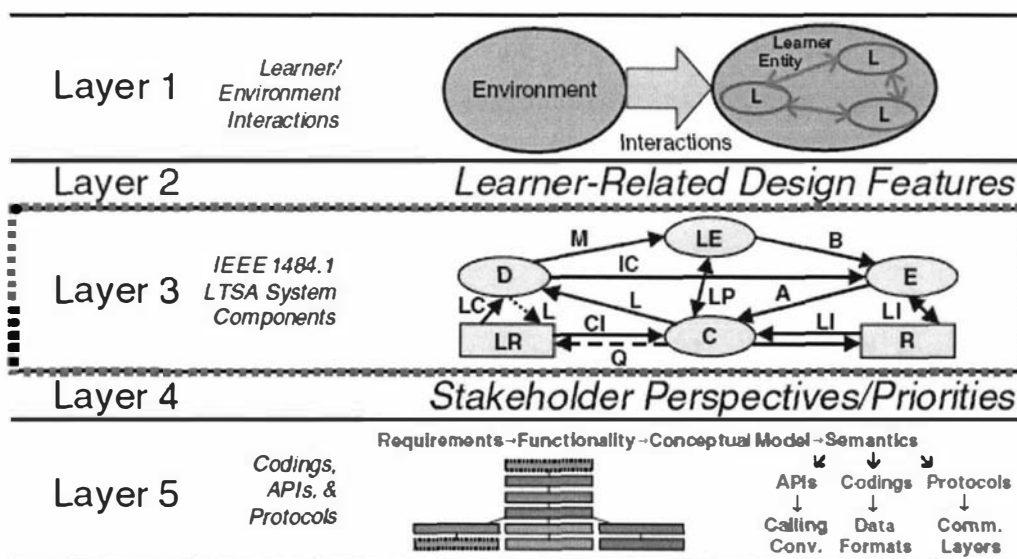


Figure 2.1 LTSA framework (LTSA, 2001)

2.1.2 JISC e-learning framework

The LTSA can be considered as an example of component based architecture. For example, layer 3 of the architecture describes the operational flows between each component within the system. Unlike LTSA, the Joint Information Systems Committee (JISC) e-Learning Framework (JISC-ELF, 2004) focuses on a service-oriented approach. JISC treats each element as a core service required to support e-learning applications, portals and other user agents. By doing so, the JISC e-learning

framework is technically inclined towards current network technology such as web services or a Representational State Transfer (REST) style HTTP protocol. This approach means that there is a strong demand to coordinate different applications from different sources within institutions and to regional federations. In the multiplatform e-learning system framework such activity is represented by the coordination dimension which focuses on coordination within the framework. However, if common services, data models, and protocols can be defined, then the multiplatform e-learning system framework could possibly coordinate services externally as well. The issue of primary concern in the current research is not so much how to coordinate several services but the eventual form, structure and speed by which the content can be delivered to various devices. One issue pertaining to the JISC e-learning framework is the user agent's layer. By involving several user agents, it is likely to create more communication overheads before the content is delivered. Thus while a service oriented approach may exhibit several advantages these may not be necessary in the implementation. Another implication of the service oriented framework is the format of the underlying content. By adopting web services, the content can rely on XML structure and using XSLT to transform services from server or client to adapt content and structure. This transformation approach is adopted in the multiplatform e-learning system implementation. The JISC e-learning framework enables the development of modular and flexible systems, where the individual components can be added or replaced more easily than in traditional models. This approach helps in a multiplatform e-learning system as some components may not be suitable or available in a mobile context. The application services layer states that it provides functionality required by the user agent; however the exact process is not clear in the JISC e-learning framework documentation. In the situation of multiplatform access, there are no specific indications and discussion within the documentation. It is likely that this aspect is still developing and that for certain mobile device using web services API is necessary. In summary, the JISC e-learning framework provides a state-of-the-art service oriented approach. It provides some ideas and possible options for implementing the multiplatform e-learning prototypes system. However there is also a need to consider multiplatform access and devise a framework that can include measurement of learner satisfaction.

2.1.3 IMS abstract framework

Similar to the JISC e-learning framework, the Instructional Management System Abstract Framework (IMS-AF, 2003) is another service oriented framework. IMS-AF describes the context relevant to the IMS e-learning technology specifications. These specifications provide only a guideline for implementing e-learning systems with a traditional campus-based e-learning system in mind (Mobilearn, 2005). Several service layers have been identified. These include an application layer, application service layer, common service layer, infrastructure layer and service access points. These layers and their functions are very similar to the JISC e-learning framework. The emphasis of the IMS-AF framework is on the interface issues among these layers. For multiplatform e-learning system to take advantage of this framework one possible option is to provide an extension that conforms to the interoperability specifications suggested by the Open Mobile Abstract Framework (OMAF) (Mobilearn, 2005). Even with the service extension, there are still basic issues of mobile usability, content structure, content adaptation, and different ways of delivery that affect the learner but which are not well reflected in the framework.

2.1.4 Learner-centred e-learning framework

So far the discussions on e-learning frameworks were more technically oriented, but e-learning frameworks can also be more theoretical. Theoretical e-learning frameworks are mostly motivated by the pedagogical issues of learners. While no specific accessing platform is involved in the theoretical e-learning framework it is likely that the focus is on traditional e-learning systems with PC access in mind. The key motivation of a theoretical e-learning framework is how to design educational systems where technology is in service to values and supports diverse learners and learning contexts (McCombs and Vakili, 2005, p. 1583) with the support of sound pedagogical theory. For example, Bonk and Cunningham (1998) emphasise the need to re-examine learner-centred principles, constructivism, and socio-cultural theories and to apply them to the e-learning system. Unlike traditional e-learning systems, in a multiplatform e-learning system the learning context can vary substantially from static to highly mobile and multi-tasking situations. Therefore by matching those theoretical motivations with the technical capabilities of an e-learning system, a multiplatform e-learning system framework can extract the best factor to fit the situation. In doing so it is more likely to improve learner satisfaction. One such theoretical e-learning

framework is the learner-centred e-learning framework suggested by the American Psychological Association (APA, 1997). One crucial aspect of this framework is that it is based on research-validated Learner-Centred Psychological Principles. There are four pillars and fourteen principles that support the learner-centred framework for e-learning. The four main pillars relevant to learning are meta-cognitive and cognitive, affective and motivational, developmental and social, and individual differences factors. Some of these principles support the concerns of the current research. For instance, the individual differences factor recognises that learners have different capabilities, preferences and control, and these are captured in the learner dimension of the multiplatform e-learning systems framework. For example, principle 6 states that learning is influenced by environmental factors including culture, technology and instructional practices. In the current research, emphasis is also placed on how the influence of environmental factors such as noisy or distracting environments affect learner satisfaction. Principle 7 stresses the importance of motivation. It states that what and how much is learned is influenced by the learner's motivation. Motivation to learn, in turn, is influenced by the individual's emotional states, beliefs, interests and goals, and habits of thinking. With respect to the current research, knowing how motivation affects learner satisfaction while using mobile devices and in urgent situations can help in the design of multiplatform e-learning systems. In principle 8, the learner's creativity, higher order thinking, and natural curiosity all contribute to motivation to learn. Intrinsic motivation is stimulated by tasks of optimal novelty and difficulty, which are relevant to personal interests, and provide opportunities for personal choice and control. There is a need to evaluate how different ways of delivery involving tasks required for offline viewing affect learner satisfaction in the context of a multiplatform e-learning system. Thus with the inclusion of a learner-centred e-learning framework that couples a focus on individual learners' experiences, perspectives, backgrounds, talents, interests, capacities, and needs (McCombs and Vakili, 2005) it is possible for the multiplatform e-learning system framework to provide the right levels of motivation, learning, and satisfaction in the right conditions.

2.1.5 The motivational framework for web-based instruction

So far the learner-centred e-learning framework draws the attention to several factors relevant to learning such as meta-cognitive and cognitive, affective and motivational, developmental and social, and individual differences factors. The aim of the learner-centred e-learning framework is to enhance e-learning through careful consideration of these factors in its design. To some extent the multiplatform e-learning system framework incorporates these factors. One key factor that appears repeatedly is the motivational factor. Traditionally, motivation is one of the most neglected aspects of the learning and design processes when applied to instructional design (Duchastel, 1997). However, with the aid of web-based learning this can be overcome. Web based learning can offer true multimedia richness, so motivation factors can be addressed through the development of web based learning or e-learning systems (Duchastel, 1997). The concerns in the multiplatform e-learning system is that true multimedia richness may not present equally well across all accessing devices. In the absence of rich multimedia, will the motivation factors be affected and subsequently influence learner satisfaction? The evaluation process (please refer chapter 5) aims to reveal this relationship. The motivational framework (Duchastel, 1997) provides several theories to support the inclusion of motivational factors in design. These factors can be helpful in the evaluation process as well. These theories include Keller's (1983) attention, relevance, confidence, and satisfaction (ARCS) motivational model, Malone's (1981) challenge, fantasy, and curiosity (CFC) motivational model, Wlodkowski's (1999) interactive and delivery (ID) motivational model and the Effin factor to measure the relationship of effort to interest (Duchastel 1996). The presence of any Effin factor can be authenticated through face-to-face interviews and the written feedback process. Other motivational factors—for example, confidence, satisfaction, interaction and delivery—are included in the multiplatform e-learning system framework and deployed in the evaluation instrument.

2.1.6 Diversity framework for web based learning

One of the reasons several e-learning frameworks were investigated is to identify similarities and differences among them and to identify factors that are relevant to the multiplatform e-learning systems framework. The previous two theoretical e-learning frameworks derived mostly from the education domain. They both share certain common factors, e.g. motivation. However, theories outside the education field can

also contribute to understanding of the learner and e-learning system interaction behaviours. The diversity framework for web based learning (Huerta et al., 2003) is one such framework. First the diversity framework postulates that media richness theory and social influencing models affect media communication choice in web based learning. The media richness model (Daft and Lengel, 1986) postulates that people rationally select a specific medium based on the medium's intrinsic richness. Media richness depends on the speed of feedback, the variety of communication channels employed, how personal the source is and the richness of the language used (Huerta et al., 2003). If medium choice is treated as synonymous with accessing devices and media richness as analogous to quality factors then the implication for a multiplatform e-learning system is that the learner may have a specific choice of accessing device but as media richness changes the specific medium choice would vary. If the choice is not provided for or is provided but not adequate then learner is likely to feel dissatisfied. If that is the case then an adaptation process may modify media richness and their choice and possibly improve their learning satisfaction. The factors that affect media richness may well be the factors that affect learner satisfaction. But which factors have more profound effect on the learner? Few researchers have addressed this issue, especially in a multiplatform e-learning domain. This research therefore is timely and necessary. Looking at the factors that affect media richness, there is certainly a similarity to the factors within the learner dimension and the communication dimension. Besides the media richness model, the diversity e-learning framework also includes the social influencing model (Fulk and Boyd, 1991), social factors and rational factors model (Webster and Trevino, 1995) and media style and preference (Rice and Case, 1983). All these models and theories point to the fact that there might not be a single way to deliver content which will satisfy all learners. In this regard the benefits of a multiplatform e-learning system might be able to mitigate the conflict by providing multi-channel access with various levels of media richness.

Secondly, the diversity e-learning framework links to the theory of knowledge reuse (Markus, 2001) which emphasises that the purpose of knowledge management is to reuse the knowledge created within the organisation. This perspective is similar to the commonly argued benefits of reusing learning objects (LO) in most learning systems. One difficulty with reuse is that the difference between knowledge producer (teacher) and re-user (learner) is the knowledge distance (level of difficulty), which

can be considerable. This is a rather common issue. In the multiplatform e-learning system framework, the function of the coordination dimension is to match the appropriate knowledge distance to the student. The knowledge distance is kept in the learner dimension.

Finally, the diversity e-learning framework proposed the use of an information structure framework (ISF) (Königer and Janowitz, 1995) to serve as a tool to evaluate information and avoid information overload for the student. This aspect is of minimum concern to the multiplatform e-learning system as the content and structure are bounded in the current implementation. The ISF suggests a four dimensional information profile to help in evaluating information. The four dimensions are selection, time, hierarchy, and sequence. In the multiplatform e-learning system framework, the selection and sequencing are governed by the coordination dimension. The hierarchy is conceived in the content dimension.

2.1.7 Summary of e-learning frameworks

The literature review identified several technical and theory oriented conceptual e-learning frameworks. The technically oriented frameworks reviewed in this section include the LTSA framework, the JISC e-learning framework, and the IMS abstract framework. The review discussed the common aspects among the technical frameworks. While there are many other abstract frameworks such as the Sakai (Sakai, 2005) framework and OKI (OKI, 2006) framework, it is not necessary to examine all of them. It is apparent that these technical frameworks are strongly focused on the services and functions of the e-learning system. A layer and object oriented approach seems to be the current trend. It is no surprise that this is the current trend in programming, system architecture and internet technology. These technical frameworks are normally platform, pedagogy, culture and operating system independent. In this aspect the multiplatform e-learning system is no different. However it is likely that these technical frameworks are strongly dependent on the theoretical framework they are built upon. The mapping between the theoretical frameworks upon the technical framework is likely to be challenging.

The theoretical frameworks included the learner-centred framework, the motivational framework, and the diversity framework. These theoretical frameworks stress the importance of pedagogical theory to support the foundation of an e-learning system. These frameworks also emphasise that learner characteristics and capabilities

such as learning styles, knowledge distance, confidence, motivation and social factors will influence the development of the e-learning content. There is thus a need for matching learner characteristics within an e-learning system. The multiplatform e-learning system framework shares most of the concerns which led to the development of some of these factors within each dimension. The main core of the theoretical framework is to realise the motivation needs of learners, their different strengths and weaknesses and to systematically create a relevant pedagogy based e-learning system that allows adapting and matching of learners' needs. Besides, for the e-learning to be successful, continued efforts are required in system evaluation and managerial support to ensure it is effective and enduring. To support this underlying principle, the current research provides a methodology for learner system interaction evaluation.

2.2 Review of content adaptation

One of the main issues for a multiplatform e-learning system is the requirement to provide meaningful access to an increasing number of accessing devices. Current web-based systems, including e-learning systems, use server-side designs that are oriented towards clients with standard screens and standard HTML browsers. These designs are unlikely to be acceptable for personal mobile devices such as mobile phones or PDAs. In order to provide meaningful access, the content, structure and navigation must be able to adapt to a multiplatform e-learning system. Thus a multiplatform e-learning system needs adaptivity, i.e., the ability of a system to adapt itself to different client needs. For the case of a multiplatform e-learning system this includes the ability to cope with bandwidth, memory and power limitations, restricted presentation capabilities and different user profiles. A review of content adaptation techniques is essential to understand and appreciate how different techniques can be helpful in the multiplatform e-learning system implementation process. It should be noted that some of these techniques, because of their assumptions, may not always be suitable for the current implementation.

To begin with, the Adaptive Web Content Delivery (AWCD) framework (Chen et al., 2000; Ma et al., 2000) provides a useful overview of the problems that have to be addressed in adaptive systems. Firstly, the system must be able to detect the parameters needed for adaptivity. This includes the automatic measurement of network bandwidth and load and the registration of used end-devices and user

preferences. The easiest approach to the latter is to use web forms. More sophisticated inference mechanisms can be based on user behaviour patterns.. And secondly, the system must provide a decision engine for determining when and how to adapt content. The first issue adopted in the multiplatform e-learning system utilised XML document string for each factor. The advantage of using XML string is the ability to provide simple exchange mechanisms with other modules and the potential to transform into other developing standards if necessary. The second issue is included in the coordination dimension of the multiplatform e-learning systems framework.

In general, there are two different classes of approaches to content adaptation as illustrated in Figure 2.2 (a) and (b).

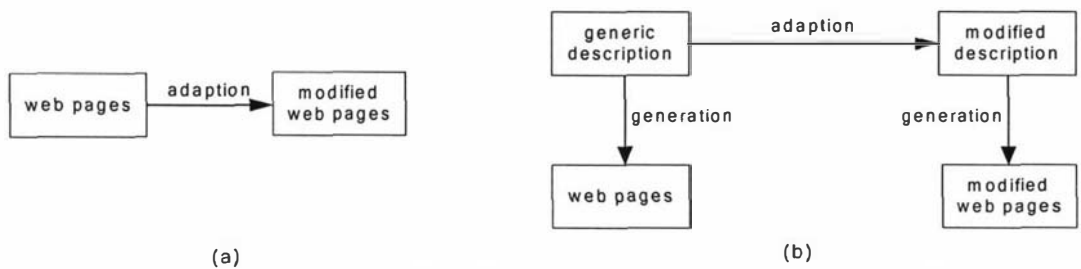


Figure 2.2 Two approaches to content adaptation

The first class of approaches deals with the problem on the level of pages, i.e. it is assumed that the web-based service is fully implemented by web pages that can be displayed by a standard browser on a standard computer display. Then adaptation has to take HTML as the format of its input. In the UWA framework (Finkelstein et al., 2002; Kappel et al., 2002; UWA, 2002) the adaptation can be expressed by event-condition-action rules. This approach assumes that a design has already been made in the PC environment and the adaptation is to transform the PC web page into another device environment. This assumption is not necessarily true in the multiplatform e-learning systems development. It is not necessary to assume PC web pages as a starting point but it is important to recognise that many existing e-learning systems do. Therefore some of the disadvantages of the page level adaptation approach may not be applicable in the multiplatform e-learning system as envisaged.

The second class of approaches handles the problem on a conceptual level, i.e. it assumes to start with a generic abstract description of the service's content, from which the actual web pages could be generated. Adaptation now takes the abstract description as its input and derives another abstract description. The pages generated

out of this modified specification can be more suitable for specific clients, in particular mobile clients. This approach may not allow other factors such as preferences and interactivity to be optimally incorporated into the cost function (Tretiakov and Kinshuk, 2004) which may affect the multiplatform e-learning system implementation.

For content adaptation on the level of pages, the most prominent approaches are re-authoring (Bickmore and Shilit, 1997) and transcoding (Bharadvaj, Joshi, and Auephanwiriyaikul, 1998; Hori et al., 2000; Smith et al., 1999). Reauthoring applies functions to web page descriptions, which will result in new descriptions that are better suited for various kinds of clients. Transcoding aims at direct manipulation of the HTTP stream. Based on these techniques several commercial products and system prototypes have been implemented such as Digestor (Bickmore et al., 1997), Spyglass (Spyglass, 1999), Intel QuickWeb (Intel, 1998), Mobeware (Angin et al., 1998), TranSend (Fox et al., 1998a), WingMan (Fox et al., 1998b), and Power Browser (Buyukkokten, et al., 2000).

Adaptivity on the level of page descriptions can be achieved more easily if data content, navigation links and presentation are separated from each other, e.g., by using XML, XLink and XSL (Goldfarb and Prescod, 1998). In a multiplatform e-learning system experience suggests that content, navigation, presentation and logic should be separated from each other. Also, the work of Chen et al. (2001) presents an interesting approach to detecting objects in pages and their categories using a functional object model. Adaptation rules are then applied to these objects. These page-based techniques for content adaptation will be reviewed in more detail.

Besides page-based techniques, newer techniques focus on paying attention to content adaptivity on the conceptual level. The apparent difference between the two classes of approaches is that for page-level adaptivity the adaptation rules will become part of the web-based service, whereas adaptivity on a conceptual level must provide generic rules for adaptivity. Application-dependent adaptivity may be easier to achieve, but it is expensive with respect to development and maintenance. Therefore, content adaptivity will also be reviewed on the conceptual level.

2.2.1 Page-level content adaptation techniques

Among the various published techniques for content adaptation, re-authoring (Bickmore and Shilit, 1997), transcoding (Bharadvaj, Joshi and Auephanwiriyaikul ,

1998; Hori et al., 2000; Smith et al., 1999) and the functional-based object model (FOM) (Chen et al., 2001) are the most relevant examples. They are reviewed below.

2.2.1.1 Re-authoring

The idea of re-authoring is to apply functions to web page descriptions, which will result in new descriptions that are better suited for various kinds of clients. As web pages usually present a mixture of content, navigation and presentation, it is desirable to first split pages into these components. In a second step, adaptation functions can be applied to the isolated components. These functions may be designed particularly for mobile clients. The third step consists of re-integrating the components into a new web page description.

Initially, the approach was designed as guidance for manual construction of alternative descriptions of pages. Of course, content adaptation aims at algorithms rather than guidelines for manual redesign, but the guidelines are nevertheless useful for designing such algorithms. On the basis of HTML pages it is very difficult, if not impossible, to provide algorithms for the first step. Therefore, it is advantageous if page descriptions exist in the form of XML documents. In the multiplatform e-learning system implementation XML documents were adopted as the starting point. This approach is motivated by a better chance of success in transformation and extensibility, if needed. An XML document provides the description of content, whereas navigation and presentation are separately described by XLink and XSL, respectively. The content adaptation functions can change or remove elements in the XML document. These techniques are known as transformation and elision (Bickmore and Shilit, 1997). The follow-on navigation adaptation functions would reduce the links to those needed for the new content. Finally, applying XSL would result in a new presentation. While this technique sounds appropriate, it does not explain how interactivity and parameter transfer can be achieved in a dynamic page.

The Digestor system (Bickmore and Shilit, 1997) used a proxy-based heuristic approach for automated re-authoring. In this particular system the technique included outlining, first sentence elision, image scaling, and building an abstract syntax tree. The authors reported that the method worked well for small screen mobile devices.

The main argument against the re-authoring technique is that it is non-generic. Even if XML is used, transformation and elision functions have to be written separately for each site and each new end-device. This shortcoming can be overcome

by organising devices with respect to their capabilities rather than treating them as different devices. In the multiplatform e-learning system, the framework is thus built upon devices' capabilities rather than device type. This approach also does not mention how to handle multimedia objects such as flash.

2.2.1.2 Transcoding

Transcoding aims at direct manipulation of the HTTP stream. Modifying the HTTP streams and changing their content in situ is called active transcoding and is done dynamically without user intervention. Transcoding can be done on both upstream and downstream HTTP strings. One implementation of this technique is the MOWSER (Mobile Browser) system (Bharadvaj, Joshi and Auephanwiriyaikul, 1998), an Apache proxy server agent written in Perl, in which the proxy modifies the incoming HTTP stream. For the modification itself transcoding rules are used, which are kept separate from the HTML pages. These rules take into account the user preferences (Bharadvaj, Joshi and Auephanwiriyaikul, 1998) and annotations (Hori et al., 2000).

In the MOWSER system user preferences and client capabilities are stored on the server. The modification and update of preferences is done via a CGI form at the website maintained by the proxy. The proxy then fetches files with the most suitable format for the mobile client. The system assumes that different formats are available for content adaptation. This is not an issue, as different formats can be created as needed and cached in the server for future requests. Transcoding of images and video is done using scaling, sub-sampling or sub-key frames. The transcoding of HTML pages is done by eliminating unsupported tags according to the stored user preferences. However, a limitation of the MOWSER system is that it does not affect navigation which may affect user satisfaction while interacting with mobile clients. The MOWSER system provides the options of pre-scaling and storing image objects, but not for flash.

Annotation is a way of providing hints for a transcoding engine to make better decisions in content adaptation (Hori et al., 2000). Basically, this method uses some predefined descriptors to define the transcoding rules. Descriptors should be stored separately from the HTML files. Annotation plays the role of a mediating representation, which provides semantics to be shared between meta-content authors and a content adaptation engine. A potential advantage of an annotation-based

transcoding approach is the possibility of content adaptation based on semantics that cannot be achieved by approaches based on web page syntax.

The principles discussed for re-authoring also apply to the annotation-based transcoding, i.e., decomposition (isolation), partial replacement of content (distillation or elision), and combination (re-mapping). The implementation reported by Hori et al. (2000) uses the RDF framework for implementing the annotation descriptors and Xpath/Xpointer for associating an external description with a portion of an existing document. Thus, the benefits resulting from using XML-related technologies have already been realised. The annotation uses a predefined vocabulary comprising alternatives, splitting hints and selection criteria. Thus to implement this approach there is a need to predefine a set of vocabulary or use existing proprietary vocabulary that may result in limited extensibility.

Annotation-based transcoding has proven to be useful for mobile systems which are task-oriented such as mobile assessment, mobile quizzes or mobile forms. The issue with annotation-based transcoding, however, is that it is application-specific, whereas customisation using a mark-up language is very limited. It is also difficult to generalise the approach, so it is unlikely to be suitable for interactivity and navigation logic. Moreover, an annotation-based method is likely to be labour intensive. Therefore it is not incorporated into the multiplatform e-learning framework.

2.2.1.3 The functional-based object model (FOM)

The FOM approach (Chen et al., 2001) detects objects in pages and generates their categories before applying adaptation rules to them. This approach is an attempt to describe the intentions behind pages and to shift content adaptation to a semantic level. Nevertheless, the approach remains on the level of page descriptions rather than switching to a conceptual abstraction.

The rationale is that every object in a website serves certain functions, which are either basic or specific functions. FOM distinguishes between objects, which themselves can be basic or composite, and object categories. Based on this, a complete website is transformed first into a FOM model, before adaptation rules are applied to the model rather than to the web pages.

A basic object is the smallest element in a hypermedia. It is determined by its presentation, semanteme, decoration, hyperlink associated with it, and its interaction. Basic objects can be grouped into finite sets, which are considered composite objects.

A composite object $C = \{O_1, \dots, O_{NR}\}$ is further described by clustering and presentation relationships.

The specific function of an object in a given application environment is represented by its category, which directly reflects the author's intention. Examples of such object categories in FOM are information objects, navigation objects, decoration objects, special function objects, and page objects.

The FOM method requires basic object detection to be performed first, then to generate the necessary category objects. Composite objects are detected by layout analysis of the web pages using an image pattern detection algorithm. Then, content adaptation rules are applied to the objects producing the adapted pages. The FOM method uses different rules for each object category.

The assumption in FOM is that the adapted page is based on an existing page, thus taking numerous steps to achieve adaptation. This assumption is not necessary for the multiplatform e-learning system framework. Data is the fundamental element in the multiplatform e-learning framework rather than web pages. The FOM approach does not address several issues relevant to a multiplatform e-learning system such as how learner preferences can be adapted, how different delivery modes can be adapted, how flash objects and image objects can be adapted and the influence of slower bandwidth. Nevertheless it indicates the principle that knowing the intention of the underlying web page functionality can be useful in providing adaptations.

2.2.2 Conceptual content adaptation

Conceptual content adaptation is a new approach to providing adaptation. One such technique is the media type approach. Media types were introduced by Feyer et al. (2000) as a means to formalise web-based systems. The major intention was to abstract completely from presentational issues, but nevertheless to keep in mind the capability for presentation. Media types provide a conceptual abstraction from the page level based on extended views. One of these extensions addresses adaptivity. The underlying idea is to include information that indicates which parts of media type content should preferably be kept together and which parts can be separated. Two mechanisms have been developed for this, one based on subtyping, and the other on numeric proximity values.

2.2.2.1 Fundamentals of media types

For content, media types provide abstract structural descriptions based on type systems including navigation structures. They also support database connections via views. The data provided by a media object may include hidden data, e.g., links, as well as context and escort information. Escort information allows the user to see the history of steps performed before being in the current state. In order to support different presentations to end-users and various end-devices, media objects allow different granularity and density of content.

Functionality is achieved by adding functions. These can be internal functions such as database processes, internal search and navigation, or external connections such as general search, links to other sites, etc., or support functions such as marking and extraction in connection with metaphorical structures.

The core of a media type is defined by a view on an underlying database. The view is created through a query q_v which transforms databases over S into databases over S_v (Schewe, 2002). The query is capable of providing navigation links with the media types for navigation adaptation. In content adaptation, media types use the technique of cohesion. Cohesion defines which information should preferably be kept together, and which information can be separated. Restrictions imposed by the client, e.g., a mobile client, may require splitting the media type into several smaller ones. The theory of media types provides two mechanisms to support cohesion based on a total (pre-) order or proximity values. Cohesion introduces a controlled form of information loss. Information loss may result in an unsatisfactory experience for the learner. In the multiplatform e-learning system there are concerned with the effect of perceived information change by the learner affecting their satisfaction when the same information is presented in different accessing devices.

This method is feasible but is not in the mainstream of development. The concept seems to be based on manipulating a large database set. This approach was not adopted in the multiplatform e-learning implementation but it suggests an opportunity for future research work in this area.

2.2.3 Summary of content adaptation

Content adaptivity of web-based systems for mobile clients is an issue. State-of-the-art content adaptation techniques based on re-authoring (Bickmore and Shilit, 1997), transcoding (Bharadvaj, Joshi and Auephanwiriyaikul, 1998; Hori et al., 2000;

Smith et al., 1999) and functional-based object detection (Chen et al., 2001) were reviewed. Despite their individual merits the major disadvantage seems to be that these approaches operate on the level of web pages with the assumption of existing PC based web pages as starting point. This assumption is not necessarily true in the multiplatform e-learning system framework. The new media type approach exploits the cohesion feature of media types, which allows the information to be tailored to the restrictions of the mobile clients. However the media type may be more suitable for large database-backed, web-based information services rather than e-learning systems.

2.3 Review of mobile learning research

One factor that triggered the emergence of multiplatform e-learning systems, as discussed earlier, is the explosive growth of mobile devices that are supported by high bandwidth technology infrastructure such as General Packet Radio Service (GPRS), third and fourth generation telecommunications (3G and 4G) infrastructure and wireless local area networks (WLAN). Mobile devices are beginning to transform traditional e-learning systems and could potentially fuse them into a multiplatform e-learning system. Therefore mobile learning research is relevant here. Reviewing research on mobile learning allows factors and issues relevant to the development of the multiplatform e-learning system framework to be extracted. Indirectly, it supports the notion that there is a variety of existing mobile learning systems that need unification and a multiplatform e-learning system may well be the answer.

Research in mobile learning is currently experiencing dynamic growth. It is not viable to cover every aspect and provide the latest developments here. The discussion is thus limited to several mobile learning and teaching applications that are currently being deployed and evaluated (Roschelle et al., 2004; MLearn 2004; Hoppe et al., 2003). The review suggests that mobile learning can significantly complement e-learning by creating an additional channel of access for mobile learners with mobile devices. If the additional channel can integrate well with the traditional e-learning system then the eventual success of multiplatform e-learning systems can be envisaged. For the integration to work well it is necessary to investigate the basic issues facing mobile learning with respect to learner satisfaction and adoption. Existing applications tend to create separate instances of the content and do not use the same content that is available for PC based applications. This creates problems of

duplication of effort, double maintenance and problems of versioning control. This is further evidence for the need of a unifying approach.

2.3.1 Mobile learning research in practice

Research in mobile learning can be categorised into four research streams. The first, practical mobile learning research involves the construction of mobile learning tools or applications and evaluates their effectiveness, satisfaction, and efficiency. These include using mobile learning for games or contests, confining mobile learning within the classroom environment, providing mobile learning in a laboratory setting, using mobile learning during field trips, applying mobile learning as distance learning tool, deploying mobile learning in an informal setting and utilising mobile learning as a tool for learning and teaching support. To some extent the current multiplatform e-learning system can be considered part of this category of research. The objective of practical mobile learning research is normally to reveal an innovation that could work well in creating an environment for effective learning. The diverse nature of practical mobile learning research can be used to extrapolate the potential benefits of having a multiplatform e-learning system as a foundation for integrating the diversity of devices. The evaluation process in practical mobile learning research includes a mix of observation, survey feedback, questionnaires and interviews. These evaluation techniques can be adopted with more precision in the multiplatform e-learning system evaluation process. The second, theoretical aspect of mobile learning research focuses on explaining and validating pedagogical and learning theory in a mobile setting. Theoretical mobile research aims to understand what actually happens between a learner and a mobile device and how learning is acquired. The third, mobile learning infrastructure research focuses on technical system architecture. It normally devises an infrastructure that facilitates deployment of mobile learning application. Current issues include reusability, meta-data content structure and the use of context meta-data. The multiplatform e-learning system framework has certain similarities in its motivation with mobile learning infrastructure research. It is however less technically oriented. Lastly, mobile usability and evaluation research focuses on fundamental issues regarding human/mobile device interactions. The aim is to devise a formal evaluation methodology and assess learner satisfaction based on interactions with mobile devices in different usage contexts. The evaluation part of the multiplatform e-learning system framework is of this nature.

2.3.2 Practical mobile learning research

Interactive games and contests using mobile devices such as PDAs and mobile phones can be used to encourage learning. Mitchell (2003) explored the potential of a games-oriented implementation for an m-portal. The findings suggested that a multi-user m-portal for games and a hybrid learning scenario can bring added value as an alternative means of attracting and engaging target audiences. It could also enable users to master team building, social and communication skills. A survey conducted by Attewell and Savill-Smith (2003) showed high interest among young people using phone-based games to improve spelling and reading and mathematics. Other games related research examined deploying English contest event learning strategy to different connected classrooms using a wireless remote controller (Chang et al., 2004) and the use of a workspace puzzle view using a tablet PC to enhance group interaction (Deng et al., 2004). These examples show that different types of game activities can be used in different kinds of mobile devices. The interesting nature of mobile games is favoured by learners. By extending these activities so that they can be reached and communicated by different accessing devices including PCs, the resulting benefit may be beyond that of individual accessing device type alone. A multiplatform e-learning system is a good candidate to achieve such integration.

A mobile learning space can be confined to a classroom environment and achieve good results. For example Dawabi et al. (2003) described a classroom of the future. Their system integrates an electronic blackboard and PDAs to provide tools for brainstorming, quizzes, and voting in a classroom environment. Goldman et al. (2004) developed a mathematics learning environment for students to explore and learn about functions, and the evaluation showed significant gains for students using the system. Cortez et al. (2004) developed a mobile computer supported collaborative learning system to support high school teachers with wireless networked handheld computers. The system is able to promote collaboration and constructivism. The evaluations showed that the environment enables the students to construct new knowledge based upon previous knowledge. These examples affirm the observation that environment can be an influential factor and should be considered in the multiplatform e-learning system framework.

In the laboratory environment mobile devices can be used for data gathering and to control robots. Milrad et al. (2004) deployed mobile and wireless technologies to support hands-on scientific experimentation and learning. They used a PDA to control

a robot in a maze in order to facilitate programming and algorithm development. Their findings showed that the experiences of learners are much enriched as the system brings them closer to real activities. Similarly Jansen et al. (2004) combined handhelds and programmable Lego bricks in a classroom environment to help a robot escape from a maze. They used different pedagogical scenarios to enhance learning. This could imply that pedagogy is an important factor in influencing learners. Likewise a PDA based laboratory for science experiments on data acquisition is useful for visualisation (Skalsky and Pastel, 2004). From the above discussion, it seems likely that these activities are generated from a PC system and subsequently adapted to PDAs. The underlying PC system is capable of performing either the same or additional functions. These are good examples of how a multiplatform system could evolve.

The obvious advantage of mobile devices is mobility. Mobility enables learning to take place in the field. Chen et al. (2003) developed a mobile learning system for bird watching based on the scaffolding concept. The system is developed based on PDAs and a WiFi network. The evaluation showed that children using the system improved their knowledge. Chen et al. (2004) further extended the system to a mobile butterfly watching learning system for supporting independent learning. The system allowed users to submit a digital picture query. The system responds with the highest matched butterfly information to the user via the PDA. Mobility can give the experience of proximity. Collaboration between the classroom and an ongoing field trip can bring excitement and immediacy. Hine et al. (2003) described a collaboration system between a classroom and a field trip. The remotely accessible field trip project is a means of spanning field trip and classroom locations to provide an integrated learning environment. These experiments showed that mobile devices can create proximity and portability that may enrich the learning experience. In the multiplatform e-learning system framework, the portability factor is included in the device dimension and participants discussed it in their feedback.

Kanamori and Kobayashi (2004) used videophone to deliver home education for a student with severe physical impairment. Using a 3G video phone makes video conferencing much more convenient to set up. Their experience showed that a video phone can be an effective educational system although some fine tuning was still needed. Britto, Lopes and Michalkiewicz (2004) developed a telemedicine and distance learning system in the paediatric oncology surgery domain that provides

mobility for doctors who are travelling across the country to access information and provide data entry. Thus in distance learning applications the ergonomic capabilities of the mobile device are crucial. In the multiplatform e-learning system framework, ergonomic capability is included as a key factor influencing learners.

Mobile devices and context aware technologies can be useful to facilitate learning in an informal setting. Informal environments include places such as museums, galleries, gardens, aquariums, and so on. Hsi (2004) deployed two applications for museum visits at the Exploratorium in San Francisco to support informal science learning using Radio Frequency Identification (RFID), handheld computers and a wireless network. The study focussed on three aspects of learning: the cognitive level, social level and interactive level. Ogata and Yano (2004) developed a context-aware language learning support system. The system can provide a learner with the appropriate polite expression derived from the learner's situation and personal information. The system also used RFID and was evaluated in a simulated environment and well accepted. Chou et al. (2004) developed a tour guide system for mobile learning in a museum. Their system aims to cater for both individuals and groups of visitors. Yatani et al. (2004) developed a system to support children's collaborative learning in a museum. Their findings suggested that children can be directed to less interactive and less attractive exhibits using questions that are related to the exhibits. Brandt, Hillgren and Björgevinnsson (2003) reported peer-to-peer informal learning at an intensive care unit where mobile technology is used for communication and interaction through the production of real situation video. The system provides an opportunity for reflection, learning, and developing work practice. Kadyte (2003) developed a mobile system for language learning. The development of the system was based on dimensions such as time, information, location and context space. Context space can include cultural, personal mobile, virtual and physical community. These examples illustrated that context factors are important in facilitating learning and will have an impact on the learner. The multiplatform e-learning system framework includes context factors such as quietness, availability of personal help from instructor or self directed exploration and multitasking in the environment sub dimension.

Technical problems in wireless connectivity can generate negative feelings in the learner. Singh et al. (2004) developed a collaborative note taking system using PDAs. Students who use the system can share their notes among members of the group.

Issues raised from such a system tended to be negative, such as information overload, privacy and connectivity problems. Relan et al. (2004) reported the experience of design, development and implementation of a project using handheld technologies to support a medical school curriculum. Their experience showed that students and faculty may not use PDAs to their maximum potential. Faculty resistance to using PDAs for teaching is another obstacle to overcome. Resistance to use can be viewed as a motivation issue. In the multiplatform e-learning systems framework these factors are included in the communication dimension, learner dimension and the content granule sub dimension.

2.3.3 Theoretical mobile learning research

Roschelle (2003) addressed the value of wireless mobile devices by arguing that wireless mobile learning is an imprecise description of what actually takes place between the learner and the mobile device. A more precise understanding of the pedagogical requirement is needed. Further research should explore rich pedagogical practice generating from simple wireless and mobile technologies. The implication is that for successful mobile learning, pedagogical and learning theory research on the use of mobile technologies is an important factor. In the multiplatform e-learning system framework, pedagogy is recognised and included in the content dimension. In relation to pedagogy, producing a set of best practice guidelines for mobile learning can be valuable. Vavoula et al. (2004) produced a set of pedagogical guidelines for learners, teachers and policy makers who are considering mobile learning technologies. Their guidelines comprise a list of recommendations of what to do and what not to do supported by theories and are validated and segmented by audience. Ten guidelines were produced related to costs, usability, choice of technology, roles, equipment management, support for teachers, administration, collaboration, services and applications, and security and privacy. Roschelle et al. (2004) developed guidelines for teachers to use mobile devices for measuring students' progress in scientific investigation. The guidelines suggested that handheld assessment should be designed for teachers 'in transition' to inquiry-oriented science teaching. Handheld assessments should help teachers initiate assessment practices that were better aligned toward inquiry-oriented instruction. They should broaden the range of assessment tasks. Handheld assessments should emphasise active roles for monitoring their own work and should be simple and focused additions to teachers' existing inquiry-

oriented practice. Not all the guidelines were relevant to the current research. Some of the relevant guidelines were considered in the multiplatform e-learning system framework, for example usability issues. Mobile learners can be different from desktop learners: Bull et al. (2004) evaluated four intelligent tutoring systems to investigate the roles of mobile learner models. They identified that not only is location information relevant to the content of an interaction, but it can also affect an individual's ability to undertake a focused study. In the multiplatform e-learning system framework, the mobile profile is recognised and is part of the learner dimension.

2.3.4 Mobile learning architecture research

Mobile learning architecture research explores system architecture issues in mobile learning systems. Sung et al. (2004) reported an innovative architecture that allows the rapid prototyping of wireless mobile multi-user applications for use in the classroom. The MIT.EDU platform combined inexpensive components and sensors providing a distributed real-time multimodal context aware application. One of the applications can gather a real-time and post processed statistic that can guide and help teacher interactions with students. Lonsdale et al. (2003) described a context-awareness architecture for mobile learning, which is object oriented and feature based. The basic operations in the context awareness system include input of context metadata, construction of context sub-state, exclusion of unsuitable content, ranking of remaining content and output of a ranked list of content. These examples reaffirm that contextual information can influence learners and to be able to use context data the system architecture must be able to support it. In the multiplatform e-learning system framework this is provided for in the environment sub dimension. Information may be lost from the original learning object when designing scalable and mobile learning for multiple technologies (Stone, 2003). There is a need for an infrastructure that supports the generation and sharing of metadata and effective meta-analysis of learning objects to support consistent pedagogy in mobile learning. Thus a framework that includes the pedagogy factor is necessary.

2.3.5 Mobile usability and evaluation research

Human/computer interface issues in using mobile devices affect the satisfaction of and adoption by the learner. This is a fundamental area that requires further

research. Simple input problems may result in total rejection of use. Houser and Thornton (2004) evaluated the typing speed of mobile devices. Their findings showed that Japanese students would require some training if using PDAs and writing in English. Vainio and Ahonen (2003) argued that learning usability is one area that is lacking in mobile systems. They looked into a critical approach to an adaptive user interface design. Their aim was to develop mobile systems that are adaptable to more than one learning context based on the hypothesis that learning is not clearly defined in most usability studies. To this end the current study includes an evaluation of the multiplatform e-learning system. Other researchers such as Syvanen et al. (2003) provided an evaluation based on the concept of fragmentation. Using a set of mobile learning questionnaires, their evaluation results suggest avoiding fragmentation in the design of mobile learning practice and material in the primary school setting. Key guidelines cover accessibility, skill, usability, flexible interaction, time to process content, connection, distraction, classroom culture, user culture and expectation, and design tools for mobile learning. Baber et al. (2003) proposed a learning space model to examine the suitability of different technologies for mobile learning. Using the concept of quality function deployment they have demonstrated that the method can aid in evaluating user requirements for the design of learning technologies that match the assumed functionality of the technology. Thus usability research in mobile learning is an important precursor to the successful adoption of the technology. The current research includes an evaluation to measure the satisfaction levels of the learners with respect to the multiplatform e-learning system framework.

2.3.6 Summary of mobile learning research

Mobile learning research is a growing field. However the mass adoption and benefits of this technology have yet to be realised. Adoption will take time as many basic issues need to be resolved such as pedagogy, adaptation, learner experience, usability and many more. Mobile content is an important influencing factor and it varies greatly. Mobile content can be as simple as a short message service (Stone, 2002) or as sophisticated as a real time video. Environmental factors such as context of use and pedagogy are two other important influencing factors. They should be used as principles to guide the implementation of mobile learning. Multimedia content factors such as the use of flash or scalar vector graphic (SVG) multimedia animation objects on mobile devices may need further evaluation from the perspective of

learners as these are emerging technologies for most mobile devices. The multiplatform e-learning system framework includes this aspect. The literature review also showed that many researchers used existing mobile device software such as browsers, file transfer, note-takers, voice recorders, and e-mail to conduct their respective experiments. These approaches may indicate that at the moment an understanding of how such common tools affect learning is still lacking, further justifying the need for basic research. Sophisticated mobile applications which involve multiple technologies such as databases, Java, ActivePerl, forms, RFID, and multi-sensors are increasingly becoming popular. These will require innovative system architecture to support the use of context data. A unifying approach may be necessary to integrate different devices. Mobile learning research may well move in the multiplatform e-learning system direction. In most of the mobile applications the design is directed towards a particular set of mobile devices. Only a few applications started with the PC in mind and moved to mobile devices with a re-design. These approaches may not be efficient and again there is a need to integrate the design approach. Manufacturers are continually launching new mobile devices. The multitude of emerging devices supports the need for a unifying multiplatform framework. Although deployment of mobile technologies is taking place, most mobile learning applications in the literature were run in a fixed mobile environment where user is physically stationary. New usability tests will be needed to realistically mimic the working situation if such tests cannot be done in real work environment. The advent of networking and wireless technologies means that using wireless local networks as well as public telecom infrastructures as the access channel will be commonplace. Mobile learning applications must be evaluated with respect to network stability and quality from a learner perspective rather than the technological perspective to measure satisfaction levels. The review also showed that discussions of implementation issues and evaluating end users' experience were very limited in scope. The current multiplatform e-learning research emphasises on both implementation and end user experience issues.

2.4 Review of W3C device independence activity

The motivation of the W3C Device Independence Activities (DIA) (W3C, 2001) is closely related to the research in multiplatform e-learning system frameworks. The goal of the DIA is to develop ways for future web content and applications to be

authored, generated, or adapted for a better user experience when delivered via multiple device types. In DIA, user experience is defined as a set of material rendered by a user agent who may be perceived by a user and with whom interaction may be possible. The goal of the current research is to devise a framework for accessing e-learning content via different accessing devices with the aim of analysing the level of influence of the factors within the framework. The current research therefore complements DIA by focusing on basic questions relevant to e-learning and learner satisfaction. In addition, the current adaptive multiplatform e-learning framework takes insights of the DIA perspectives of user, authoring and delivery mechanisms to formulate a competency framework that focuses on content, learner, device, communication, and coordination dimensions that better fit the e-learning environment.

2.4.1 DIA principles

Motivated by future access scenarios, DIA looks at how web content can be accessed from three perspectives: the user perspective, the author perspective, and the perspective of delivery mechanism. DIA identifies seven working principles to achieve the goal (W3C, 2001). The seven working principles are: device independent access, device independent web page identifiers, functionality, incompatible access mechanism, harmonisation, characterisation of delivery context, and adaptation preferences. The goal of the device independent access and device independent web page identifier principles is to ensure that a functional user experience is always possible via any access mechanism. In multiplatform e-learning system implementation this is achieved by matching the devices' capabilities with functional content. In the evaluation process, comparison is made between e-learning systems that provide functional user experience to various accessing devices to determine the level in learner satisfaction. The functionality, incompatible access mechanism and harmonisation principles aim to ensure that functional experience, if not met, should give appropriate feedback to the user and that harmonised user experience is possible from the author perspective. A harmonised user experience is one that meets the user delivery context and also the quality criteria of the author. In the multiplatform e-learning system, if the user delivery context can not be met, the lowest version of the functional user experience is rendered depending on the device's capability. The harmonised experience is governed by the coordination dimension which provides

harmonised adaptation based on attributes from other dimensions such as bandwidth, device capabilities and environment factors. Finally, the characterisations of delivery context and adaptation preference principles ensure that delivery context is made available to the adaptation process and that users can change their preferences to modify the adaptation process. In the multiplatform e-learning system, the delivery context such as bandwidth, device profiles, learner profiles and preference are either stored in XML files or estimated in real time to allow the adaptation to process. User preference can be changed by the user to be reflected in the adaptation process.

2.4.2 Summary of device independence activity

The device independence activities mentioned above strongly demonstrated a vision for the future of a multiple devices accessing scenario in general web service. The current research of a multiplatform e-learning system framework is aligned with the direction of W3C's DIA. This research concentrates on the domain of e-learning and also devises a set of competency principles to operationalise the multiplatform e-learning system framework. E-learning is a revolutionary way of teaching. With the advent of mobile technology e-learning is constantly evolving, thus there is an increasing need for more research. The multiplatform e-learning research also aims to gain new knowledge by focusing on fundamental factors influencing learners when exposed to a variety of accessing devices. In this regards, the current research goes beyond and complements the DIA activities.

2.5 Review of device identification techniques

Device identification is extremely critical in the adaptation process. Without the capability of device identification it will be very difficult to perform adaptation. A review of the technologies currently deployed in web device-browser identification is essential to provide an understanding of how these technologies can be used effectively and efficiently to facilitate a rapid prototype implementation of the adaptive multiplatform e-learning system.

2.5.1 Client-side identification

The most basic technique is the client-side scripting technique (Homer, 1998). This technique first requires the device browser to support client side scripting. Once the script detects the browser type in the navigation object property it is able to select

and adapt the content to the client device type. Script support is normally limited in mobile devices so this can be an issue. Client-side detection is also limited in scope as it currently only identifies the “userAgent”, “appName” and “appVersion”. Another limitation is that the entire content must be delivered to the client browser for adaptation otherwise multiple HTTP calls must be made. Nevertheless user preferences can be adapted easily but not efficiently in term of bandwidth, delay and content consumption. It is unlikely that this technique would be deployed without additional backup.

2.5.2 Server-side identification

Server-side identification can be achieved via different technologies such as CGI, ASP, JSP, XSP, Java Servlet, or PHP (Blaylock, 1999; Isaacs, 1998). Almost all server-side scripting languages can perform device browser detection and respond to adapted content accordingly. The main method used for server-side detection is to detect the HTTP header user-agent string. In the active server page (ASP), the HTTP string content can be read via the “*Request.ServerVariables*”. In PHP a similar string variable “*\$HTTP_USER_AGENT*” contains the information about the browser. In most cases, performance, preference and consistency will determine the choice of technologies used. Compared with client-side techniques, server-side techniques are practical choice for devices with low processing power, limited battery time and little memory such as mobile devices. In view of this, the multiplatform e-learning system implementation adopted the server-side identification technique.

2.5.3 Browscap technique

Browscap is a server-side identification technique that allows the active server page to use the “Browscap.ini” file to identify the requesting browser (Homer, 1998). The browser capabilities information is stored in the “Browscap.ini” file and allows the information about the browser to match with the ActiveX component objects as defined in the “*server.createobject*”. This is an active server page (ASP) method and is therefore restricted to server that supports ASP.

The Browscap technique has several limitations (BH, 2002). One such limitation is accuracy. If browser information is not stored in the “.ini” file, it will report the browser as “Unknown” instead of providing the necessary information. Browscap sometimes incorrectly identifies an IE browser as Netscape, or vice-versa. Also

common is misidentification of the properties, such as reporting the version number for the IE 4.01 browser as 4.0. Likewise there are cases where the browser and version properties are correct, but additional properties such as Platform are reported as "Unknown". Another limitation is maintenance. Browscap requires ongoing updates to make sure it recognises new browsers as they are released. Most often it will not, and an updated Browscap file will be required. The final limitation is its capability. Browscap provides basic information about a browser, such as its major and minor version number and platform. It is unable to provide information such as cookies or scripts support, file upload, SSL, DHTML, XML, style sheets, DHTML, and many others. While this method may have its limitations, it is freely available and can be deployed rather quickly.

2.5.4 Browserhawk technique

BrowserHawk is another server-side technique to detect device capabilities. It can provide more comprehensive detection of browser capabilities (BH, 2002). It is similar to the Browscap method of using the ActiveX/Com method of Microsoft technology. It can integrate with an ASP.Net framework and provide a more comprehensive detection scheme than mobile Internet tools in a .Net framework. These features will be useful for multiplatform e-learning system implementation.

BrowserHawk software can detect IE, Netscape, Opera, and AOL browsers, WebTV browsers, Konqueror, Mozilla, AWeb, iCab, Dreamcast and many others regardless of the version, platform, language or any other factor. One of the valuable features of BrowserHawk is the ability to detect mobile devices. These include WAP and i-Mode phones, Palm and iPaq PDAs, interactive TV, web kiosks, and more. BrowserHawk can provide information on over 120 properties such as security setting, cookies, script, multimedia player, mobile browser, connection speed, firewall, proxy setting, display setting, frames, language setting, IP address and many more. Thus it is a commercially available product that could facilitate the implementation of the multiplatform e-learning system if needed.

2.5.5 CC/PP and UAprof

In the W3C community there are standardising activities that look at frameworks for device independence access in the general web domain. One such activity is CC/PP which stands for Composite Capabilities/Preference Profile (Butler, 2001a;

W3C, 1999a, 1999b, 2000a). CC/PP is both a contextual framework and a profile framework. A contextual framework allows accessing devices, whether mobile or stationary, to communicate their capabilities to the server while the devices request information. A profile framework allows the user to structure assertions about preference objects. Thus a contextual framework allows device capability in the device dimension to pass on the information to the server while a profile framework allows learner profiles and preferences in the learner dimension to pass on information to the server. The design in CC/PP is leveraged on the use of resource description framework (RDF) for namespace, assertion structure and XML encoding.

In the open mobile alliance forum community, the UserAgent Profile framework (UAProf) is targeted toward mobile phones and is also based on RDF and CC/PP (Butler, 2002a, 2002b). CC/PP and UAProf are conceptually very similar. The implementation guideline for UAProf is however more defined than that for CC/PP.

One shortcoming of CC/PP is that it does not specify the mechanism of how the profiles should be communicated to the server and how the server resolves the profile. Thus resolving is up to the developer. There are two ways to implement profile resolution. One is to write a servlet (in e.g., C, java, Perl) in the server engine and the other way is to implement a CC/PP proxy server that is able to resolve the profile and channel the adapted request from the server to the requesting device.

One such implementation is DELI developed by the HP lab that allows Java servlets to resolve HTTP requests containing CC/PP information (Butler, 2001b). Another extension approach to DELI, which has been incorporated in Apache Cocoon XML publishing, requires creating conditionals in XSLT that query the profile using XPath. This extension, however, of specifying constraints for matching device profiles in XPath is complicated and cumbersome. Furthermore there is no easy method of abstraction to allow common sets of constraints to be reused in multiple stylesheets. Another implementation is DICE, which is again based on DELI but uses HTTP/1.1 request string to resolve the CC/PP Profile. Other commercial implementations of CC/PP include Cysive (Cysive, 2002; Izdepski, 2002), Argogroup (Argogroup, 2005), and IBM (IBM, 2005). While CC/PP implementation is emerging, it is not easy to integrate with the multiplatform e-learning system. Moreover it was reported to have various problems (Korolev and Joshi, 2001).

2.5.6 Problems with CC/PP

Korolev and Joshi (2001) pointed out several problems with CC/PP. One such concern is that the CC/PP framework describes every detail of the client device. This fine grained descriptiveness complicates the development of the web services, because the web server will have to fetch all the necessary descriptions that are specified by the client, apply the required profile differences “DIFFS” and maintain profile caches in order to reduce document regeneration. In addition to that, the web server has to analyse the received descriptions and provide suitable content. With the large number of variables in the CC/PP descriptions the resulting possible number of transformations of any particular document is very large. This makes the transformation process very complex and makes caching of the transformed document less efficient.

Korolev and Joshi (2001) also pointed out that the fine details of CC/PP descriptions also contribute to the complexity of the client’s software, because the web browser must be aware of all possible configuration changes on the client, and create the necessary “DIFFS” to standard configuration, which requires relatively expensive computation of MD5 signatures for the original profiles.

Finally, according to Korolev and Joshi (2001), having a separate description for every single model of client device even if those devices are essentially the same in terms of their capabilities and connectivity (e.g. a Dell notebook vs. Compaq Notebook, a 3COM Palm Pilot vs. Handspring Visor) will generate a lot of extra traffic and will require a large amount of storage in the caches for fetching and storing duplicate capability descriptions, which is not desirable in wireless networks. In addition to that, there is a considerable processing overhead on the server associated with merging the standard capability description of the client device with user-supplied differences.

Thus the multiplatform e-learning system framework does not dictate a specific implementation. Implementation should adhere to the overall objective of the research. And in this case, the ability to evaluate overall learner satisfaction and the factors influencing it are of primary concern.

2.5.7 Other implementations

Morphis (2002) uses proprietary device capability database in the Morphis open source device transcoder. Morphis uses the XML standard to provide profiles, which

is not CC/PP compliant but is capable of providing device and profile resolution. The profiles are kept in a “device.XML” document for dynamic item selection. The device.XML is the file that defines the rules that identify the device and its capabilities. It is a feature of Morphis WAX that enhances the delivery of the proper content to devices. The Morphis API provides for some device abstracts.

HAWHAW stands for HTML and WML hybrid adapted Web server (HawHaw, 2002) and is a toolkit to create universal mobile applications. HAWHAW checks the HTTP request information, namely USER AGENT header and ACCEPT header, and then decides how to create an appropriate HTTP response.

The HAWHAW API offers a “least common denominator” of various mark-up languages such as HTML, WML and cHTML. HAWHAW users create applications that can be mapped into many devices and browsers. The mark-up language code is generated by HAWHAW to achieve maximum portability across as many different handheld devices as possible. HAWHAW sites are able to serve XHTML, HDML, i-modeTM, MML, PDAs and voice browsers.

Wireless Universal Resource File (WURFL) uses an XML configuration file which contains information about capabilities and features of several wireless devices, typically WAP devices (WURFL, 2002). The WURFL site does not provide enough information on device detection techniques. Based on the Java documents provided, it can be assumed that Java API is written to detect the user agent. WURFL uses the concept of a family of devices to minimise the multi-devices and multi-capabilities variations. All devices are descendants of a generic device, but they may also descend from more specialised families. Unlike UAProf, one advantage of WURFL is that it can be installed onsite and does not need to grab device profiles from a repository.

One of the latest technologies from Microsoft is the .Net framework (Microsoft, 2005). The ASP.NET mobile application (Microsoft Mobile Internet Toolkit) provides an extensible mechanism for identifying a client device, and for making the information available to the Mobile Internet Controls Runtime and the Web application. The “HttpBrowserCapabilities” class and the “MobileCapabilities” class can provide information about the browser making the request. The technique used is server side HTTP user agent string identification. Device mapping is performed in the server that contains a device capabilities dictionary in the “machine.config” file and the “<BrowserCap>” tags. Currently there are more than 200 devices supported by the framework and users can add new device controls and capabilities.

2.5.8 Summary of device identification

While W3C CC/PP and UAProf are the latest technologies, both have huge unresolved problems such as profile interoperability, unspecified functionality, serialisation, RDF type identity, and much more (Butler, 2002c). Nevertheless these are the protocols so far that addresses the preference profile and changes of preference during sessions. The .Net Framework is able to implement an adaptive system but requires its proprietary detection (similar to BrowserHawk) and content adaptation technique. The solution to enhance these techniques, to allow changes of preference, is not clear at this point. No attempts have been found so far, but future research in this area is possible. The .Net Framework provides a consistent set of tools from design to server support but it might be deficient in adapting user preferences which are possible to implement. Other implementations, such as Morphis, HAWHAW and WURFL are also possible. The only shortcoming is that they are limited in their scope to support a variety of devices. WURFL represents a more promising solution than the rest.

According to the literature review, the use of XML documents is prevalent in implementing device identification and profile matching. With many issues still unresolved in CC/PP, the multiplatform e-learning system implementation uses a simplified device detection method with simplified XML documents similar to the full device profiles and preference profiles of CC/PP to achieve the objective of rapid prototyping and evaluation with respect to satisfaction and quantifying the factors that affect satisfaction.

2.6 Summary of chapter 2

The study of adaptive multiplatform e-learning systems draws on multi-disciplinary areas of research. E-learning frameworks were reviewed from both the technical perspective and theoretical perspective. In technical frameworks, the concerns focus mainly on creating an open system that can be easily integrated. The use of abstract service layers is to facilitate service integration from several open sources. This allows new services to be integrated without the necessity of re-design. The technical frameworks strive to be pedagogy, culture, system and platform independent. The theoretical frameworks are mainly concerned with learner characteristics, pedagogy, and the use of technology and its influence on the learner. For example, the motivational framework of e-learning stresses the motivational

aspect of learners and the opportunity rendered by e-learning systems through rich media interaction. The review provides further evidence that these two perspectives of e-learning frameworks are interdependent. The basic question is how to merge these two perspectives to create a realistic e-learning system and evaluate its overall learner satisfaction. The adaptive multiplatform e-learning system aims to acquire such knowledge. The review of content adaptation, device detection and identification, and the W3C device independence activities provided insight into how a realistic implementation could be developed for a prototype system. The DIA principles provided some guidelines on the requirements for formulating the multiplatform e-learning system framework. The content adaptation, device detection and identification techniques provided an overview of the current state of the art technologies that are useful in prototype implementation. Finally, the review of mobile learning examined the levels of sophistication and diversity within the domain of mobile learning that is part of the characteristics of multiplatform e-learning systems.

Chapter 3 Foundation of the multiplatform e-learning system framework

3.1 Motivation and foundation

Previous chapter had reviewed multidisciplinary research areas that support the current work. Two key research areas provide further motivation to the research on multiplatform e-learning systems framework. First, the work in W3C Device Independence Activities (DIA), Composite Capabilities/Preference Profile (CC/PP), UserAgent Profile (UAprof), Wireless Universal Resource File (WURFL) and Morphis provided strong background evidence that web services are moving towards multiple accessing devices. However specific domain areas such as e-learning have yet to be fully explored. Second, mobile learning research suggests that learning is possible through various mobile devices despite some limitations. Nevertheless there are few studies integrating several accessing platforms with respect to design, deployment and evaluation. Thus one of the research questions is to address the issue of what constitutes a multiplatform e-learning system framework with the aim of evaluating the factors that influence learner satisfaction during learner/system interaction. In attempt to answer this question the approach is to examining the current state of e-learning systems, the relevant enabler technologies and research findings to provide evidence and to extract relevant factors to aid the formulation of the multiplatform e-learning system framework. Besides focusing the attention on factors influencing learner/system interaction, determinants that could possibly be adapted from the server or by the client side that may have an impact on learner satisfaction are also identified.

Before proceeding further, it is necessary to gain an understanding of the meaning of “e-learning”. The Knowledge and Learning Systems Group at the University of Illinois at Urbana-Champaign (NCSA) (Wentling et al., 2000) defined e-learning as follows:

E-learning is the acquisition and use of knowledge distributed and facilitated primarily by electronic means. This form of learning currently depends on networks and computers but will likely evolve into systems consisting of a variety of channels (e.g., wireless, satellite), and technologies (e.g., cellular phones, PDAs) as they are developed and adopted. E-learning can take the form of courses as well as modules and smaller learning objects. E-learning may incorporate

synchronous or asynchronous access and may be distributed geographically with varied limits of time. (p. 5)

Zhang and Nunamaker (2003) defined e-learning as:

E-learning refers to any type of learning situation when instruction content is delivered electronically via the Internet when and where people need it...e-learning, referring to learning via the Internet, provides people with a flexible and personalised way to learn. (p. 207)

Djamshid et al. (2004) defined the e-learning system based on the constructivist learning model. They defined e-learning as:

We will call e-learning all forms of electronic supported learning and teaching, which are procedural in character and aim to effect the construction of knowledge with reference to individual experience, practice and knowledge of the learner. Information and communication systems, whether networked or not, serve as specific media to implement the learning process. (p. 274)

From these definitions, two key points regarding e-learning are apparent. First, the NCSA e-learning definition implicitly encompassed multiplatform e-learning systems. It contains a vision of a multi-channel and multi-device accessing scenario. This definition further confirms the vision of this study of a multiplatform e-learning system. Second, e-learning can be defined from different perspectives such as technical (Wentling et al., 2000), situational (Zhang and Nunamaker, 2003) as well as theoretical (Djamshid et al., 2004). Different perspectives highlight issues relevant to their perceived importance and research experience. In the multiplatform e-learning system framework research, attention is also drawn to the evaluation of learner satisfaction in human/device interaction based on various accessing devices. In addition, the construction of the multiplatform e-learning framework and its implementation are also demonstrated.

By examining these definitions for structural dimensions and features, six aspects of e-learning can be identified. First, e-learning involves content. E-learning content can be instructional, procedural or in the form of courses as well as modules and smaller learning objects (Djamshid et al., 2004; Zhang and Nunamaker, 2003;

Wentling et al., 2000). Second, e-learning involves the learner. E-learning provides learners with a flexible and personalised way to learn. It affects the construction of knowledge with reference to individual experience, practice and knowledge of the learner (Djamshid et al., 2004). Third, e-learning involves accessing devices. Traditionally the accessing device used to be a PC but cellular phones and PDAs are becoming prevalent as they are developed and adopted (Wentling et al., 2000). Fourth, e-learning involves communication. E-learning requires a communication channel for the acquisition and distribution of e-learning content. The communication channels facilitate synchronous and asynchronous access through various accessing devices (Wentling et al., 2000). Fifth, e-learning may involve adaptivity. Adaptivity in e-learning allows the customization of content delivery and presentation based on preference, experience, and the learning profile of the learner (Djamshid et al., 2004). Lastly, though not mentioned implicitly in the definitions, e-learning involves coordination for it to be successful as described in these definitions. E-learning requires considerable coordination to deliver content to learners through various communication channels and capacities via different modes of delivery that adapt to the individual experience, practice and knowledge of the learner.

In summary the structural features can be organised into five dimensions: content, learner, device, communication and coordination dimensions. The feature of adaptivity can be included in the coordination dimension. Therefore these five dimensions together lay the foundation and constitute the multiplatform e-learning system framework. To build up the multiplatform e-learning system framework it is necessary to continue analysing, examining and justifying many of the attributes within these dimensions.

3.2 Content dimension

Content has been identified as one of the dimensions in the multiplatform e-learning system. Indeed content is treated as an important component in e-learning systems by many researchers. Henry (2001) identified three core elements in e-learning systems. The first core element is content; technology and services are the other two elements. Similarly Davis and Harden (2001) identified four major components in e-learning systems. These components are courseware, authoring software, virtual learning environments and learning management systems. Again, courseware, which holds content, is treated as an important component. Commercially

for example, the Blackboard e-learning system consists of a content system, a learning system, and a community system. These examples again highlight the necessity of content. Thus one can safely recognise content to be the basis and most significant element of all e-learning systems. Though briefly discussed earlier in the definitions of e-learning systems (Wentling et al., 2000; Zhang & Nunamaker, 2003), content is the eventual information that is delivered to the learner and other components either support or build upon it. Without content, learning is not possible.

The impact of content is significant as it affects both the teaching experience and learning satisfaction. In traditional classroom teaching, teachers select and present the content, topics, and course material, and organise discussions in the classroom. In traditional e-learning systems teachers are still responsible for the content. However students now can select appropriate content, initiate discussions and revisit content individually according to their progress. According to Djamshid et al. (2004), besides learning content, learner interaction, media choice and the underlying software systems that support the e-learning system could influence learning. In multiplatform e-learning systems, these influences could be amplified due to various accessing devices and the requirement of content transformation and adaptation. How these factors influence learners in the multiplatform environment has yet to be fully explored.

3.2.1 Pedagogy

To develop content in e-learning systems there is a need to deploy pedagogical principles to form the very basic features of e-learning systems. Khan (1997) in his e-learning framework already stressed the importance of the pedagogical dimension for teaching and learning. These pedagogical principles should be integrated into the e-learning systems where every feature included is accompanied by explicit guidelines on the best method of their use to effect pedagogically sound instructions (Govindasamy, 2002). Similar concerns were addressed by Chute, Thompson and Hancock (1999). They pointed out that to achieve a satisfactory learning experience, close attention to content design and delivery is of crucial importance. This means that pedagogy surrounding the design of content must be sound and should be based on established learning theories. This observation is consistent with Firdiyeyek (1999) and Vrasidas (2004) who criticised the mismatch between features in e-learning systems and the lack of explanation, support and guidelines of the didactic principles

underlying the use of these tools. Thus sound pedagogy or at least some guidelines are needed for e-learning to be successful (Vrasidas, 2004). For multiplatform e-learning systems the concern is that pedagogical principles deployed for a specific platform in mind, usually PC, may not necessarily be applicable to various accessing devices and contexts of use. Hence the pedagogical factor in a multiplatform e-learning system framework may reduce learner satisfaction if inappropriate pedagogy principles are used.

3.2.2 Organisation and granularity

In an e-learning system, content organisation is another key factor. Content must offer sufficient challenges and be structured in such a way that it offers no barrier to the extraction of information by the learner (McFarlane et al., 2003). This suggests that the organisational structure of the e-learning content and its granularity, which both influence learner satisfaction, must be carefully mapped out. In traditional e-learning systems, content organisation needs only to focus on just one platform. However, in multiplatform e-learning systems content organisation needs to consider various mobile platforms. In mobile platforms, there is a stronger need to organise a larger chunk of content into smaller learning objects or modules to fit small mobile devices. For example, multiple choice questions may display four questions in traditional PC based e-learning systems. For PDA and mobile phone, one question at a time may seem more appropriate. Smaller granularity also makes content easier to share and re-use (Govindasamy, 2002). Having too fine a granularity may result in too many versions of the learning content. Thus a coarse grouping can be built to classify learners into groups such as novices, beginners, competence, proficiency, and expertise (Baumgartner et al., 2001).

While content, organisation, granularity and pedagogy all influence learners, one should also be aware that in a multiplatform e-learning system, a particular pedagogy, organisation, and granularity of the content that suit a particular learning situation may not necessarily suit another learning situation even if the accessing device is identical.

3.2.3 Learning module

One of the greatest strengths of e-learning content development is that the e-learning systems provide opportunity to deploy multimedia formats. Multimedia is the

delivery of information that integrates two or more media (Beckman, 1996). The combined media may include text, graphics, videos, animations, sounds and other formats. The benefit of deploying multimedia content is that it provides a multi-sensory learning environment. A multi-sensory learning environment can help maximise the learner's ability to retain information, which affects learning (Syed, 2001). Research has shown that the use of multimedia instruction content can enhance an individual's problem solving skills, and entice learners to focus their full attention on a task through the vividness of the presentation (Zhang and Nunamaker, 2003). E-learning systems also provide opportunity to deploy multimedia to stimulate motivation (Duchastel, 1997). An extension of multimedia is interactive multimedia. Interactive multimedia is defined as the use of a computer to present and combine various formats such as text, graphics, audio and video, with links and tools that let users navigate, interact, create and communicate (Hofstetter, 1995). Interactive multimedia has also been widely adopted in e-learning to enhance learners' interactivity and to improve learning effectiveness. One such example is the "Learning By Asking" system (LBA) (Zhang and Zhou, 2003). LBA system presents synchronized multimedia materials on the Internet in an interactive and cohesive manner by responding to learner's questions. While multimedia content contributes to e-learning systems significantly and the use of multimedia in e-learning systems has become a common practice, proper choice of multimedia is important. The diversity e-learning framework (Huerta et al., 2003) through the organisation communication theory identified that media richness could affect media communication choice in e-learning systems and hence affect learner satisfaction. This raises the issue of how multimedia and interactive multimedia content affect multiplatform e-learning systems, especially mobile devices. To what extent learner satisfaction is affected by mobile devices' capabilities when engaging with multimedia content and to what extent learner satisfaction is affected by the removal of multimedia content during the adaptation process will need further investigation.

3.2.4 Summary

Content has been identified as the most important dimension in e-learning systems including multiplatform e-learning systems. While both types of systems might contain similar characteristics, several issues stand out for multiplatform e-learning systems. Within the content dimension, pedagogy, multimedia in the learning

module, organisational structure of content, and granularity have been shown to affect learning. Compared to traditional e-learning systems, multiplatform e-learning systems represent a new environment in which many research areas have yet to be fully explored. It is with this in mind that the current research examines how these dimensions behave and interact in this new environment.

3.3 Learner dimension

While content is vital in e-learning systems, ultimately content has to be delivered to the learner. Learner/content interaction is an integral part of the learning equation. Various perspectives that could help in identifying the important attributes within the learner dimension are examined. First, in the process of packaging content to the learner is there any approach that can be adopted that is likely to positively affect the learning process? Second, can e-learning systems provide support for the adopted approach in delivering content to the learner? Third, what other factors surrounding learners could affect learning? Finally, are there specific issues for multiplatform e-learning systems?

3.3.1 Personalisation

First, constructivist learning theory advocates that content should be personalised to the individual learner for effective learning (Djamshid et al., 2004). Personalisation means learning according to individual interest, previous knowledge, style, and so on (Zhang and Nunamaker, 2003). Not all learning situations can be personalised easily. To provide personalisation there is a need to move from an instructor-centric approach, typically used in traditional face-to-face classroom teaching, towards a learner-centric approach (Zhang and Nunamaker, 2003). With the flexibility of e-learning systems, a learner-centric approach can be achieved much more easily than in traditional classroom teaching. In a learner-centric situation, emphasis is placed on relevance, personalisation and learner flexibility in time and location (Zhang and Nunamaker, 2003). Focussing on the learner allows individual learning contexts such as background and learning profiles to better fit the learning activities designed for e-learning. With a better fit, better learning outcomes have been reported for the learner-centric approach in e-learning (Beam and Cameron, 1998). E-learning systems have the necessary ingredients to provide personalisation using the learner profile and learner context, and provide learners with access flexibility in time and location.

Hence in the process of packaging content for the learner one should consider personalisation as advocated by constructivist theory. In multiplatform e-learning systems, personalisation can combine with different accessing devices and contexts of use that complicates the learning process. This aspect may need further investigation in order to understand its influence on learners.

Second, to achieve personalisation, it is necessary to look at more than one criterion to characterise a learner in order to achieve optimal performance for that learner (Tavangarian and Lucke, 2002). The criteria for personalisation could focus on various learner characteristics such as the ability to concentrate, previous knowledge and interests (Zhang and Nunamaker, 2003). The ability to concentrate depends on the learner's environment and motivational factors. The tracking of previous knowledge can be captured in a learning history. In multiplatform e-learning systems, it might be necessary to distinguish static and mobile learning histories due to the mobility of mobile devices. Learner interest depends on learner preferences such as learning style and presentation preferences. Learning style has been identified as a key factor that influences learning satisfaction. Learning style comprises the characteristic behaviours of learners that serve as relatively stable indicators of how they perceive, interact with, and respond to the learning environment (Keefe, 1979). For learners whose learning styles are concrete and experimentation-activity oriented, computer-assisted instruction would be an appropriate option (Reiff and Powell, 1992). In addition to learning style, other aspects such as content, form of presentation, time needed, level of difficulties and organisation of subject matter can also be adapted to provide personalisation. The ability to track learner progress is an important factor in personalisation. Whitehurst, Powell, and Izatt (1998) developed a dynamic mechanism to keep track of the learning progress of individual learners to allow an e-learning system to adapt an appropriate level of materials for each learner, making their learning more effective. The system was developed with a student model as a means to determine the current knowledge state of the learner. The student model then keeps track of what the student knows, what content the student has gone through and the learner profile. The dynamic personalised learning profile contains the learner's learning style, interests and preferences, problems encountered and so on. For multiplatform e-learning systems, criteria for personalisation would require categorising capabilities for various accessing devices to minimise the different sets of profiles and complexity. For example, Dreyfus and Dreyfus (1986) offered a simple

method of personalisation by classifying learners into five levels so that customisation could be achieved without involving too much complexity. The five learner levels used are novice, beginner, competence, proficiency, and expertise, which are identified as being useful for actual implementation.

Thus strong evidence supports the importance of learner preferences and learner profiles in influencing learning in an e-learning system. The key issue that concerns in this research is how these learner characteristics and their relationships vary from traditional PC based e-learning systems across different accessing platforms as in multiplatform e-learning systems.

3.3.2 Motivation

Besides personalisation, motivational factors can directly influence learning and should be considered in multiplatform e-learning systems. There is a high correlation between motivation and learning success. Indeed, according to Dörnyei (2001) motivation is one of the key factors that determine the rate of and success in language proficiency attainment. McCombs and Vakili (2005) in their learner-centred e-learning framework identified four research validated domains that affect learning. These domains include meta-cognitive and cognitive, affective and motivational, developmental and social, and individual differences factors. The motivational factor has been singled out as one of the key principles in the learner-centred e-learning framework. The motivational and affective factors further included three principles (McCombs and Vakili, 2005). First, the principle of motivational and emotional influences on learning identified that what and how much is learned is influenced by the learner's motivation. Motivation to learn, in turn, is influenced by the individual's emotional states, beliefs, interests and goals, and habits of thinking. Second, the principle of intrinsic motivation to learn identified that the learner's creativity, higher order thinking, and natural curiosity all contribute to motivation to learn. Intrinsic motivation is stimulated by tasks of optimal novelty and difficulty, relevant to personal interests, and providing personal choice and control. Lastly, the principle of effects of motivation on effort identified that the acquisition of complex knowledge and skills require extended learner effort and guided practice. Without learners' motivation to learn, willingness to exert this effort is unlikely without coercion. The learner-centred framework identified that learning is strongly influenced by learner motivation and motivation is influenced by the learner's emotional state (McCombs

and Vakili, 2005). By modifying the emotional state it is possible to alter a learner's motivation and change their learning satisfaction.

Motivation can be encouraged or elicited by various means. The motivational framework of e-learning (Duchastel, 1997) asserted that an e-learning system provides the opportunity to elicit learner motivation through the richness of multimedia and to improve learning satisfaction. Besides multimedia capable of altering learner motivation, Perry (2003) reported that having a fashionable mobile device itself can spur motivation. However, fashionable does not mean that the device or technology needs to be complex or unfamiliar. It was reported that students were excited and highly motivated when they were given PDAs in an experiment on using mobile devices. This observation is important as the goal of multiplatform e-learning systems is to further support mobile devices in addition to traditional devices. Urgency of learning need may affect motivation for mobile usage (Chen et al., 2002). Chen et al. (2002) identified that one of the characteristics of mobile learners is the urgency of learning need. Gribbins et al. (2003) also identified situational factors such as urgency and mobility that could influence usage and the impact of technologies on the organisation. Schrott and Gluckler (2004) concurred that when communications were urgent and stationary infrastructures were not available, mobile devices were used more frequently. More generally they suggested that conditions of stress and the need for immediate communication will alter user's behaviours into using mobile devices. Conversely, it is likely that learners may associate the devices with stress if they mainly decide to use mobile devices in urgent situations in comparison to a standard desktop PC. Urgency can alter learner characteristics such as motivation and the adoption of mobile learning. Push technology that allows a central system to send information spontaneously and quickly to an end-user, without action on the part of the user or mobile device such as WAP or SMS can be used to deliver urgent content to learners. In addition, integrating different types of mobile phone ring tones could possibly alter learner states of emotion and motivation. While urgency of need can alter motivation, there are also secondary factors such as speed of network, duration of transfer and cost that can create barriers to use and influence the overall learning satisfaction (Pippow et al., 2002). Neutralising these barrier factors could possibly alter motivation as well. Use of simple and familiar technology has shown that it can improve learner motivation and organisation (Mayer, 2002). For example, Kennedy and Sugden (2003) revealed the merits of using text messaging as a means of

communicating with the learners. This increased their use of email and improved overall communication thus resulting in better learner satisfaction. Using games as learning tools can also alter motivation. The combined use of voice, language, sounds and 3D movement can contribute and possibly creates a feeling of urgency (McMullen, 2004). This aspect will be useful to elicit sense of urgency during the experiment and in real situation.

These studies clearly illustrated that motivation and situations that induce changes in motivation can influence learning. In the multiplatform e-learning systems environment, there is a need to investigate how much motivational factors influence learner satisfaction. Will increased motivation caused by a mobile device compensate for its limitations with respect to learning satisfaction?

3.3.3 Environment

Besides personalisation and motivation which have been shown to have effects on learning, the learner's environment is crucial to the effectiveness of learner/system interaction. Environmental factors should be considered carefully in the multiplatform e-learning system due to the mobility of mobile devices. Environment is defined as whatever in the world provides a surrounding in which the machine is supposed to operate (Finkelstein et al., 2002). While this definition is rather broad, the term machine can refer to an e-learning system and the term surroundings can be treated as the learner and their current context. Context is defined as any information that can be used to characterise the situation of an entity. An entity is a person, place or object that is considered relevant to the interaction between a user and an application, including the user and application themselves (Anind, 2001). Thus environmental parameters and context are two closely related concepts.

According to the above definition (Anind, 2001), context can include any factors that characterise the learner/e-learning interaction. In multiplatform e-learning system scenarios, a learner can access the e-learning system from various devices anytime and anywhere. These devices could be mobile or stationary such as kiosks, TVs, PCs, PDAs, mobile phones, smart phones or hybrid devices. The environmental factors and the context of use are likely to vary substantially and are naturally more dynamic (Owen et al., 2003) in multiplatform e-learning systems than traditional e-learning systems. Comparing the environmental parameters and context of use of the traditional classroom e-learning system to that of a multiplatform e-learning system

the prevailing scenario is commonly characterised by a noisy background and multi-tasking (Tamminen et al., 2004), and is motivated by self exploration. According to Ayres and Williams (2004), for a learner with young children, the home environment may not be conducive for productive learning because children can be noisy and they are likely to demand priority attention from a parent (learner) who is physically present. Such a scenario highlights the noisy, multitasking, interruptive and self exploratory characteristics of the mobile scenario which is likely to be the case for the multiplatform e-learning systems operating scenarios.

Therefore it is necessary to take environmental factors into consideration in multiplatform e-learning systems. A good example that justifies such concern is the mobility and learning environment research at site K3 (Jönsson et al., 2002). That research focuses on engaging people in the design of their everyday environments and deals with enabling concentration and in-depth meeting places for groups in an open and relatively noisy environment (Jönsson et al., 2002). Besides a noisy environment, Dunlop and Brewster (2002) suggested that because learners are mobile they will not have many of the props around them to support work (e.g. notes on desks) and are likely to have a far from ideal working environment and that this environment will change drastically as the learner moves. They suggested taking mobility into design consideration. Thus to achieve effective design in multiplatform e-learning systems it is important to consider these factors, but there is also a need to investigate further the degree of influence these factors can have on learning satisfaction. Will these factors only be transitional and thus have less impact once the learner adapts to the environment?

3.3.4 Feedback and communication

Besides personalisation, in the e-learning environment there seem to be evidence of growing communication between learner and instructor (Zhang and Nunamaker, 2003). Because learners have the flexibility in time and location to obtain guidance, help and feedback from instructors in e-learning systems, e-learning systems are usually perceived as having greater opportunities for communication than in a traditional classroom (Burgstahler, 1997; McCloskey et al., 1998; Marold and Haga, 2004). These findings and perceptions are based on a traditional e-learning system using a desktop PC with standard keyboard and screen. In the context of multiplatform e-learning systems, it is likely that the communication component

would be weakened due to the ergonomic limitations of mobile devices in terms of ease of input and the limited screen size for presenting content and multimedia delivery. In a multiplatform e-learning system environment how would the factors concerning communication such as guidance and help as perceived by the learners influence them? Will they perceive these factors to be less critical as they presumably understand the circumstances of use or will they have equal demand for the service?

Instant face-to-face (F2F) feedback is an important factor for both teachers and learners (Neal and Ingram, 1999; Mory, 2003; Passier, 2004). Instant F2F feedback helps the teacher to determine the learner's level of comprehension. Instant F2F feedback allows the teacher to deal with queries that could hinder progress if unanswered. While remote learners in e-learning environment may not receive the similar kind of instant F2F feedback available in traditional classroom settings e-learning systems have the opportunity to integrate various forms of feedback mechanisms to make e-learning more effective. These feedback mechanisms may include online help, online chat, online video conferencing, e-mail, SMS, and discussion forum (Neal and Ingram, 1999; Lian, 2004). However, in a multiplatform e-learning system scenario, these feedback mechanisms may not be fully available for learners due to devices limitations. How would learner satisfaction being affected in the absent of instant feedback and help?

3.3.5 Summary

So far strong evidence has suggested that a learner's profile, preferences, motivation, and environment can have an influence on learning. While some of these findings may be common to both traditional face-to-face learning and e-learning situations, multiplatform e-learning systems seem to create further dimensions of complexity. Such complexity is due partly to the proliferation of mobile devices and their intrinsic ergonomic characteristics such as mobility and portability. With mobility, the learner can move to a new learning space beyond that of traditional face-to-face teaching and e-learning systems, thus creating new situations that require further research. Learner interaction with a multiplatform e-learning system is one such area of concern.

3.4 Device dimension

Besides content and learner dimensions, e-learning systems have an additional requirement. E-learning content is accessed through some sort of device. Traditionally accessing devices have been desktop PCs but cellular phones and PDAs are becoming more common (Wentling et al., 2000). Due to the proliferation of mobile devices, the use of these devices to access e-learning will challenge the design of the e-learning systems. Common practices in the design and the use of pedagogy with PC based e-learning systems will need to be re-evaluated for their suitability, acceptability and adaptability for mobile device access and for the broader range of multiplatform access. Mobile devices differ from traditional PC access in various ways. Mobile devices have smaller displays, limited input capabilities, lack of floating-point accuracy, limited colour and sound support, limited application size, high latency, high interruptibility, smaller storage capacity, lower availability due to network constraints, lower interconnectivity, limited sensory capability, lower data transfer rate and lower bandwidth (Ericsson, 2002; Brewster, 2002; Dunlop and Brewster, 2002; Gribbins et al., 2003; Harri and Virpi, 2003; Nokia, 2003; Pennanen and Keinänen, 2004; Schrott and Gluckler, 2004; Varshney, 1999; Wood, 2003). These capabilities can be classified into presentation, operational and ergonomic capabilities. When designing multiplatform e-learning systems, ignoring how these capabilities influence learners may result in poor learner satisfaction and ensuing refusal to continue using the systems. Therefore there is a need to examine these capabilities in relation to learner satisfaction.

3.4.1 Device capabilities and characteristics

Wood (2003) provides a useful comparison between different devices with respect to cost, prevalence, portability, mobility, weight, power, functionality, memory and storage capacity as depicted in Table 3.1. The portability and mobility features, which are part of the ergonomic capabilities, are stronger in mobile devices, while other factors, mainly the operational capabilities, are weaker in mobile devices. This implies that multimedia content designed for PC based e-learning systems cannot be blindly transferred to mobile devices without giving consideration to the amount of memory, processing speed and display of the mobile devices.

	Mobiles	PDAs	Tablet PCs	Laptops	Desktops
Cost	Handsets are often free with contracts, £0 - £450 for the new 3G models	£80 - £500	£800 - £1800	£650 - £3000	£500 - £2000
Prevalence	Teenagers never seen without them!	More commonly found in business	Only just hitting the market	More commonly found in business	Essential office equipment, not as common in the home
Portability	Easily fit into pockets	Just about fit into large pockets	Can be carried in one hand	Normally carried in a case	Need several boxes
Mobility	Can be used with one hand	One hand to hold and one to operate pen or keyboard	Can be used like a clipboard	Difficult to use on the move	Impossible to use on the move
Weight	70 - 100g, 200g for 3G	125 - 180g	1.2kg - 1.8kg	1.2kg - 3.5kg	Several cumbersome, heavy items
Power	2-13 hours talktime	8 hour battery life	Battery life 3-5 hours	3 hour battery life	Mains connection
Functionality	Phone, organiser & WAP functions, now include MP3, camera, video	Scaled down version of desktop OS, with handwriting recognition	Equivalent to desktop OS, plus handwriting recognition	Equivalent to desktop	N/A
Memory (typical)	N/A	32 - 64MB	256MB	256MB	512MB
Storage capacity (typical)	300 - 1000 contacts, up to 64MB in new 3G units	128MB	40GB	40GB	240GB

(All figures are approximations as at March 2003)

Table 3.1 Comparing devices' capabilities and characteristics (Wood, 2003)

By investigating the usage of web and mobile services, Harri and Virpi (2003) observed four main differences with respect to context of use. These differences are the device itself, the network, the user and the usage context. These perspectives are valuable for e-learning systems design because e-learning systems can be seen as

integrated web and service architecture (IMS-AF, 2003; JISC-ELF, 2004; LTSA, 2001; Sakai, 2005). In fact, some of these observations coincide with the multiplatform e-learning system framework (Goh and Kinshuk, 2002) despite using different terminologies. These observations indirectly support the direction of the current research work. The constraints and concerns regarding the operational capabilities of mobile devices suggest that mobile devices might not be useful for all purposes. Mobile devices are best used for limited and appropriate purposes (Harri and Virpi, 2003). For example, they should not be targeted for high performing advanced graphical transformations or content filtering operations.

These examples illustrate that operational and presentation capabilities are both relevant and important. The adaptive process must take these into consideration, especially in the multiplatform e-learning systems.

3.4.2 Ergonomic

While the operational and presentation capabilities of mobile devices are significant in multiplatform e-learning systems, ergonomic capabilities are equally relevant. An interesting study of how familiar users were with operating their mobile devices found that the users were not as familiar with using their mobile devices as they were with web browsing on a PC (Harri and Virpi, 2003). Another observation was that users of mobile services not only have highly varied needs, they often tend to be impatient. Consequently these behaviours not only result in stronger demand for the e-learning design to match the devices' ergonomic factors, e-learning design also needs to match the learner's situation. Thus in multiplatform e-learning systems, the demand for the content to suit the ergonomic factors of a variety of devices would certainly have an influence on learning. How these ergonomic factors interact and influence learners is part of the current investigation.

Mobility and portability capabilities are stronger in mobile devices than in PCs (Wood, 2003). Research has shown that mobile users are generally "on the move" (Harri and Virpi, 2003). Even though they might be stationary while using the system, the surrounding environment can be very noisy and distracting and may require multi-tasking from the users. Schrott and Gluckler (2004) also identified the difficulty of inputting data using mobile devices. Generally text input that uses a small keyboard or type-recognition keyboard is less comfortable than a conventional keyboard in most mobile devices. These observations suggest that the task complexity of e-learning

content must be simplified when it comes to mobile device access. A light, simple and informative approach appropriate for the situation can potentially achieve a better learning satisfaction.

Slow establishment of a connection between a mobile device and the e-learning system may be perceived by some users as being difficult to use. The speed of connectivity in most mobile devices can influence usage and adoption. Generally speaking, mobile devices with Bluetooth, GPRS or Wi-Fi connections are slower than a PC with a direct LAN connection. Poor connection speed can create a barrier for learning using mobile devices. Thus connection speed must be taken into consideration in multiplatform e-learning systems design.

3.4.3 Perceived usefulness and limitations

Besides focusing on the limitations of mobile devices, there is a need to take advantage of the perceived usefulness of mobile devices. Perceived usefulness can lead to better adoption of multiplatform e-learning systems. Wood (2003) identified several positive as well as negative aspects of mobile devices in terms of learning. Wood’s findings are re-organised below into presentation, operational, and ergonomic capabilities in Tables 3.2(a) and 3.2(b). Presentation capabilities include the screen and display, and browser capabilities. Operational capabilities involve device hardware, software, security, and inter-connectivity capabilities. Ergonomic capabilities comprise of ease of use, portability and mobility. Tables 3.2(a) and 3.2(b) clearly show that these capability factors have positive and negative effects on learning. The design of multiplatform e-learning systems must also consider the ways in which these factors relate to each other in influencing learning.

Table 3.2(a) Perceived limitations

Presentation issues
<p>Screen and Display</p> <ul style="list-style-type: none"> ▪ Mobile phone and PDAs have small screens which limit the amount and type of information that can be displayed. ▪ Mobile devices lack of common platform (eg. different sized screens—horizontal screens with some handheld computers, small square screens with mobile phones etc) which can be difficult to develop content that will work anywhere. ▪ Animation can be difficult for some mobile phones. Future 3G and 4G system will eventually

allow this.
Operational issues
<p>Hardware</p> <ul style="list-style-type: none"> ▪ Mobiles devices have limited storage capacities. ▪ Batteries require regular charging, and data can be lost on some devices if this is not done correctly. ▪ Mobiles devices are much less robust than desktops. ▪ Mobiles devices are more difficult to upgrade and limited potential for expansion.. ▪ Mobiles devices lack of connectivity and interoperability, though new technologies such as Bluetooth and wifi are getting common. ▪ Mobile devices have security issues when accessing wireless networks. ▪ Bandwidth may degrade with a larger number of users when using wireless networks. ▪ Mobile devices can become out of date very quickly in an fast-moving market.
Ergonomic issues
<p>Ease of use</p> <ul style="list-style-type: none"> ▪ Users may require extra training in order to be able to use the devices effectively. ▪ Mobile devices may face difficulties with printing, unless connected to a network. <p>Portability and Mobility</p> <ul style="list-style-type: none"> ▪ Mobile devices are easily lost or stolen than desktops, more attractive to thieves.

Table 3.2(b) Perceived usefulness

Presentation
<p>Screen and display</p> <ul style="list-style-type: none"> ▪ Using standard software, some mobile devices can draw diagrams, maps, and sketches directly onto a tablet. ▪ Mobile devices facilitate just-in-time learning/reference tool for quick access to data in the field e.g. accessing step-by-step guides to help you achieve a task. ▪ Some mobile devices could trace an image directly onto the tablet's screen. ▪ Mobile devices can take notes directly into the device during outdoor lessons or on field trips, either typed, handwritten or voice.
Operational
Hardware-Communication

- Mobile devices allow sharing of assignments and facilitate collaborative working. Students can pass the device around a group, or “beam” the work to each other using the infrared function of a PDA, or a wireless network such as Bluetooth.

Software

- The handwriting recognition software in PDAs and tablets has been found to help improve students’ handwriting skills.
- SMS can be used to get information (e.g. timetable changes) to staff and learners more easily and quickly than phone calls or email, for example.
- Mobile devices can be an assistive technology for learners with learning difficulties.

Ergonomic

Portability and mobility

- Students can interact with each other instead of hiding behind large monitors.
- Mobile devices require far less space in a classroom than several desktops.
- PDAs or tablets holding notes and e-books are lighter, less bulky and easier to carry than bags full of files, paper and textbooks, or even laptops.
- Mobile devices can be used anywhere, anytime, including at home, on the train, in hotels—such places are conducive to learning because you cannot be disturbed by meetings, you are often alone, it might be quiet—this is invaluable for work-based training.

Ease of use

- Handwriting with the stylus pen is more natural than using keyboard and mouse.
- Mobile devices can be used for electronic registration and inputting data in practical lessons or outdoors where desktops are not appropriate or too cumbersome e.g. science experiments, kitchens, and farms.
- Stylus pens are much more natural for web browsing.
- Annotate work using stylus pen can be more easily and naturally.

Motivational

- Mobile devices can engage learners. Young people who may have lost interest in education do like mobile phones, gadgets and games devices..
- Mobile devices can increase motivation and personal commitment to learning and encourage responsibility.
- Mobile devices generally cheaper than desktops can contribute to narrow the digital divide.

3.4.4 Summary

The devices used for accessing e-learning systems have a strong influence over the outcome of learning, and that the situations where the devices are used also affect

the learning satisfaction. For multiplatform e-learning systems to be successful the device presentation and operational capabilities (such as screen and display, device hardware and software, device inter-connectivity capabilities), ergonomic capabilities (such as ease of use, ease of input, ease of browsing, ease of navigation, portability and mobility), and motivation factors due to trendiness of mobile devices must be explored and investigated to further take advantages of these factors in enhancing the learning satisfaction.

3.5 Communication dimension

The content, learner and device dimensions can be viewed as the three main pillars of e-learning. To allow concurrent usage and to allow access and delivery of e-learning content at any time and any location through various devices would demand the support of a suitable communication network. A communication network that effectively facilitates the interactions between learner, device, and the e-learning system is critical to the overall learning satisfaction. To enhance understanding of the communication factors that influence multiplatform e-learning systems, this section discusses communication characteristics, gives an overview of wireless communication technologies and examines the relationship between perceived quality and methods of delivery of e-learning content.

3.5.1 Communication characteristics

Several issues regarding communication characteristics that might have an influence on learning in the multiplatform e-learning systems shall be examined. First, a communication channel can be simplex or duplex. In traditional e-learning systems, it is normally duplex with the downstream much faster than the upstream. In multiplatform e-learning systems, duplex may not be the only kind involved. In a simplex situation, learning content can be broadcast to learners without the possibility of interaction. This requires the e-learning system to adapt content appropriately.

Second, different kinds of communication channels exist for various devices. While in traditional e-learning, content is normally accessed on PCs through a LAN, it is now common to find laptops and mobile devices equipped with more than one communication channel. Wireless LAN, Bluetooth and IR are typical. These communication channels are not equal in terms of bandwidth speed, range, quality

and cost. In multiplatform e-learning systems, the type of communication channel available depends on the device and its location. This adds complexity to the design of the content delivery on multiplatform e-learning systems and its influence on learners.

Third, the actual throughput between the e-learning system and the accessing device is governed by the available bandwidth, the device's data input/output (I/O) speed and the browser rendering speed. These factors are eventually perceived by learners as the waiting time or response time of the e-learning system. These factors can therefore directly affect the learning satisfaction.

Fourth, different types of communications network present different levels of "ease of use". For example, using SMS for e-learning might be easy for most young people but using WAP and micro browsers might be a barrier. Using a PC to access e-learning content might be easy for most learners but using a PDA to synchronise and download content may be difficult for them. Though throughput is crucial, the subsequent method of delivering content will influence learners as well.

This set of characteristics illustrates that handling communication issues is not straightforward. Communication channel properties can intertwine with content, devices, location and learner in ways which are more profound in multiplatform e-learning systems than in traditional e-learning systems.

3.5.2 Wireless communication technologies

As mentioned earlier, overall throughput of a network depends on the type of communication network available to the device in use; they must match each other to achieve optimal content delivery. While the deployment of the network depends on requirements for bandwidth, range, and transmission power, the adoption and usage of technology normally depends on the perceived usefulness, perceived ease of use, and other factors such as cost, according to technology acceptance model (TAM) (Davis, 1989, 1993). Wireless communication networks being deployed today can be classified into one of four segments (Intel, 2005): Personal Area Networks (PANs), Local Area Networks (LANs), Metropolitan Area Networks (MANs), and Wide Area Networks (WANs). These segments sometimes overlap with each other. For example, a location can be covered by both a Wi-Fi and 3G network.

In PANs typical network coverage is up to ten metres, but performance varies depending on the standard employed. The Bluetooth IEEE 802.15.1 standard is primarily used for unwiring computing and communication peripherals, such as a

computer to a printer or a handset to a headset. Bluetooth is rated up to 1 Mbps in performance data rates. The second standard is the IEEE 802.15.3 standard. It is designed for delivering multimedia services. It supports data rates over 400 Mbps, allowing for video of digital video disc quality to be shared throughout the home. In this case the PAN becomes a high-speed Personal Area Network.

Wireless local area networks can cover a greater distance than PANs, normally up to 100 metres. Standards based LANs typically service more applications and users than PANs do. A LAN aggregates PANs. The wireless standard associated with LANs is IEEE 802.11. Three major revisions to the physical layer have been released. 802.11a supports bandwidth speeds up to 54 Mbps with operating frequency of 5GHZ; 802.11b supports bandwidth speeds up to 11 Mbps with operating frequency of 2.4GHZ; and 802.11g supports bandwidth speeds up to 54 Mbps with operating frequency of 2.4GHZ. The maximum range of 802.11g devices is slightly greater than that of 802.11b devices, but the range in which a client can achieve full (54 Mbit/s) data rate speed is much shorter than that of 802.11b. Using directional antennas or implementing pre-standard Wi-Fi mesh topologies can increase performance beyond 54 Mbps and can cover over 10 km using the 802.11 standard.

The wireless MAN aggregates LANs and typically covers areas up to 50 km. Both WiMAX and copper wire technologies are used in this usage segment. WiMAX is a wireless Metropolitan Area Network technology that provides interoperable broadband wireless connectivity to fixed, portable and nomadic users. It provides up to 50 km of service area. WiMAX allows users to get broadband connectivity without the need for direct line-of-sight to the base station, and provides total data rates up to 75 Mbps.

WANs aggregate MANs across large geographic areas. A WAN uses a variety of communication media to pass along large amounts of traffic from the various MANs. The most common medium used is fibre optic links. This set of high-speed, high-bandwidth interconnections is referred to as the core network. The performance of WAN networks is up to 10 Gbps and depends on the type of traffic the network handles.

Evidently communication speed and coverage can vary substantially. E-learning contents that are designed for video delivery in a broadband network and a non roaming environment are unlikely to satisfy learners in a low bandwidth channel and localised environment. These factors must be taken into consideration in the design of

multiplatform e-learning systems. The multiplatform e-learning systems potentially face several kinds of wireless communication channels. While some of these channels may be transparent to users, the multiplatform e-learning systems must have the capability to determine the overall response and delay in order to facilitate appropriate delivery of content.

3.5.3 Perceived quality and methods of delivery

The wireless communication technologies reviewed so far suggest that there is a range of possible connection speeds available to mobile devices that are equipped with the necessary communication hardware. The implication is that in multiplatform e-learning systems there are likely to be preferred and optimal ways to transfer the learning content from the source to the destination devices. However, the preferred and optimal ways might not match each other with respect to quality, ease of use, and pedagogy. For instance, Shim (2002) adopted SMIL and video streaming technology in an e-learning evaluation using a PC. The preference was to deliver the content in real time. Because learner geographical locations were diverse, the bandwidth conditions were not consistent, so the surveyed learners expressed several concerns about the use of SMIL and video technology in e-learning. While no quantitative data were presented on learner satisfaction, learners were concerned about network speed, network traffic, network quality, reliability of the channel, reliability of the server and quality of the video. Thus not only is response time important, but unreliability can also cause a poor learning satisfaction. One solution to the problem is to change the mode of delivery to offline mode. This alters the learning satisfaction. Other solutions include real time computation of the actual throughput of the system and provide the optimised and compressed content to the learner. In the event that no good option is available the multiplatform e-learning systems must be capable of providing alternative delivery modes other than real time delivery.

The effectiveness of these techniques is also considered by several researchers. For instance, bandwidth has been considered a key quality component in the AWCD system (Chen et al., 2000; Ma et al., 2000). The AWCD system computes the available throughput and provides the necessary adaptation of multimedia content to the user. Similarly, in another adaptive system developed to reduce the user-perceived latency in web content delivery, Nakano et al. (2002) integrated transmission time control and transmission order control mechanisms which ultimately monitor the

available bandwidth for inline objects content delivery. The objective is to maintain real time delivery and there is a general understanding that shorter perceived response time enhances the user's satisfaction. Without adaptation, trying to fit all scenarios in one form is likely to degrade the learner satisfaction. Network adaptation is recommended for sudden disconnected events (Kappel et al., 2003). Examples of these are user voluntary disconnection to avoid disturbance, or because the battery becomes empty or network connection is lost due to travelling. Consequently, variations in bandwidth conditions make adaptation in either the content or the methods of delivery almost a necessity to achieve good learning satisfaction.

Similar concerns were also reported by Attewell (2005). While mobile phones and PDAs are capable of delivering learning objects and providing access to online systems and services, in general, network infrastructure and coverage are lagging behind handset development. As a result, bandwidth is still an issue for full mobile learning, and coverage and signal problems are still barriers in many areas and while users are in motion. Attewell (2005) suggested a mixture of online learning and learning using materials downloaded onto handheld devices for using offline.

These examples strongly support the idea of alternative delivery modes to alter the perceived quality experienced by the learners in the event that poor response time and poor stability are encountered during multiplatform e-learning access.

3.5.4 Summary

The variations in network speed due to different wireless technologies in use and the various types of device communication capabilities and the context of use suggest that delivering content to learners is neither static nor straightforward. Extending the research to multiplatform e-learning systems, the e-learning systems must adapt to different available bandwidths for different modes of delivery commonly operating in a multitude of devices. The mode of delivery must be able to adapt to real time online mode, pre-fetching mode, and off-line synchronisation mode. These modes of adaptive deliveries will need to be validated for their relationship in enhancing learning satisfaction as it not only reduces perceived response time but also changes the pedagogy and user interfaces in most instances.

3.6 Coordination dimension

Previously four critical dimensions were identified that are challenging e-learning systems today. These dimensions, which are grounded by research, theories and technologies, have considerable impact on learners. It is argued that in multiplatform e-learning systems, the appropriate use of the attributes within these four dimensions in design and delivery of e-learning content can provide a more positive influence on learner satisfaction. The dimensions that have been discussed, such as content, learner, device and communication dimensions are interdependent. These dimensions can also conflict with each other. For instance, when rich multimedia content is desired for delivery but the communication channel is not able to provide the necessary bandwidth then there is a conflict between content and communication. In another instance where navigation within the content is through image and hotspot but a mobile phone is in use, such navigation techniques become inappropriate, creating conflict between content navigation and device. Thus certain coordination efforts are needed to harmonise these factors. Even if the situation does not generate conflict, the interdependency of the factors requires coordinating the sequence of activities such as reading the device profile, learner profile and context profile, transformation of content, and creating navigation and interaction activities. These tasks must be executed in a timely and orderly fashion. The discussion so far illustrated that coordination is a value added effort which should be analysed carefully within the context of multiplatform e-learning systems. It should be treated as relevant not only to the e-learning systems developer but also to the instructors who provide the content. The theory of coordination (Malone and Crowston, 1990) supports current observation that coordination is critical when it comes to ensuring the execution of separate tasks in time, in the right order and of the right quantity (Reezigt, 1995 cited in Crowston et al., 2004). Precisely, the theory of coordination defines coordination as “managing dependencies between activities” (Malone and Crowston, 1990).

The outcome of a properly coordinated effort enables concerted actions between interdependent units (Thompson, 1967) and accomplishment of a larger goal (Singh and Rein, 1992). With respect to the multiplatform e-learning systems, the outcomes of appropriate coordinated efforts thus enable the right content to be delivered via the right mode, with the right navigation, for the right interaction, to the right devices, through the right communication channel, at the right time and to the right learner to achieve the goal of a better learning satisfaction. In this regard, the relevancy of

coordination theory and practical implementation in web service coordination with respect to multiplatform e-learning systems shall be examined.

3.6.1 Coordination theory

Coordination theory identifies several common dependencies. One such dependency which is relevant to present case is the producer/consumer or flow dependency. Producer/consumer dependency dictates that one task creates a resource that is needed by another. Three sub-dependencies have been identified, which have been labelled fit, transfer and precedence (Malone and Crowston, 1994). The fit sub-dependency means that the resource created by the first task must fit the needs of the second task. The transfer sub-dependency means that the resource must be moved from source to destination where the consuming task will be performed. And finally, the precedence sub-dependency means that the learner performing the second task must learn when the resource is available and the task can be started. To illustrate the flow dependency, let us consider a learner using a mobile phone to access e-learning content. The coordination theory suggests first to examine the “fit” requirement. Thus the learner profile, device profile and communication channel are to be read and examined. Once these have been done, the adapted content is “transferred” to the destination through a communication channel. The learner needs to wait for content to be completely downloaded. Once the “precedence” content has been successfully downloaded, the learner can subsequently perform the task of learning the content.

To overcome these coordination problems, the learner must perform additional work, which Malone and Crowston (1994) of MIT Center for Coordination Science call coordination mechanisms. Learner’s ability to perform off-line downloads may be considered as coordination mechanism. To manage a fit sub-dependency, the content resource must be tailored and adapted to the needs of the learner (meaning that the learner profiles, preference information, and device capability information must be provided for the system). Coordination theory also suggests alternative coordination mechanisms, resulting in different processes. Different adaptation to content can be considered as alternative mechanism. Coordination theory suggests that, given the need to achieve a goal, one way to generate alternative coordination mechanisms is to first identify the particular dependencies and coordination problems faced by that goal and then consider what alternative coordination mechanisms could be used to manage them. In particular, new computing technologies can support coordination techniques

which contribute to system design. For example, the coordination mechanisms of reading the learner profile, device profile, and communication channel can be alternatively implemented using multi-agents technologies such as Knowledge Query and Manipulation Language (KQML) instead of server side technology to coordinate and negotiate between different agents such as learner, device and communication agents and deliver through content agents. Thus coordination theory is not only conceptually logical but it is also practically viable with respect to deploying current technologies. Besides agent based technologies, web services coordination is another possible solution.

3.6.2 Web Services Coordination

Web Services Coordination (WS-Coordination) is a proposed IT industry standard (WS-Coordination, 2005) on how individual Web services can interact with each other in order to accomplish an application task. WS-Coordination is one of a series of specifications from an industry group that includes IBM, Microsoft, and BEA Systems. Not surprisingly, the use of service architecture is common in modern e-learning architecture. For instance, the JISC, IMS, and Sakai e-learning frameworks comprise application services and common services. These services may call other services, creating dependencies on each other. Services are intended to be modular, reusable and portable across environments. The coordination theory with respect to alternative mechanisms can be applied in this instance where learner profile, device profile, and communication channel can be treated as application services and common services and content delivery can be treated as service transactions. Thus it is possible to use the WS-coordination standard to validate the coordination theory.

3.6.3 Summary

The concept of coordination theory and standards such as WS-Coordination and agents based coordination provide strong evidence that coordination activities are necessary for interdependence activities. The multiplatform e-learning systems concept contains many interdependencies within the framework. The coordination dimension is clearly relevant in multiplatform e-learning systems. For example, content depends on the learner, the learner depends on the device, and the device depends on communication. Coordination needs to harmonise these factors to achieve a larger goal (Singh & Rein, 1992) of enhanced learner satisfaction. Thus the

multiplatform e-learning framework advocates that coordination is one critical dimension within the framework. Coordination efforts should be considered from the beginning.

3.7 The multiplatform e-learning system framework

So far several factors that support the formulation of the multiplatform e-learning system framework have been examined, analysed, compared, synthesised and justified. It is necessary now to consolidate these findings to provide an overall view of the multiplatform e-learning system framework, and the key dimensions and sub-dimensions within the framework. Each dimension is illustrated with several example attributes. The framework intends to serve three purposes. First, it should provide a preliminary phase for requirement analysis similar to the information system architecture (Zachman, 1987) for the construction of future multiplatform e-learning systems. It should serve as an initial expandable template that allows system analysis to capture users' requirements. Second, it should serve as a guideline for system implementation. A framework is useful only if it can be operationalised. The multiplatform e-learning system framework has been operationalised to validate its usefulness in an implementation which will be discussed in the next chapter. Third, the framework should serve as a resource instrument for evaluating learner satisfaction while using a multiplatform e-learning system. The adaptation framework was first published in Goh and Kinshuk (2002) and subsequently refined in Goh and Kinshuk (2003; 2004; 2005) who also describe the competency principles necessary for operation of multiplatform e-learning systems.

The multiplatform e-learning system framework can be organised into five core dimensions: content, learner, device, communication and coordination dimensions. Some of these dimensions may also relate to the traditional e-learning systems, however the adaptation requirement, learning satisfaction perspective, multiple devices access requirements and context of use such as the learner dimension and device dimension would differ greatly in operation compared with the traditional e-learning settings. Each of these dimensions includes various sub-dimensions as depicted in Table 3.3. These dimensions and their sub-dimensions and the competency principles that constitute the multiplatform e-learning system framework will be examined in more detail in following sub-sections.

Table 3.3 Multiplatform e-learning system framework

Content Dimension	Learning module	Organisation	Granule	Pedagogy
	Text	Modular	Beginner	Teaching strategy
	Multimedia	Hierarchical	Intermediate	(Guideline)
		Mixed	Advanced	
			Expert	
Learner Dimension	Environment	Motivation	Learning Profile	Preference
	Quietness	Urgency	Static learning history	Presentation preference
	Available of help Self exploration	(Trendy technology)	Mobile learning history	Learning preference
	Multitasking			
Device Dimension	Presentation Capabilities	Operational Capabilities	Ergonomic Capabilities	
	Media player	CPU	Platform (input)	
	Screen	Memory	Browser	
	Browser	Power	Portability	
		Sensor	Mobility	
		Networking		
Communication Dimension	Delivery	Quality	Connectivity	
	Real-time	Perceived response	Wired	
	Synchronised (off-line)	Perceived stability	Wireless	
	Pre-fetch			
Coordination Dimension	Navigation	Interactivity	Presentation	Software & Algorithm
	Link	Forms	Display	Script
	Button	Parameters	Transform	Servlet/ Server page
	Hot spot	Variables		CGI
	Option	Feedback		Agent
	List	Cookies		Web service

3.7.1 Content dimension

The content dimension represents the actual content and knowledge base of the e-learning system. It includes various sub-dimensions. The organisation sub-dimension describes how content presentation should be organised. Attributes such as modular, hierarchical and mixed structure are the main considerations. Another sub-dimension

is the granularity level of the content that indicates the level of difficulty of the content presented to the learner. This may include beginner, intermediate, advanced, and expert levels. The learning module sub-dimension represents the learning objects of the actual material. It is normally represented by text or multimedia versions of the content. Multimedia includes the use of text, audio, animation, video, 3D video, and so on to represent the content to the learner. The pedagogy sub-dimension represents the teaching models (strategies) that the system adopts, for instance activity based and problem based learning. Teaching guidelines can also be considered here.

Competency Principle 1:

The multiplatform e-learning system must have the competency to select the appropriate content organisation structure, learning content, granularity and teaching strategy, and deliver the content according to the engaging situation.

3.7.2 Learner dimension

The learner dimension consists of environment, motivation, learning profile and preference sub-dimensions. The environment sub-dimension represents the actual social and situational factors surrounding the learner when the system is in use. The environment may be very noisy. The social environment might require self exploration without external help or even involve multi-tasking and interruptions. Different environments such as cafés, hot spots and classroom situations will have to be treated differently. The motivation sub-dimension reflects the emotional aspect of the learner such as urgency of need or the acquisition of new devices motivated by a desire for trendy gadgets. The adaptation must take into account various motivations and emotions involved in using the system. The learning profile sub-dimension of the learner dimension includes the static learning history and mobile learning history attributes. These attributes capture the complete learner profiles. These are normally represented by parameters such as date of module completion, weight and score, time taken, date of last access, device access type and so on, depending on the algorithms used in determining the learner profile. Static learning history captures information when a learner is engaged in a traditional e-learning environment. Mobile learning history captures learner information when a learner is using mobile devices or in other learning scenarios. The learner preference sub-dimension contains presentation

preference and learning preference attributes. These are normally represented by parameters such as preferred difficulty level, background, font and learning style.

Competency Principle 2:

The multiplatform e-learning systems must have the competency of organising, extracting and utilising the learner information to best suit the content to the learner.

3.7.3 Device dimension

The device dimension consists of the presentation, operational and ergonomic capability sub-dimensions. The presentation capabilities sub-dimension relates to presentation attributes such as the media player, screen and browser. The operational capabilities sub-dimension relates to the hardware aspect of the device such as CPU, memory, power, network interface and sensory capabilities. The ergonomic capabilities sub-dimension relates to the ease of use of the device such as the mechanism for inputting text, ease of use of the browser interface such as navigation, and the portability and mobility capabilities of the devices.

Competency Principle 3:

The multiplatform e-learning systems must have the competency of identifying and utilising some or all of the capabilities of the devices.

3.7.4 Communication dimension

The communication dimension relates to the quality of the network and the delivery mode. Within this dimension, there are three sub-dimensions. The connectivity sub-dimension consists of attributes such as wired and wireless connection in the learning situation. Wired connections can be dial-up, ADSL, or LAN. Wireless connections can be 802.11(a,b,g,s), wireless mesh networks, bluetooth or infrared. The quality sub-dimension relates to the perceived response and perceived stability of the system from the learner perspective. The delivery sub-dimension relates to the mode of delivery such as real-time online mode, pre-fetching and offline synchronisation mode.

Competency Principle 4:

The multiplatform e-learning systems must have the competency of deciding which mode of operation is best suited for the communication conditions.

3.7.5 Coordination dimension

The coordination dimension represents the software and algorithm sub-dimension of the application, the presentation sub-dimension, the interactivity sub-dimension of the application and the navigation sub-dimension. In any adaptive system, these dimensions must be well coordinated to provide the learner with a good learning experience. The software and algorithm sub-dimension contains the script language and server page language, agents' communication, or a web service coordination standard to control the flow of the application from generating content, feedback, interactivity and navigation sub-dimensions. The presentation sub-dimension links to the final transformation and display of the content to the learner. The interactivity sub-dimension represents how the user information can be sent as feedback to the application. Within the http protocol, these normally use web forms, post and get techniques, and cookies for registration and communication of parameters and variables. The navigation sub-dimension provides manoeuvres and control within the web pages and applications usually implemented with anchor links, buttons, hotspots, options, and list boxes. For instance, in the communication dimension mentioned earlier, when a learner operates under a synchronisation sub-dimension, certain interactivities in the coordination dimension have to be dropped and cookies and scripts must be activated to store interactivity information such as the answers to a test. The coordination dimension here can provide these adaptations.

Competency Principle 5:

The multiplatform e-learning systems must have the competency of effectively isolating the content, presentation, navigation and interaction components and subsequently integrating them seamlessly and effectively.

3.8 Summary

The multiplatform e-learning system framework has been presented in this chapter. The framework identifies the core competency dimensions needed for the operation of adaptation. The framework identifies five dimensions that influence

learning satisfaction and the effectiveness of the adaptive measures that are likely to lead to better learning satisfaction of using the multiplatform e-learning systems. However, two issues remain. First, these factors must be validated against their influence on learning satisfaction. Second, adaptive measures - taking into account these parameters in the multiplatform e-learning system implementation - need to be validated under multiplatform environments. To address the above issues, a prototype has been implemented using the framework. The prototype has been used for the validations and will be discussed in a later chapter.

To formulate the multiplatform e-learning systems framework, one can examine the foundation through various e-learning definitions. From structural analysis of these definitions, content, learner, device, and communications dimensions are identified to support e-learning systems. To further support the operation of these dimensions the need for a coordination dimension is identified. These five dimensions set the foundation of the multiplatform e-learning systems.

In the content dimension, pedagogy, multimedia in the learning module, organisational structure of content, and granularity are shown to affect learning. Multiplatform e-learning systems represent a new environment that has yet to be fully explored. The current research examines how these dimensions behave and interact in this new environment.

In the learner dimension, strong evidence had suggested that learner profile, learner preference, motivation, and environment can influence learning. Due partly to the proliferation of mobile devices and their intrinsic ergonomic characteristics such as mobility and portability, multiplatform e-learning systems create further dimensions of complexity beyond that of traditional e-learning systems.

The device dimension reveals that accessing devices and the context have considerable influence on learning. In designing multiplatform e-learning systems, device presentation capabilities and ergonomic capabilities should be explored and adapted to facilitate meaningful learning.

Next, the availability of various communication channels and a multitude of device communication capabilities result in wide deviations in available bandwidth and response time. Also, the quality and connectivity sub-dimension and communication dimension require multiplatform e-learning systems to be capable of adapting different modes of delivery for different levels of bandwidth. The modes of delivery identified are real time online mode, pre-fetching mode, and offline

synchronisation mode. The relationships between different modes of delivery and learning will require validation.

Finally, in order to coordinate several dimensions to achieve the necessary goal of delivering content to learners, the coordination dimension is necessary. The concept of coordination theory, the WS-Coordination standard and agents based coordination technologies provide strong support for the coordination dimension.

Chapter 4 Overview of technologies and system implementation

In the previous chapters, the multiplatform e-learning system framework has been reviewed and formulated. For the framework to be useful there is a need to validate its usefulness. Usefulness can be demonstrated through successful implementations as well as by transforming the framework into an instrument for the purpose of evaluation. Thus the main objective here is to demonstrate its usefulness through a successful implementation. To achieve this goal, it is necessary to focus on four aspects that account for the necessary technologies underpinning the prototype implementation. First aspect focuses on mobile content design, drawing on the experiences gained and guidelines for implementation. These key experiences include browser experience, Flash design experience, and Pocket PC (PPC) design experience. Second aspect focuses on transformation technologies. These include XML XSLT, DOM, and MSXML development and programming technologies. Third aspect focuses on implementation relationships between several entities. These entities include the current framework, the derived logical architecture, the prototype system and various implementation technologies. The mapping, linkages and relationships between these entities will be highlighted. Last aspect intends to focus on giving examples via a comparative walkthrough to illustrate the different aspects of the multiplatform e-learning system with different accessing devices.

4.1 Browsers experience

For mobile phone content design, the Openwave Phone Simulator version 6.2 was initially adopted and later the Opera browser was used that comes with the Nokia 6600 smart phone. The Openwave Phone Simulator is a PC-based mobile phone simulator for devices with Openwave client software (Openwave, 2003). The Openwave simulator Software Development Kit version 6.2 and mobile browser were used during the first phase of design and during the course of a pilot evaluation. During that time the SDK version 6.2 was the latest version available. It was also chosen because at that time the telecom network and the supported mobile phones were all using the Openwave mobile browser. Besides, Frost and Sullivan's (2003) analysis and testing revealed that Openwave is a better browser than NetFront v3.1 and AU Mobile Internet Client; particularly due to its superiority in offering additional menu options/features, and due to the seamless overall browsing experience that it offers. Another reason was the popularity of the Openwave mobile browser estimated to capture 51% market share in 2003. Several other features come with the simulator such as the Openwave Messaging Client and the capability of

supporting test services using XHTML Mobile Profile 1.0 with Cascading Style Sheets (CSS) and MMS-SMIL without the use of any gateway, making it a good starting tool. XHTML Mobile Profile and CSS provide application developers with significant benefits by enabling a more standardised, portable, efficient and cost-effective development environment for creating multiplatform web applications. This offers a better option than having an actual phone. In addition to supporting the XHTML mobile profile it also supports WML, cHTML, and WAP push. It was also one of the few SDKs that deployed UAProf and user agents while standardisation is still in a draft stage. Thus it provides a possible test scenario. Other SDKs such as those developed by Nokia and Ericsson were tested but gave unsatisfactory user experiences and support and were excluded from the design. One shortcoming at that time was that none of the micro browsers were supporting Java Script. This contributes several obstacles in bandwidth and media player detection. Several specialised server scripts and html meta tags were used to resolve the problems.

The Opera browser version 6.1 that comes with the Nokia 6600 phone was eventually used for the final evaluation. Opera browser has similar capabilities as the Openwave micro browser but it has a PC version with a small screen rendering function. This feature allows immediate comparison between PC and mobile devices and has proven to be very useful. However when it comes to actual devices such as the Nokia 6600 there were some limitations and differences when it encountered a table structure. The initial idea of using Nokia 6600 was to use Bluetooth to pass through Internet connections with the synchronisation utility in the phone which is similar to using IPAQ and active sync software. The reason for doing this way is to save on connection costs. However the Nokia 6600 phone was reported to be locked down by the vendor and this approach was no longer feasible. A real connection was eventually used.

Compared to a WAP browser, the mobile browser makes it easier to adapt PC-based web user interfaces to handheld devices. The design is more intuitive and easier to use, and thus narrows the gap between PC and mobile experiences. However the needs of a mobile learner are often quite different from a desktop PC learner in an e-learning environment. Such differences must be taken into consideration in the design of the multiplatform system.

4.1.1 Browser design guidelines

Designing for mobile devices is different from large-screen devices as noted by several studies (Openwave, 2005a). Mobile devices may render web pages differently due to many

factors, such as browser variation, device variation, rendering engine, and mobile gateways. Designers must take these factors into consideration to ensure that an e-learning system performs within expectations for use with different mobile devices. Some of the experiences gained from implementation and from Openwave's design documentation are summarised. These guidelines can be generalised to other browsers and devices and are thus not necessarily restricted to Openwave supported devices.

i. Text input

Text input is generally difficult in most mobile devices. Using a Dual-tone multi-frequency (DTMF) keypad and stylus input is cumbersome compared to a full keyboard. Designers should avoid making users input long texts and use selection and links if at all possible. In the multiplatform e-learning context, multiple choice assessments seemed more appropriate than short answer assessments.

ii. Screen

Mobile devices display screens are small and about 120 pixels in width, which is about 1/10th of the size of the 800 or 1024 pixels screen size of a typical desktop computer where most users will have some difficulty reading complex pages. In the multiplatform e-learning context, summarised and concise text may be more powerful in conveying the information than using images. Interactive multimedia will have limited success when the screen is very small.

iii. Speed

Mobile processor and transfer speeds are generally slow. High-end mobile devices on high-speed networks are going to be slower than computers attached to high-speed - or even dial-up - networks. In the multiplatform e-learning context, alternative modes of delivery such as offline and pre-fetch may need to be adapted to minimise the perceived delay which might affect learner satisfaction.

iv. Mobility

Learners can be mobile. Roaming learners have different goals, tasks, and environmental constraints than a learner who is sitting in front of a computer or is stationary. In the multiplatform e-learning system context, the adaptation process must either take advantage of the situation or take the constraints into consideration. For

example, audio can be provided if the surroundings are quiet, or it could be helpful to minimise any further multitasking activities such as additional inputs.

v. Navigation

Every extra keystroke, navigation, link and selection in mobile devices is likely to degrade usability. Design should avoid forcing learners to scroll through the entire page. In the multiplatform e-learning context, proper use of links that allow easy navigation within the pages and site should be adopted instead of relying on the forward and back buttons available in most mobile devices which occasionally change to other functions if the user is not careful.

vi. Cost

While cost may not be an issue during the research phase, data transfer costs are likely to be higher for mobile access than normal access and should be minimised. Designers should avoid a huge amount of data transfer if at all possible. Alternative data transfer modes such as synchronisation should be included in the design from the beginning. With respect to the multiplatform e-learning context, image adaptation and scaling should be done by the server rather than the client, even if the client has the capability, to reduce the data transfer.

vii. Gateway validation

Gateways, which are normally provided by carriers, can affect how content is rendered. Some gateways are strict and may allow only validated XHTML Basic through; they may translate graphics, and they may do other things. Again, a usability test is needed.

viii. Layout

Most mobile devices display in portrait rather than landscape format. A mobile user views the top first on mobile devices. Horizontal navigation bars, tabs, and side-by-side positioning should be avoided as they can cause usability problems. This applies to most mobile phones regardless of browser type. A portrait format is adopted in the multiplatform e-learning system implementation.

viii. Tables

Different devices may render tables differently. For instance, different devices enable different types of navigation; users may have to scroll horizontally through each row before being able to scroll downward. The Opera browser behaves this way, which makes navigation extremely unpleasant. Sometimes tables are rendered wider than the screen. Such experiences will cause frustration and usability problems.

ix. External CSS

Applying external CSS to an entire site can reduce the amount of downloading. However many browsers do not cache the CSS and can cause repeated downloads for each page the user visits. This is costly and creates delays. Further, when the CSS is downloaded, the already-displayed content may jump around to render the new styling. Thus in the multiplatform e-learning system, XSLT was adopted for presentation style and logic instead of using external CSS.

x. Background images

Background images should be kept very small and reused if possible to reduce downloads. Some devices do not support background images, so the design must work well with and without backgrounds. Some browsers do not support coloured text, so it is important to be aware that such text could become unreadable if it merges with the background. No background images were used in the multiplatform e-learning system implementation to provide a consistent look.

4.1.2 Summary

These design guidelines suggest that delivering content to mobile devices is far from ideal and unexpected outcomes may occur if no consideration is given to the variables that affect the rendering process. While various guidelines are suggested, they are by no means foolproof. In multiplatform e-learning implementation, several iterations and evaluations are necessary for minimising usability problems. This is also why a framework must also provide a way for evaluation to be conducted. This study has addressed these issues as well.

4.2 Flash experience

To deliver interactive multimedia for mobile devices one of the key requirements is the ability to deliver low-bandwidth animations, presentations, and dynamic data-driven content. Currently there are two possible options available: using SVG-tiny (scalar vector graphic) or using Flash from Macromedia. SVG-tiny is an emerging standard for mobile devices championed by Adobe. At the time of implementation, SVG-tiny was still in draft form. Moreover there is a lack of good authoring software that supports SVG-tiny. Thus during the time of implementation, Flash offered the best option. However future implementations should monitor the development of SVG-tiny. It is a technology that has great potential. Flash offers a rich set of capabilities such as action scripting capabilities, variety of components and templates, and server-side connectivity for rapidly creating engaging applications, such as e-learning (Flash 2003a, 2003b). According to NPD online research (NPD, 2005), Flash Player currently has a penetration of up to 98.7% worldwide while SVG player has only 11.5%. This is another reason why Macromedia Flash was adopted for the design of interactive multimedia e-learning content in this study.

4.2.1 Macromedia Flash Player

One of the key advantages of Macromedia Flash (Flash, 2003a) is its reusability that can be used by a wide range of browsers, platforms, mobile and smart devices. These include Flash Player 6 for Microsoft Pocket PC PDA and Pocket PC Phone Edition devices. In addition, many major phone vendors are supported with Macromedia Flash-lite. Thus a Flash object is capable of supporting and being utilised by various devices with minimum alteration. Moreover, Flash files are compact, making them perfect for wireless carrier networks where transfer rates range between 9.6 and 60 kilobytes per second (Kbps). Thus Flash is appropriate for the multiplatform e-learning environment where connecting speed varies widely.

Flash offers two types of players: ActiveX (DLL) and stand alone player (SAP). When using an ActiveX player, direct loading and playing is not supported. Thus content adaptation must be utilised to eradicate this slight problem. Flash content must be embedded within an HTML file through either hard coding or adaptation via transformation. The Flash Stand Alone Player (SAP) for Pocket PC is a client-side application. It allows flash content to be distributed together with a player and allows stand alone playing. This aspect seems to be advantageous if the e-learning content is all flash. Where there is a separation between Flash content and other e-learning content, an

ActiveX version seems more appropriate. Moreover, SAP is not free (unlike Flash Player) and is rather expensive. Thus in the multiplatform e-learning system the ActiveX player was adopted.

4.2.2 Design issues with Flash and Pocket PC

Flash is a very powerful application: almost any type of content can be created in Flash for the Pocket PC platform. However, designing Flash content for a Pocket PC (PPC) is not as straightforward. Due to limitations of devices and browsers, several design issues require specific attention. These issues include performance, usability, technologies and optimisation (Flash, 2000b). During the course of implementing the multiplatform e-learning system, several useful and relevant experiences were gained which can be summarised below:

i. Flash object

When using an object tag in HTML to embed the Flash object, the pixel option is to be used instead of the % option. The codebase attribute in the `<OBJECT>` tag should be deleted as the player is not downloaded in this manner. The `<EMBED></EMBED>` tag is not supported in pocket Internet Explorer and should be removed. Reducing unnecessary markup can lighten the entire transfer and allow a faster transfer and rendering.

ii. Screen orientation

Pocket PC allows portrait and landscape orientation, yet most designers and users are not aware of this option. Using a landscape orientation for the interface might suit the functionality and purpose of some applications. For example, in module 2 of the e-learning system that deals with the subject content regarding lens, using landscape orientation can provide a more complete view of the ray tracing than portrait orientation.

iii. Fonts and text

For applications or static graphics, Flash with embedded text can be used. PPC devices include Tahoma and Courier fonts. These fonts render well on bitmap displays at all resolutions, which is ideal for use on small screens were adopted in the multiplatform e-learning system. In general, most sans-Serif fonts display better than Serif fonts. Serif fonts tend to lose their details on screens, creating a blur effect and should be avoided.

iv. Colour balance

Pocket PC has good colour depth from 4,096 to 65,535 colours. However PPC display technologies are not as advanced as desktop monitors and often have low contrast. Highly contrasting colours are therefore recommended to anticipate mobile environments. Also, graphics should have a high contrast ratio between colours and crisp edges in the details of the picture. Blue or black and white background was adopted.

v. Navigation

Navigation is an important usability factor in interactive Flash design. Factors influencing navigation design for Flash content are the amount and type of content, type of navigation, purpose of the application and user input method. Proper navigation design is required to ensure that all parts of the content are easily accessible without traps. In PPC, Flash objects can be dragged and moved across the display. This characteristic is seldom exploited and users are usually not aware of such navigation. In the multiplatform e-learning system implementation and evaluation, every participant was taught how to drag and move the Flash object across the display. A usability test is essential to achieve maximum satisfaction.

vi. Sound

Flash Player 6 for Pocket PC 2002 can be used to deploy sound, music videos, mobile entertainment, and animations. However, sound consumes large amounts of processing power and precious power resources. In current implementation the used of sound was minimum.

vii. Animation

Factors that influence the speed of animation are the amounts of animation, visual effects such as the use of tweening, masking, motions, alpha blending, complex vectors, and key frame selections. The amount of animation should also consider the processor speed and capabilities along with pedagogical considerations. Utilising a capabilities check can avoid unsatisfactory user experiences. Simple Flash was adopted without complicated tweening in the multiplatform e-learning system.

4.2.3 Summary

Using Flash for mobile devices is not straightforward. It is unlike designing with the PC in mind. More comprehensive testing is required to ensure better usability. While Flash is supported by various devices there are still various slight differences between the devices. Finding a common denominator that works across each device with minimum modification is a cost effective choice. Many design aspects differ from the PC perspective. These differences support the assertion that an adaptive multiplatform e-learning system is needed to provide a better learning satisfaction. The technologies that enable the multiplatform e-learning system to be implemented are still evolving while the system is developing. The development of these technologies in the future will only further extend and enhance the capabilities of multiplatform e-learning systems without affecting the underlying multiplatform e-learning system architecture. For instance, the processing power and memory of the devices will allow faster processing and decrease delays. The development of SVG-tiny allows interactive multimedia development for mobile devices instead of relying on Macromedia Flash. The full compliance of JavaScript will allow design to be more consistent across different platforms.

4.3 Pocket PC experience

The IPAQ pocket PC PDA was adopted as the accessing platform for two reasons. Firstly, the Pocket PC operating system is very similar to the PC based operating system and most students who are using Windows operating system may find the learning curve much shorter (Jeong & Lee, 2004). Secondly, the documentation and SDK for the Pocket PC are readily available to begin the design from the simulator. The SDK was adopted for the initial design. However experiences showed that while designing from a simulator is cost effective, it is not exactly the same as the real device. For instance, Bluetooth support cannot be realised using a simulator, Flash objects cannot be supported, there is no stylus support, no sense of mobility and portability, and the web setup is lost after the simulator is closed. Besides, there are many more features requiring attention in the real device. Nevertheless, simulator can provide a good starting point.

4.3.1 Design issues with Pocket PC PDA

There are several key features of the Pocket PC that are relevant to and affect the design of multiplatform e-learning systems. A brief summary is provided below (PPC, 2000).

i. Display

The full screen size on a Pocket PC is 240 by 320 pixels but the actual estate that can be used depends on various situations. The usable content area in Pocket Internet Explorer (PIE) is 229 by 255 pixels. The optimal size for displaying content is a maximum width of 220 pixels without the appearance of horizontal scrollbars at the bottom of the screen. If the content exceeds 245 pixels in height, it will trigger the vertical scrollbar. Pocket PCs contain a built-in software keyboard. When activated, it consumes 240 by 81 pixels of screen space. This means that user input through textboxes or forms on a web page has a smaller width area and should not be exceeded.

ii. Connectivity

The Pocket PC can be used in two ways to access Internet content: direct TCP/IP connection through a wireless Flash modem or using an adapter (IR, Bluetooth) with mobile phone and desktop pass-through. Alternatively, disconnected offline operation is possible via caching the data through mobile favourites and synchronisation. In the multiplatform e-learning system evaluation, the Bluetooth wireless pass-through connection method was used to allow controllability and mobility.

iii. Scripting

Pocket IE supports only a subset of the HTML 3.2 standard. The latest browser can handle HTML 4.0 and XHTML. The latest pocket PC supports JScript 3.0 but not in full. The time variable is in seconds rather than milliseconds. VBScript is not supported by the browser. Pocket IE cannot open multiple browser windows; it uses a single window only. Script errors are also turned off by default. There is no support for CSS; instead, XSL style sheets can be used. Scripting not supported in full, making delay estimation rather challenging in the multiplatform e-learning system implementation. Also, web forms must be designed in a defined order for the scripting to work correctly.

iv. User interface

Designs using a stylus or touch screen must consider the size of the user interface (UI). Pocket PC has a .24 dot pitch display. For a stylus UI a size of 5.04mm or 21x21 pixels is recommended. For a finger UI a size of 9.12mm or 38x38 pixels is recommended. These sizes could be increased to compensate for viewing at an angle. In the multiplatform e-

learning system implementation, there is always a need to balance the size of the UI objects within in the Flash multimedia object.

v. Simplicity and clarity

Simple user interface that meets the required task should be used in order to avoid overloading the user with a complex user interface. Commands for critical features should appear in a prominent area such as a menu, while advanced and less-frequently used commands can be in a less prominent area such as a submenu or settings dialogue. In the multiplatform e-learning system, simple text anchors or buttons were adopted for marking, reset and for page navigation.

vi. Dialogue box

The use of dialogue boxes can reduce the visibility of relevant information. Feedback should be used appropriately and within a reasonable time. In the multiplatform e-learning system implementation, the use of dialogue boxes is minimised. For example, a feedback message box was used in the assessment module.

4.3.2 Summary

The selection of the IPAQ PDA with the pocket PC 2002 operating system for evaluation was not a difficult choice. In early 2003, this was one of the top of the line PDA available. While there were rich resources on design guidelines, the SDK emulator, and an abundance of online forums, using the IPAQ was not trouble free. There were issues regarding its operational capabilities such as battery charging, system crashes, Bluetooth connection, pass-through connection, JavaScript compatibility, and timing precision issues just to name a few. These problems were eventually solved though not easily. The lesson for multiplatform e-learning system implementation was that to achieve consistency and reliable output, algorithmic and presentation operations should be consolidated at the server side instead of relying too much on the client's device capabilities.

4.4 Transformation technologies overview

Transformation technologies allow a minimum set of content to be deployed without duplication efforts, minimising content maintenance problems. While there are many techniques to achieve content adaptation, as reviewed in chapter 2, the W3C standards and directions have been adopted in the current practice. Thus an overview of the technologies that facilitated the system implementation is necessary. These technologies include XML, XSLT, DOM, and MSXML.

4.4.1 XML overview

XML is a W3C standard (W3C, 2005). It permits interchange and communication of structured textual data between computer software programs. An XML document is written in a simple text format which is easily constructed by any text editor. There are a few reasons why XML was adopted in the implementation of the multiplatform e-learning system. First, using the XML standard can facilitate the web service framework adopted in many e-learning standards. Naturally this provides a future extension plan for the multiplatform e-learning system framework. Second, XML separates data from presentation. It allows e-learning content such as text and multimedia to be separated from the presentation type and format of the end user devices. This requirement is necessary in the multiplatform e-learning system as the system potentially faces a multitude of different accessing devices. Listing A.1 in Appendix A shows an example of the learning modules used in the multiplatform e-learning system implementation that separate the text, data, and multimedia content. Third, to facilitate collaboration between e-learning systems, there is a need to pass data between applications and to different e-learning systems. For instance, learning content can be reused for other e-learning systems; learner profiles may need to be transferred to other systems as well. An XML based standard document allows such flexibility of data exchange. Separation of content from presentation also allows manipulation of content such as summaries, aggregation or extraction of content to suit the learner.

An XML document can be defined using a Document Type Definition (DTD) or an XML schema to describe the data. XML with a DTD or XML schema is designed to be self-descriptive. Listing A.2 in Appendix A shows the XML schema for the learning module as in Listing A.1. Displaying the XML document itself is of no benefit to the learner. The XML document needs to be converted in such a way that a learner can easily understand the content. In a web based e-learning system, transforming XML to HTML

format allows learners to easily understand the content. Therefore XML to HTML transformation is adopted in the multiplatform e-learning system design and implementation.

Besides the need for transforming XML to HTML, there is a need to transfer data between application and XML files. For instance the learner profile and the assessment output may need to transfer data to each other for updating profile which requires XML document methods such as extraction and saving. Other transformations may require extracting and combining data from one set of XML documents to generate another set of XML documents. To perform these tasks, XSLT were used to achieve these requirements.

4.4.2 XSLT overview

XSLT is capable of either transforming one XML document into another XML document or it can transform XML documents into other text-based formats (XSLT, 2000). There are two stages involved in the transformation. The first stage is a structural transformation. During structural transformation, the structure of the incoming XML document is converted to the structure of the desired output document. The second stage is formatting. In the formatting process, the new structure is output to the required format such as HTML, WML or another XML. To accomplish the transformation, it is necessary to invoke an XML parser. There are two principal APIs for parsing XML: the Simple API for XML (SAX) and the Document Object Model (DOM). The discussion will focus on DOM (DOM, 2005) as it is used in the current implementation.

The DOM API parser interrogates XML document and builds a tree-like object structure in the memory. XSLT manipulates this tree-like structure directly rather than the XML document. Using high-level declarative language, XSLT can navigate around a node tree, select specific nodes and perform complex manipulations on these nodes. To prepare for transformation, the transformation rules must first be defined. These rules are based on defining a template that generates the desired output when a particular pattern occurs in the input. When a match is found, XSLT will transform the matching part of the source document into the resulting document. In the transformation process, XSLT uses XPath to define parts of the source document that should match one or more predefined templates. XPath is a language for finding information in an XML document. XPath is used to navigate through elements and attributes in an XML document.

It is useful to distinguish the functions of XSLT and DOM. In DOM, the programmer is responsible for handling the low-level manipulation of information constructs. In XSLT, the XSL processor decides the most efficient way to achieve the output for the transformation required by the style sheet. Figure 4.1 shows various parts of the technologies involved in the XSLT transformation process. This figure can be compared with Figure 4.3 of the DOM and programming process. Both methods are involved in the current multiplatform e-learning system implementation.

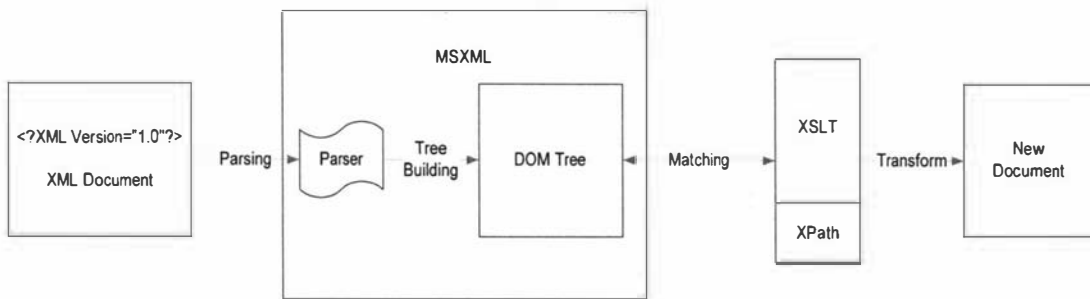


Figure 4.1 Technologies used in the XSLT transformation process

To deliver adapted content to learners, a three-tiered architecture (XSLT, 2000) can be adopted as in Figure 4.2. The adapted content can be transformed by web browsers with XSLT on the host, or on the user agent, or even on both. Two approaches are possible. First, the server can distribute the processing load to XML/XSLT-aware user agents by delivering a combination of the style sheet and the source information to be transformed on the user’s platform. This approach may cause delays and deliver more than the essential data to the client. Alternatively, the server can perform the transformations centrally to accommodate those user agents supporting only HTML. For the multiplatform e-learning system the second approach was adopted as most mobile devices have a lower processing power. Also consistency of the output may be in doubt if the XSLT is not compatible.

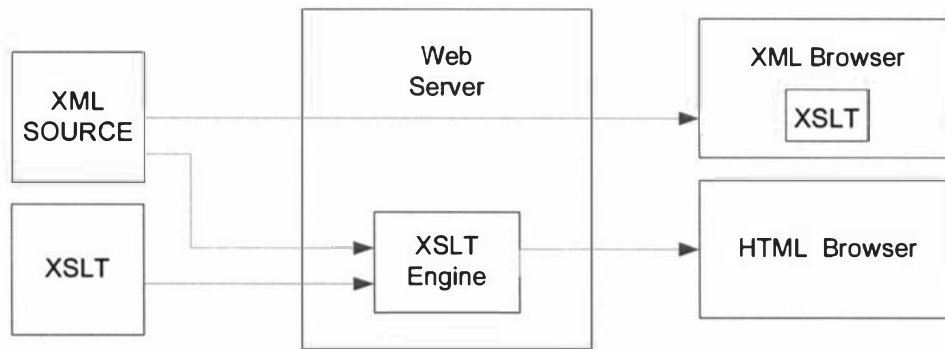


Figure 4.2 Server-side transformation architecture

4.4.3 DOM overview

Document Object Model (DOM) is another W3C standard (DOM, 2005). DOM is an application programming interface (API) for handling HTML and XML documents. It defines the logical structure of XML documents through a hierarchy of node objects. The nodes in the DOM structures represent objects and a data structure. These objects have functions and identities. The data itself is encapsulated in objects. These objects hide the data, protecting it from direct external manipulation. The functions associated with these objects determine how the objects may be manipulated, and they are part of the object model. Through these nodes, the documents can be accessed and managed. These include the interfaces and objects used to represent and manipulate a document, the semantics of these interfaces and objects - including both behaviour and attributes - and the relationships and collaborations among these interfaces and objects. In addition, scripts can be written to navigate within the document structure, to add, modify, or delete elements and content. The DOM is separated into different parts - Core, XML, and HTML - and at different DOM Levels 1/2/3. Core DOM defines a standard set of objects for any structured document; XML DOM defines a standard set of objects for XML documents; and HTML DOM defines a standard set of objects for HTML documents.

Various objects and methods exposed by DOM are valuable in the multiplatform e-learning system implementation. These objects are the “*DOMDocument*”, “*XMLDOMNode*”, “*XMLDOMNodeList*” and “*XMLDOMNamedNodeMap*”. To create a DOM, the “*DOMDocument*” object was used. The “*Load*” or “*LoadXML*” methods was used to load an XML file into the DOM. The “*LoadXML*” method loads a string containing the XML data. To save a parsed XML document to a file, the “*Save*” method was used.

4.4.4 MSXML overview

MSXML (Microsoft XML Core Services) is one of the DOM implementations (MSXML, 2005a). MSXML is a parser which allows documents to be loaded or created. MSXML also gathers errors, accesses and manipulates the information and structures contained within the document, and saves the document back to an XML file using the save method. The MSXML parser generates the Document Object Model (DOM) that presents an easily processed standardised interpretation of an XML document to applications and scripts. In the multiplatform e-learning system, the implementation takes advantage of the methods built into MSXML to manage the XML content, instead of creating specialised codes. Figure 4.3 shows the entire process. The MSXML parser can support JavaScript, VBScript, Perl, VB, Java, C++, etc. It has complete XML support, full DOM and namespace support, DTD and validation, complete XSLT and XPath support, SAX2 support, and Server-safe HTTP. These features fit well with the current requirements for the multiplatform e-learning system implementation and potentially provide for future extensions such as web services.

When the MSXML parser loads an XML document into a DOM, it processes it and creates a logical model of nodes from the structures and content within the XML document. The document itself is considered a single node that contains all of the other nodes, including a node representing the root element, which, in turn, contains all of the element, attribute, and text nodes in the document. In the multiplatform e-learning implementation, server scripts were written to manipulate these elements for extraction, and update XML documents such as the learner preferences and profiles. Listing A.3 in Appendix A shows the generation of a DOM tree using the *“Server.CreateObject”* method. The *“XML.getElementsByTagName”* method is used to access the DOM tree. The *“XSLProc.Transform”* method is used to process the modified XML document. The *“XSLProc.Output”* method is used to display the output to user’s device.

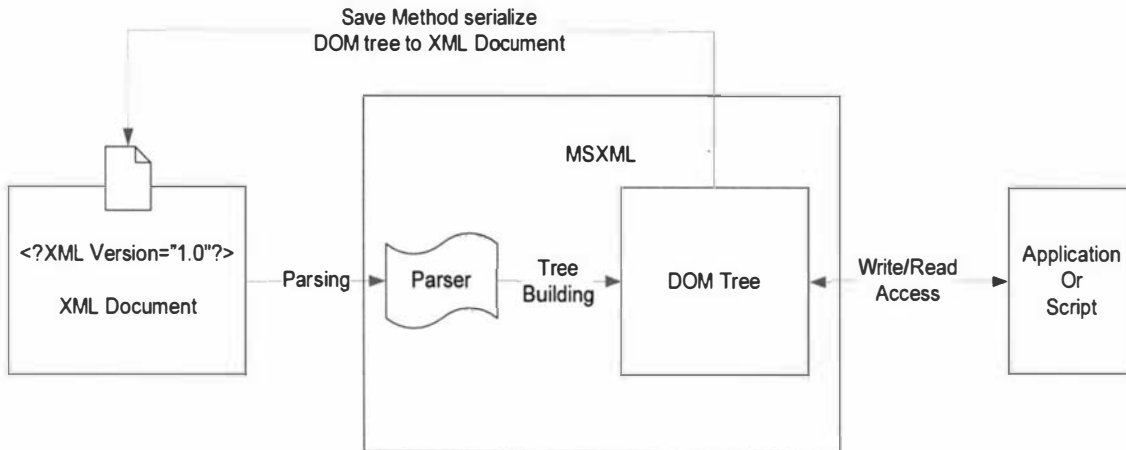


Figure 4.3 Technologies used in the DOM process

4.4.5 Summary

Successful implementation of multiplatform e-learning systems requires effective content adaptation. The transformation technologies that involve XML, XSLT, DOM and MSXML can be very effective in providing content adaptation with provision for web services. Two other areas need attention. First, the focus so far is on the transformation of text documents; however, technology which enables transformation of vector graphics from Flash to SVG when needed is being developed and should be considered. This is so because of the development and adoption of SVG-tiny in the next generation mobile devices. This development will only strengthen the multiplatform e-learning systems framework. Second, the current implementation used the DOM technologies but there is a need to investigate the use of SAX with respect to performance (MSXML, 2005b) and usability issues in a real environment.

4.5 Implementation of the multiplatform e-learning system

After the overview of various technologies, the implementation of the multiplatform e-learning system will be discussed. The implementation closely follows the multiplatform e-learning framework. It should be emphasised that the framework is technology independent and does not dictate which technologies are to be used for implementation. As such, there could be many possible instances of implementation based on different combinations of technologies, such as autonomous agents and web services technology. Technologies aside, the current implementation aims to achieve the following objectives:

- (a) To operationalise the framework and validate the usefulness of the framework through an implementation.
- (b) To provide a test bed for supporting evaluation and exploring the relationship between factors influencing learner satisfaction in different use scenarios.

Currently the physical design technologies are based on XML, XSLT, DOM, MSXML and ASP. The logical design guidelines and considerations are based on the multiplatform framework and the derived architecture. The design framework adopts a consistent goal of separating data layer from presentation layer and presentation layer from logic layer as far as possible. Thus it is necessary to closely examine the XML/XSLT/ASP approach in achieving the seamless design framework as well as looking into problem areas and specific technologies involved in the implementation.

4.5.1 Multiplatform e-learning system architecture

First, through the multiplatform e-learning system framework formulated earlier, an abstract logical architecture is synthesised as shown in Figure 4.4. Each dimension of the framework is mapped exactly to each layer of the logical architecture of the e-learning system. The equivalent physical architecture model similar to the IMS model (IMS-AF, 2003) is shown in Figure 4.5. The final system implementation architecture of the multiplatform e-learning system is shown in Figure 4.6. The logical representation consists of the following five layers:

i. Content

This layer represents the actual learning content delivered which will be determined by the coordination layer.

ii. Learner

This layer authorises learners to gain access to the system. This layer holds the learner profile, preferences, environmental context and motivation information. The learner is able to gain access to the system through an accessing device.

Content Layer	Module	Pedagogy
	Organisation	Granularity
Learner Layer	Environment	Preference
	Profile	Motivation
Device Layer	Presentation	Operational
	Ergonomic	
Communication Layer	Delivery	Quality
	Connectivity	
Coordination Layer	Navigation	Interaction
	Presentation	Logic

Figure 4.4 Logical architecture of the multiplatform e-learning system

iii. Device

This layer represents the accessing device. Normally this is represented by the browser agent. It also carries the device profiles and network communication protocol. Content is delivered to the device browser and the supporting media software.

iv. Communication

This layer represents the basic communication infrastructure from browser to device gateway and to the Internet backbone. This layer is characterised by its network quality. Relevant information is extracted by the coordination layer to determine the mode of delivering the content to the device layer.

v. Coordination

This layer represents the logic and is the heart of the multiplatform e-learning system. It determines which content format is used and how it is delivered to the device browser by making a decision based on information gathered from all the above layers.

The physical representation consists of the following core structures:

i. Core network

The core network is the primary network that interconnects the servers' computers and is normally the Internet. This is part of the communication layer in the logical model.

ii. Access gateway network

The access gateway network is the network that links the accessing device to the core network and may consist of telecom fixed and mobile networks, cable networks, and other wireless networks. This is part of the communication layer in the logical model.

iii. Repositories

Repositories hold the e-learning content, learner profiles, device profiles and other relevant databases. They aggregate the learner layer, device layer and content layer in the logical model.

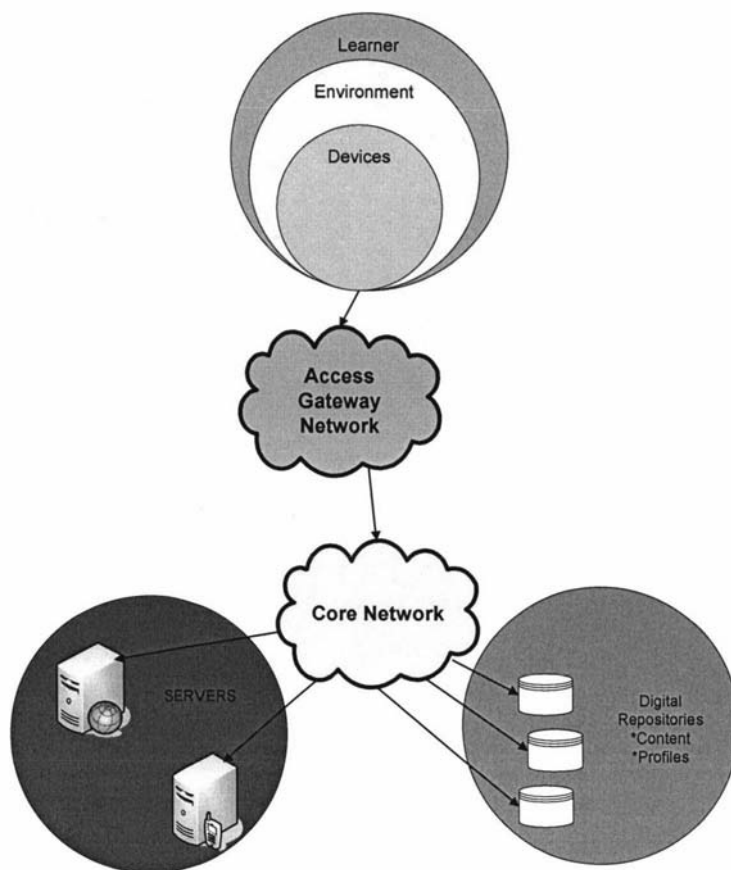
iv. Servers

Servers are the actual systems that hold and support the entire e-learning system. This is a major part of the coordination layer in the logical model.

v. Learner environment and device

This comprises the learners, their environment and the physical devices used to access the e-learning system. It aggregates the learner and device layers.

The final multiplatform e-learning system developed consists of four learning modules as shown in Figure 4.7. Each module consists of two learning concepts and an exercise which are linked by an index page. Within each module, there is a Flash interactive multimedia simulation to allow learner to explore and verify the learning concepts. The Flash simulation can also be accessed via the revision link.



A Physical architecture for adaptive multiplatform e-learning system

Figure 4.5 A Physical architecture of the multiplatform e-learning system (after IMS-AF, 2003)

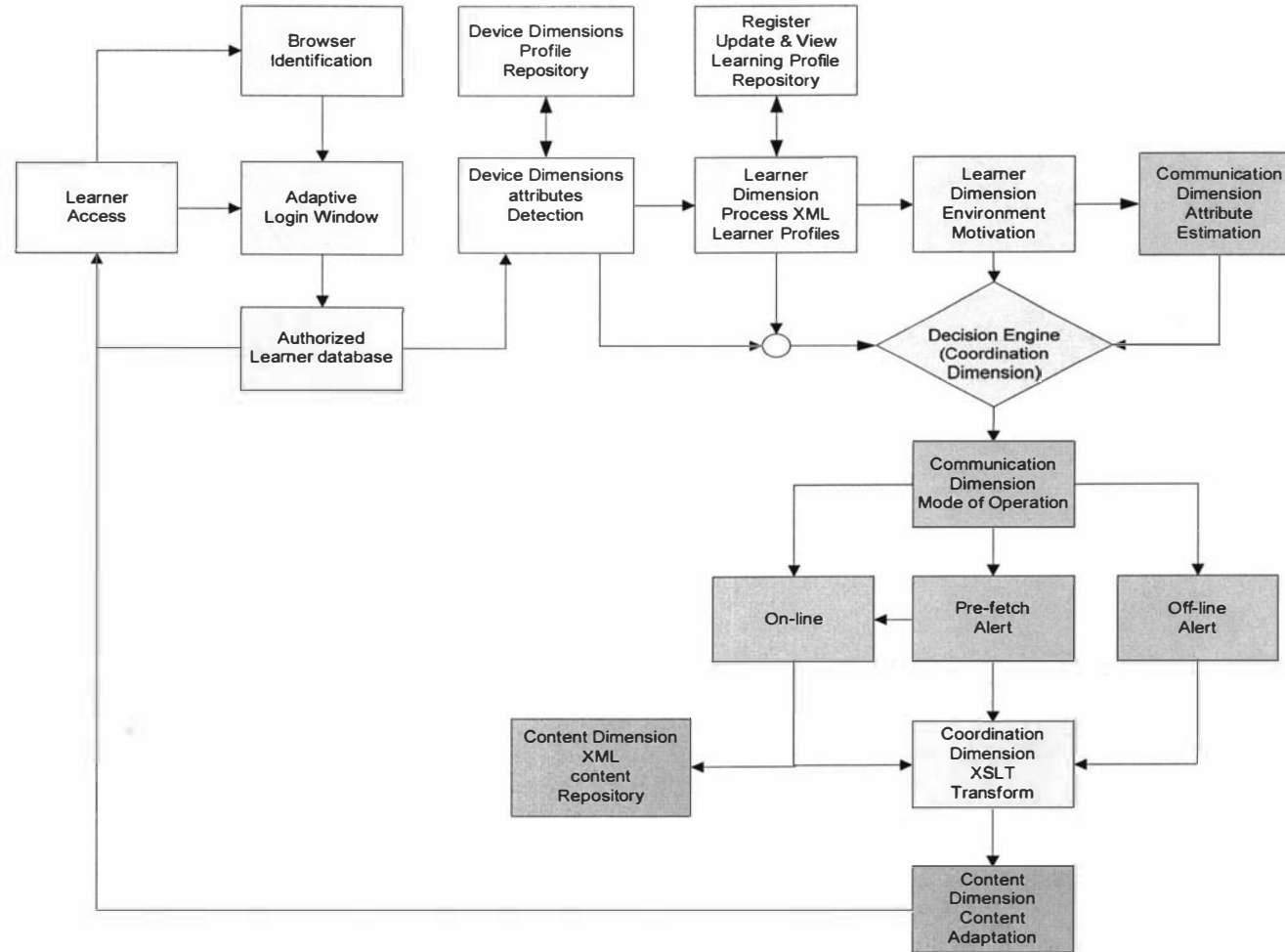


Figure 4.6 System architecture of the multiplatform e-learning system implementation

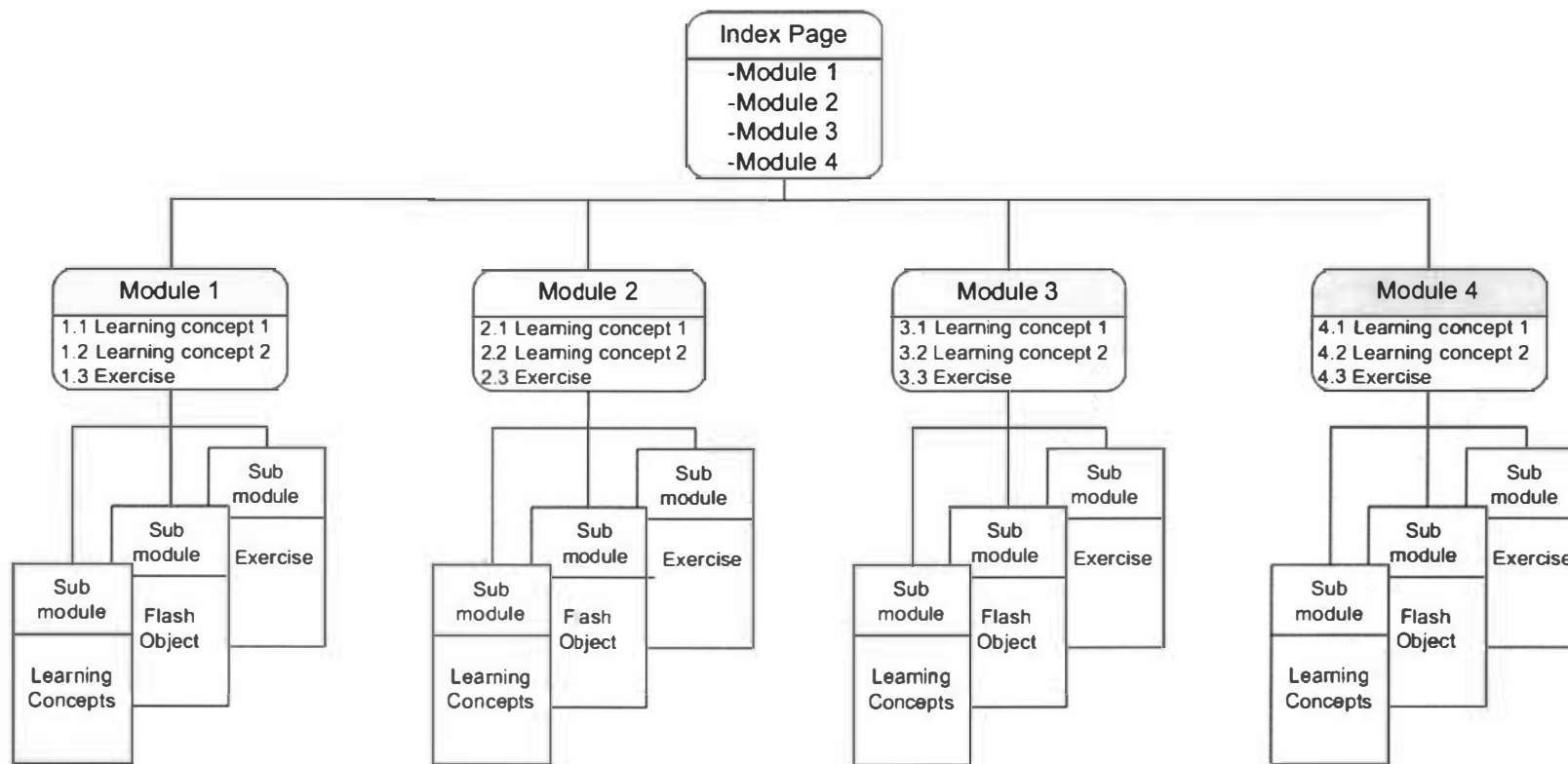


Figure 4.7 The multiplatform e-learning system learning content map

4.5.2 XML data source

The use of XML data sources is directly associated with the content dimension for storing learning content, the devices profile in the device dimension, and the learner profiles and environment factors in the learner model. While XML is used as a data source in order to provide a separation of the data from the presentation, it is not adequate. When the multiplatform e-learning system requires dynamic feedback from the learner through the presentation layers as well as the need to adapt content delivery from learner profiles and device capabilities, the logic layer intervenes with both the data source and the presentation layer. The separation of data and presentation alone is not sufficient to handle a dynamic scenario. Thus there is also a need to separate the logic from the presentation and from the data to make the system easier to modify and update. In this regard, the design approach adopted aims to utilise ASP for logic, XSLT for presentation, and XML for data with a proximity design approach that clusters objects of similar usage. The multiplatform e-learning system utilises the following technologies:

- i. MSXML parser, MSXML2, MSXML3 and MSXML4
- ii. IIS5, IIS5.1 (window XP Pro)
- iii. Active server page
- iv. XSL extensible style sheet transformation engine
- v. Openwave mobile browser SDK6.2, IE6, IE5.5, Netscape 4.7, IE-CE browser, and Opera browser
- vi. IPAQ5450 Pocket PC2002, Pocket PC 2003 SDK emulator, and Openwave emulator
- vii. Bluetooth (DBT-120) for wireless access from PDA, Active Sync 3.5, and Active sync 3.7

4.5.3 MSXML parser

The MSXML parser is associated with the coordination dimension. It is mainly applied to the content, device, and learner dimensions. The MSXML parser was deployed to generate the tree structure from the XML data source to allow navigation, extraction, updating and insertion operations to be performed on the XML data files. Several issues were encountered during the implementation process. Specifically, the object methods in various versions of the MSXML parser were not consistent.

Typically it affected the Globally Unique Identifier (GUID) and Programmatic Identifier (ProgIDs) used in the lower version of the MSXML parser.

By default, IE (5 and 6) uses MSXML2 or MSXML3 as a parser to allow client side parsing of XML documents. With respect to coding, using the client side style sheet is much simpler but it lacks an effective way to produce and track dynamic interactions. Therefore the implementation adopted the server side processing using XSLT which requires ASP scripting to instantiate the object model and to load and parse the XML documents. In addition, the use of the process output method is necessary to generate the transformed output and response to the http browser agent for viewing.

4.5.4 Flash Player 6 and Pocket PC 2002/2003 SDK

Flash Player is associated with the device dimension. In order to view a Flash movie, Flash Player 6 for Pocket PC 2002 must be loaded into the PDA. The player is an add-on so the Flash movie must be embedded in a web page. Performing this task correctly will involve the style sheet transformation and device capabilities detection within the coordination dimension. A Flash movie (swf file) cannot be played directly from the PDA unless the stand-alone player and Flash projector are available. The current implementation also supports Flash Player 6 with Pocket PC 2003. During the implementation process, the Pocket 2003 SDK emulator was used as a PDA device without media player support and the adaptive algorithm control in the coordination dimension was able to identify the situation correctly and made the necessary recommendations to the learner.

4.5.5 Wireless access

Wireless access is associated with the communication dimension. For IPAQ 5450 the built-in Bluetooth can communicate with computers that are Bluetooth enabled and have access to the Internet. In order to support network access, the Bluetooth in the desktop or laptop computer must be able to support network access. For current implementation, a D-link DBT-120 Bluetooth adaptor was used for creating a short range wireless access to either a stand alone laptop that ran a web server (XP Pro with IIS5.1) or an office PC connected to a Local Area Network that had Internet access. With the stand-alone laptop, all the content and software were loaded and the PDA was able to access the complete e-learning system module. This setup was in

preparation for the learning satisfaction evaluation. With Bluetooth, the tested communication range was about 20-30 metres depending on building obstruction. Also, the distance between the two devices affected the overall throughput. Thus the setup was useful in varying the speed of the communication channel and validated the adaptive algorithm in the coordination dimension.

4.5.6 XML documents

As stated, the use of XML documents was associated with the content dimension, learner dimension and device dimension. A sample XML document associated with the content dimension for the exercise module and used in the multiplatform e-learning system is shown in Listing A.4 of Appendix A. In the XML document, each question is identified by its “ID” and the difficulty level of the question is indicated by the tag “Level”. New questions with different levels of difficulty can be added to the document. The “Level” tag is used to match the level tag in the XML document that contains the profile of the learner. Currently the learner profile XML contains elements such as level, score, date of last attempt, and user name, to simulate the learner profile. Additional tags can be easily extended. The key objective is to achieve the ability to extract these properties from an external XML learner profile file from a style sheet and perform the matching or adaptation within the style sheet to deliver the appropriate content to the learner. These transactions validated the functionality and interaction between the learner dimension and the coordination dimension. The object method used for the style sheet was the *document()* object method in the style sheet. Another reason this method was adopted is that the XML data source document that contains the questions, answers and hints of the content dimension had already been successfully parsed using the active server page method of the coordination dimension and some variables were successfully passed to the style sheet using the parameter method in the coordination dimension. The *document()* object method further validates the interaction between style sheet in the coordination dimension and XML document in the learner dimension.

4.5.7 Active server page

The active server page (ASP) is associated with the coordination dimension. The active server page currently consists of three main sections. Listing A.5 in Appendix A shows the code of the main ASP. The *Getdevice()* function identifies users’ device

profiles (supported browser types and capabilities) in the device dimension. The device browser type is returned to the main ASP page and passed as a parameter to the style sheet. All these transactions are done within the coordination dimension. Subsequently, the style sheet uses this information for adapting presentation. To validate the adaptive process, the background colour was adapted for different device browsers. This operation validated the capability of passing device parameters to the style sheet via ASP and also provided a simple validation of a device's capabilities adaptation. Other device parameters such as screen size and colour support can also be passed to the style sheet to perform adaptation and selection. For text-based content, most browsers would be able to adapt and fit it on the screen. While there are many device capabilities that can be adapted, consideration should be given to overall improvements of the learning system that enhance learning satisfaction.

The main goal of the ASP page is to create a DOM object on the XML data source for traversing using the XSL style sheet. This is done using the *createobject()* method for the XML data source and the XSL style sheet. Once the DOM object is created it is loaded using the *xml.load* function. Another objective of the ASP page is to track variables and parameters. The parameter "curq" tracks the current question. This parameter is passed to the style sheet to consume and send back via the form action in the style sheet. In order to pass a parameter, an *xslProc* needs to be created using *xslt.createProcessor()* and the parameter is added using *xslProc.addParameter*. The device parameter is also added in a similar way. The "Feedback" parameter, which tracks the state of the question, is also added in the same way. Once the learner has answered, the learner response is captured in the parameter "ans". To verify the answer with the XML data source, the *xml.getElementsByTagName("CorrectAns")* is used to compare the answers. A learner can only proceed to the next question if the current question is answered correctly. However a "score" parameter can be added together with a time stamp and written to the learning profile that would allow future adaptation to be performed by quantifying learner performance in the order of "Advanced", "Normal", or "Beginner".

4.5.8 Style sheet

The style sheet is associated with the coordination dimension. The style sheet is used to transform the XML data source into appropriate content for a device browser in the device dimension. Currently the style sheet is designed to detect PC, PDA

(iPAQ), and mobile phones with Openwave™ browser and Opera browser. Listing A.6 in Appendix A shows the main style sheet. No difficulty for supporting other browser types is anticipated. Any WAP2.0 compatible browser can be supported. To parse an external XML document in the style sheet other than through the ASP DOM object, the *Document()* method can be used. This method is used to validate the capability and ability of parsing an XML document such as those that the learning profile file contains in the learner dimension, the device profile file contains in the device dimension, or the learner preference file contains in the learner dimension within a single style sheet. It should be reiterated that all these files are in XML format. To validate this, a learner profile file that contains the expertise level of the learner is constructed. This parameter is used to select the question level. As mentioned, the expertise level can be a learner’s choice or a calculated choice through the learner record. If it is a calculated choice, the multiplatform e-learning system is able to update this information if required, once the user has completed a learning module. The ASP module can do this effectively. Several other XSL commands play a pivotal role in the style sheet transformation. Table 4.1 explains some of these important commands.

Table 4.1 Important XSL commands

<code><xsl:param name="curq"/></code>	Allows the style sheet to capture parameters from the ASP code.
<code><xsl:variable name="profile" select="document('learner profile.xml')"/></code>	Allows tag content be extracted from the “learner profile.xml” file within the style sheet.
<code><xsl:attribute Name="bgColor">#FFFFFF</xsl:attribute></code>	Allows the manipulation of presentation attributes in the style sheet.
<code><xsl:if test="\$FeedBack= 0"></code>	Allows condition statements to be tested.

4.5.9 End-to-end response time measurement

Before any adaptation process can take place there is a need to identify the capabilities of the resources and subsequently provide the necessary adaptation to the learner. One such capability is the end-to-end response time. This is part of the competency requirements in the multiplatform e-learning system framework. The end-to-end response time is highly dependent on the available bandwidth. It also depends on server latency and device CPU processing power, memory size and

browser implementation. For a web based system, the end-to-end response time will also depend on the number of multiple target windows being launched and the simultaneous bandwidth consuming applications being activated such as the voice channel as in 3G mobile devices.

There are several methods to estimate the end-to-end response time to provide the necessary input for system adaptation. Because of the different browser and device capabilities, all these methods were integrated to provide a multi-pass process for the estimation of end-to-end response time in the multiplatform e-learning system.

i. Client side estimation method

Client side end-to-end response time estimation utilised client side script with JavaScript to provide a timestamp when a pre-defined known size data page is loaded in the background to the client side browser. When the download is completed the end time is captured. The end-to-end response time is computed using the time difference between the start time and end time when the page is completely downloaded. The timing information is automatically submitted to the multiplatform e-learning server from the browser. Knowing the data size, the bandwidth can be computed, if required. This method does not take server latency into account and is accurate if the bandwidth is low. This method is deployed in the current implementation for devices with client side script support.

ii. Server side estimation method

Not all browsers support JavaScript. For example, Openwave mobile browser 6.0 does not support any scripting languages at all. Thus the client side scripting method will fail when it will encounter such a browser. Also some browsers support only a subset of JavaScript even though JavaScript is enabled and detected. The detection of JavaScript does not guarantee that the estimation will take place without problems. The server side estimation method uses server page script such as ASP to keep a time stamp once a request is initiated. The ASP will send out a dummy page to the requesting browser, which is transparent to the user. Once the page is fully loaded it will be re-directed to the ASP page to capture the end time. The re-direction must work for browsers without script support. This method assumes that there is no script support in the browser. This method is also deployed in the current implementation

for devices with no script support. Because of several re-directions from client to server, users may perceive a longer delay which may affect their level of satisfaction.

4.5.10 Flash player detection

A device's capability detection is part of the competency requirements in the multiplatform e-learning system framework. To check if a device has had a Flash media player installed, an empty Flash file is sent to the client browser. Within the Flash file is a self submitting form. If the multiplatform e-learning server receives a pre-defined parameter from the Flash form then the device is validated to support the Flash player. The version of the Flash player can be submitted together with the Flash form. If the device does not have a Flash player installed then no parameter will be submitted from the Flash file and a JavaScript that immediately follows the embedded Flash page will submit a predefined parameter through a Java scripted self submitting form. If this pre-defined parameter is received it validates that the device has no Flash player installed. In the event that neither parameter was received within a specific time then it indicates that the device has no pre-installed player and also does not support JavaScript. If connection breaks, a new request is required.

4.5.11 Multimedia e-learning content

Deploying multimedia content in e-learning systems can improve memory performance and information retention for learners (Badii & Truman, 2001). Badii and Truman (2001) conducted an evaluation of the e-learning environment which showed that a music-oriented learning environment using text, voice, colours and animation can facilitate a gain in information retention rates from 36% to 49% under a single 30 minutes exposure scenario. For distributed scenarios where participants were exposed to two short 15 minutes exposures, the use of voice, text, colour and animation can achieve information retention rates from 67% to 80%. Research has also shown that the use of multimedia instruction content can enhance an individual's problem solving skills, and entice learners to focus their full attention on a task through the vividness of the presentation (Zhang and Nunamaker, 2003). Interactive multimedia has also been widely adopted in e-learning to enhance learners' interactivity. In some cases e-learning systems containing interactive multimedia can improve learning effectiveness. One such example is the "Learning By Asking" system (LBA) (Zhang and Zhou, 2003). Together these examples illustrate that

combining visual images, animations and dynamic representations can be an effective tool in supporting e-learning for demonstrating facts, concepts and rules. Evidently, using interactive multimedia is positively perceived. Providing a dynamic and interactive simulation not only gives learners the opportunity to experiment and explore various perspectives and representations, but it also allows learners to construct meaningful concepts to understand the relationships and influences of each element within a theory.

In the current multiplatform e-learning system multimedia content development, the design is adhered to two proven principles to maximise the potential of multimedia effectiveness (Tversky et al., 2002). First, according to the Congruence Principle, the content and format of the multimedia should correspond to the content and format of the concepts to be conveyed. Second, according to the Apprehension Principle, multimedia should be accurately perceived and appropriately conceived. Sometimes, if designers do not consider their choices carefully, animations become too complex or too fast to be accurately perceived (Tversky et al., 2002). This was the case in the pilot development and trial where the animation adhered to the congruence principle but failed in the apprehension principle, which was commented on by the participants. Besides these two principles, appropriate use of several studies validating effects related to multimedia design can be helpful (Mayer, 2001, 2003). First, according to the multimedia effect, students learn better from words and pictures than from words alone. Second, the coherence effect states that learning improves when extraneous material (such as sound) is excluded rather than included. Third, according to the spatial contiguity effect, it is more effective to place printed words near rather than far from corresponding pictures. And lastly, the personalisation effect states that students learn better from text written in conversational rather than formal style.

Given these principles and guidelines, the multiplatform e-learning system includes both text and animation modules with the intention to improve learner satisfaction and foster learning. In the adaptation process, for example, when a Flash player is not supported, the Flash is transformed into interactive gif files with text and pictures next to each other. The self running animated gif were not adopted in the end as recommended by the apprehension principles. An example of the e-learning module is shown in Figure 4.8. Figure 4.8 (a) shows the text version with a PDA and Figure 4.8 (b) shows an animated version.

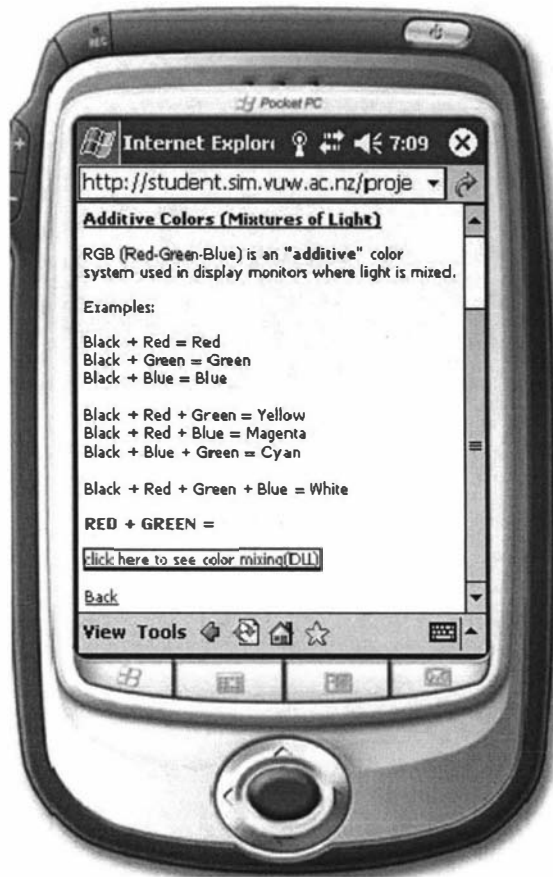


Figure 4.8(a) Text Content



Figure 4.8(b) Animation Content-with permission from OSIM.

4.5.12 Summary

The successful implementation of the multiplatform e-learning system has demonstrated several capabilities as dictated by the competency principles (Chapter 3, pg 75-78) within the adaptive multiplatform e-learning framework. First, the ability to identify device browser type and capability of extracting and transferring such information to the style sheet for adaptation processing was achieved. This aspect operationalised competency principles three and five. Second, the ability to parse XML profile documents with server page technology and the ability to update and insert parameters into these documents was achieved. This aspect operationalised competency principles two and five. Third, the ability to transfer parameters between an active server page and a style sheet for adaptive processing was achieved. And the ability to extract an external XML profile file within a style sheet and provide such information for adaptive processing was also achieved. These aspects again operationalised competency principles one and five. And lastly, the ability to estimate

the bandwidth and extract the information for the adaptive content delivery process such as offline and pre-fetch operationalised competency principles four and five. In short, all the competency principles were adhered to and operationalised successfully.

During the implementation process, further understanding was gained regarding the adaptive multiplatform e-learning systems. This has implications for future research, system developments and enhancements and is summarised below:

- (a) There are far too many device parameters to adapt in the device dimension. There is a need to identify a few “best” parameters for adaptation. The choice of such capability parameters should be based on the ability to enhance learner satisfaction. This will lead to a more systematic approach in device adaptation for content delivery.
- (b) Bandwidth is a critical factor in the adaptation process. Identical device capabilities might not necessarily lead to the same adaptation. When different devices have the same multimedia capabilities but operate in different communication channels, the adaptations will be different. The communication dimension precedes the device dimension.
- (c) Long delays, slow responses and instability would contribute to unsatisfactory learning experience, affecting in turn the learning profile model. Thus the ability to pre-fetch content for the learner as an adaptation capability is crucial in developing a “seamless” experience. The challenging task here was to pre-fetch dynamic content.
- (d) In the situations where a learner prefers to engage with off-line content, the adaptive e-learning system strives to provide similar experience to the learner by adapting entire or partial content to the learner. However the tasks required by a learner to receive the content might not be as straightforward as in a real time scenario. These additional steps might affect the perceived usefulness and perceived ease of use of the system and therefore influence the learning satisfaction and adoption decision.
- (e) The objective of the adaptation process in the multiplatform e-learning system is to improve learner satisfaction. From a mathematical perspective, this can be viewed as a constraint-optimisation model. The adaptation process is a multi parameter function. The function output is the learner satisfaction. The inputs to the multidimensional function are the parameters within the content, learner, device, communication, and coordination dimensions. To simplify the adaptation

process, a stereotyping template matching approach was adopted using a decision tree algorithm. It is envisaged that near optimal results would only be achieved after several iterations of design modifications.

4.6 A comparative walkthrough

Upon successful implementation of the multiplatform e-learning system, there is a need to evaluate the system in comparison with traditional e-learning systems, such as Blackboard, with which most students are familiar. Following sub-sections provide a comparative walkthrough between a traditional e-learning system (system A) and the multiplatform e-learning system (system B) with three accessing devices, mainly PC, IPAQ PDA and Nokia 6600 mobile phone. Several screen shots are shown in sequential order. The e-learning system comprises four learning modules. Modules 1 to 3 are used in the experiment evaluation while module 4 is used for training the participants only. Figure 4.9 to Figure 4.28 depict the screen shots from the traditional e-learning system A (Blackboard) whereas Figure 4.29 to Figure 4.47 depict the screen shots from the multiplatform e-learning system B. Figure 4.48 to Figure 4.50 depict the screen shots from the Openwave emulator.

4.6.1 Traditional e-learning system A - PC

a. Learner navigates to PHYSICS 101 folder

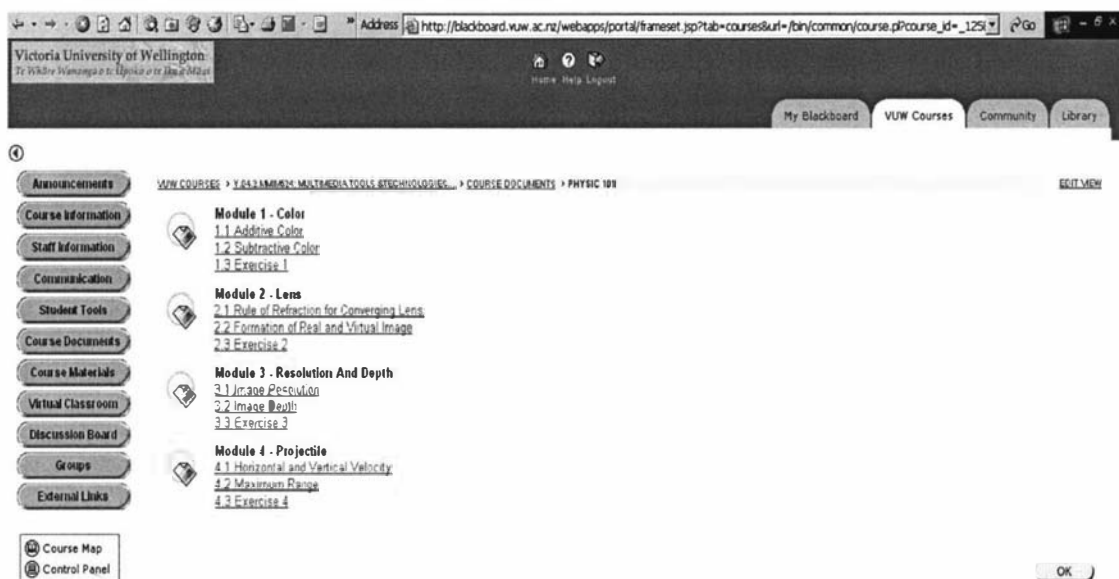


Figure 4.9 Blackboard PHYSICS 101 e-learning system A

b. Learner accesses module 2 – lens

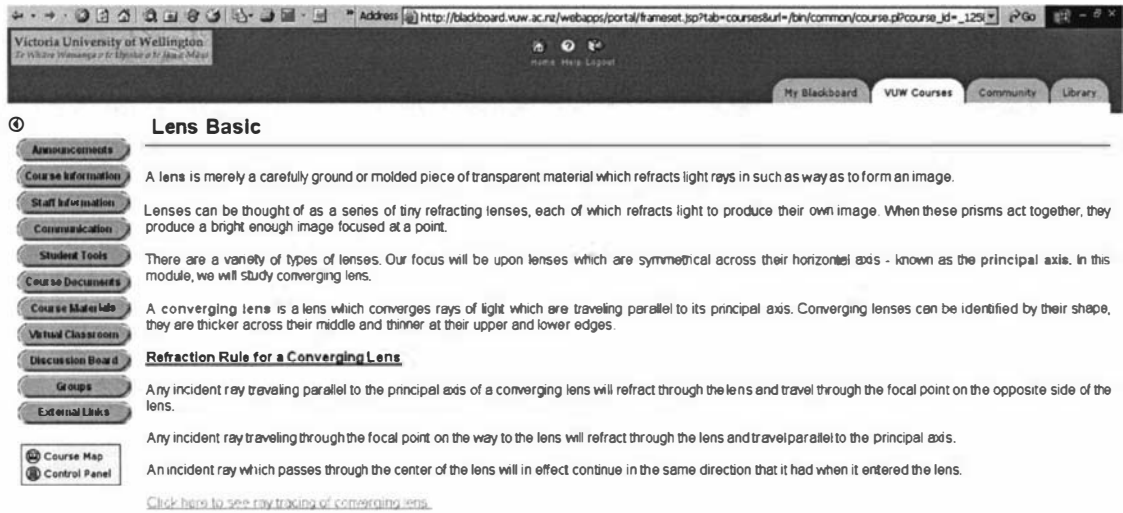


Figure 4.10 PHYSICS 101 module 2 content

c. Learner accesses interactive multimedia

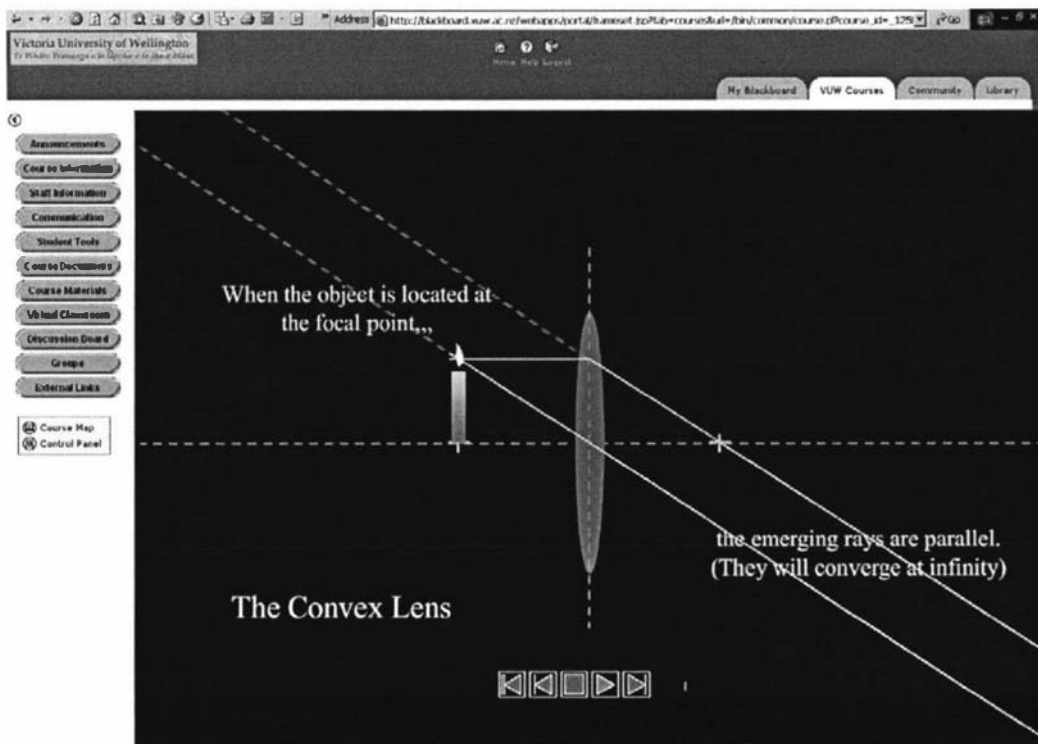


Figure 4.11 Interactive multimedia for module 2 with permission (Ion, 2005)

d. Learner accesses exercise

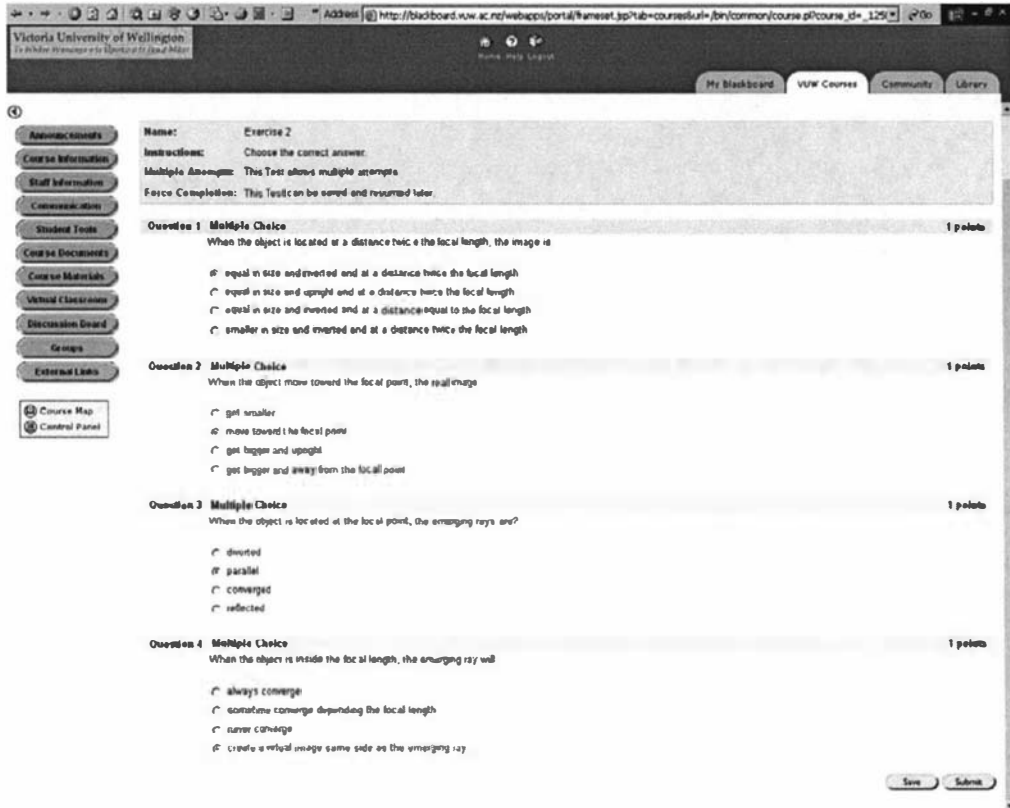


Figure 4.12 Assessment exercise for module 2

e. Learner accesses marked exercise

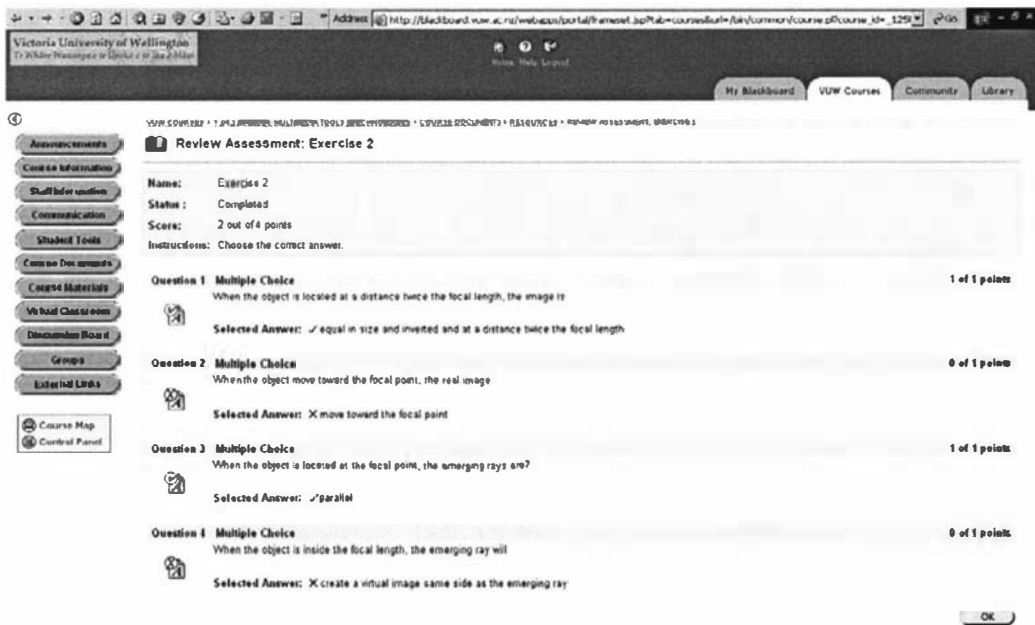


Figure 4.13 Blackboard feedback for exercise module 2

4.6.2 Traditional e-learning system A - PDA

- a. Learner accesses Blackboard home page and login



Figure 4.14 PDA Blackboard access sequence

b. Learner navigates to PHYSICS101 folder



Figure 4.15 PDA access to e-learning site A

c. Learner accesses module 1 – Colour

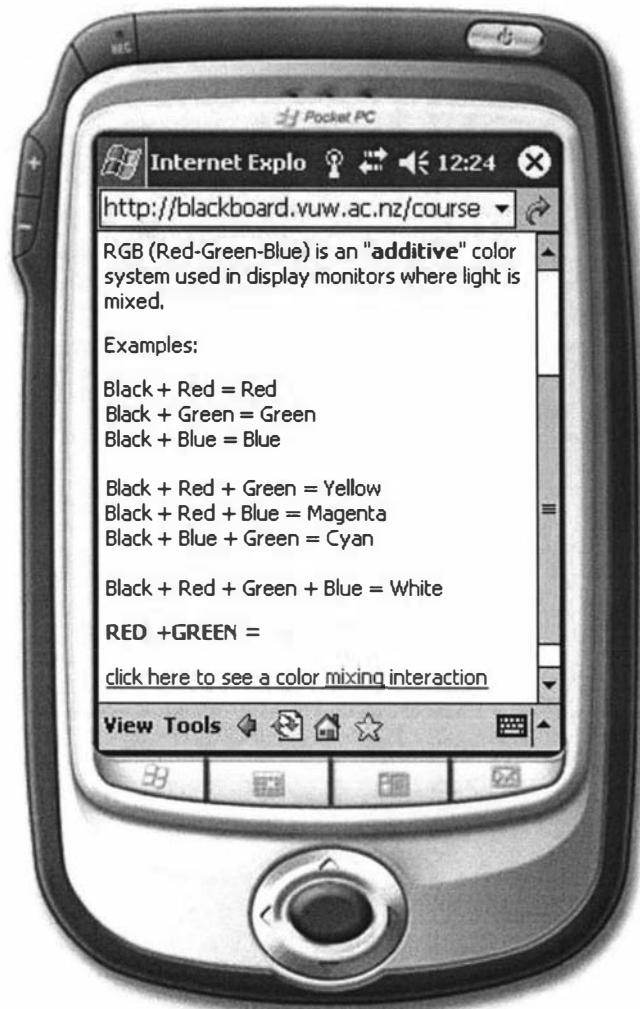


Figure 4.16 PDA access to module 1 content

d. Learner accesses exercise



Figure 4.17 Assessment exercise and feedback

4.6.3 Traditional e-learning system A - Mobile Phone

- a. Learner accesses Blackboard home page

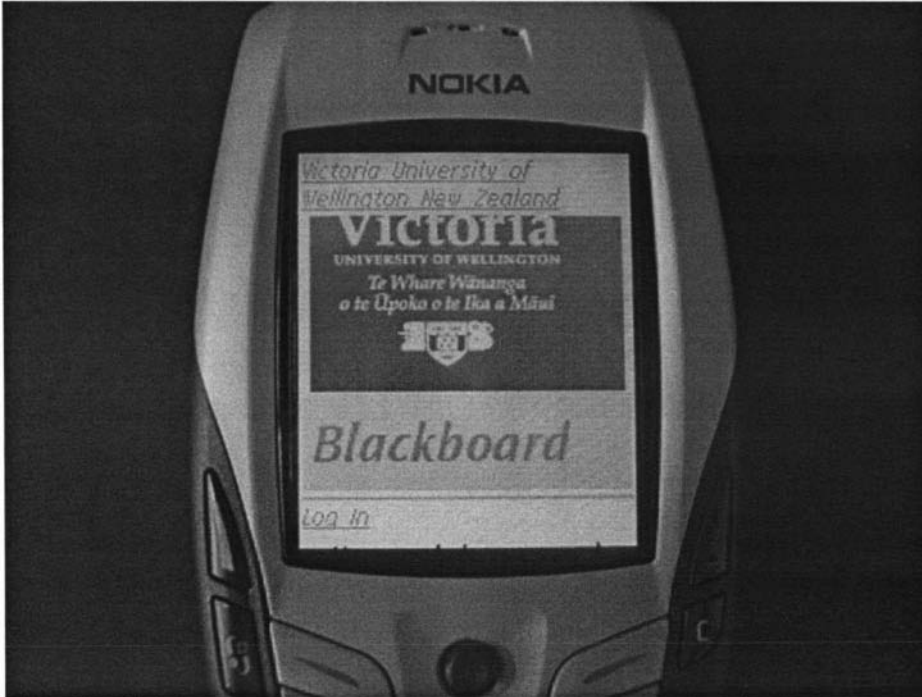


Figure 4.18 Nokia 6600 accessing e-learning system A

- b. Learner accesses Blackboard and login

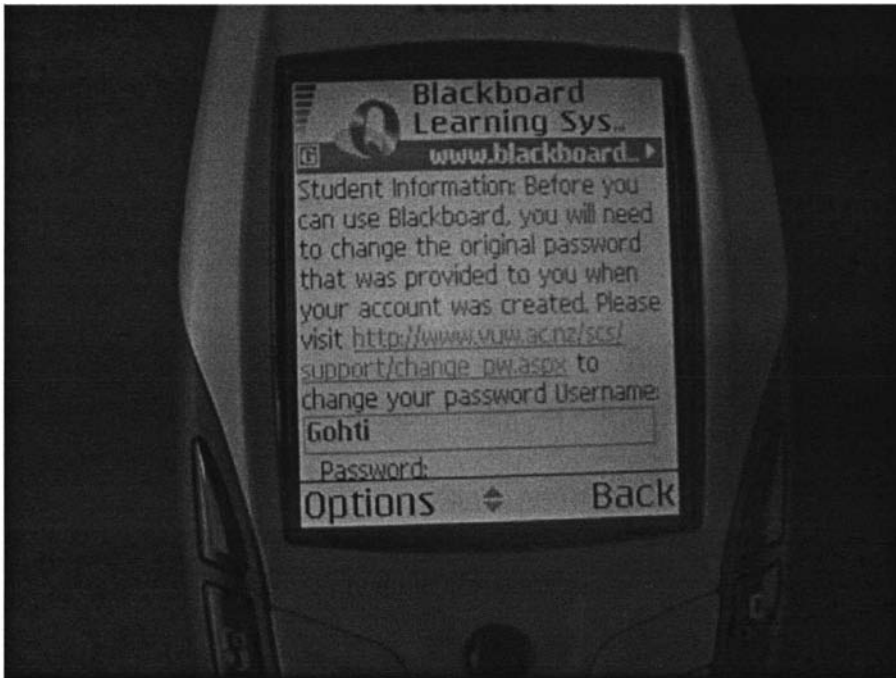


Figure 4.19 Nokia 6600 log in

c. Learner continues to access Blackboard

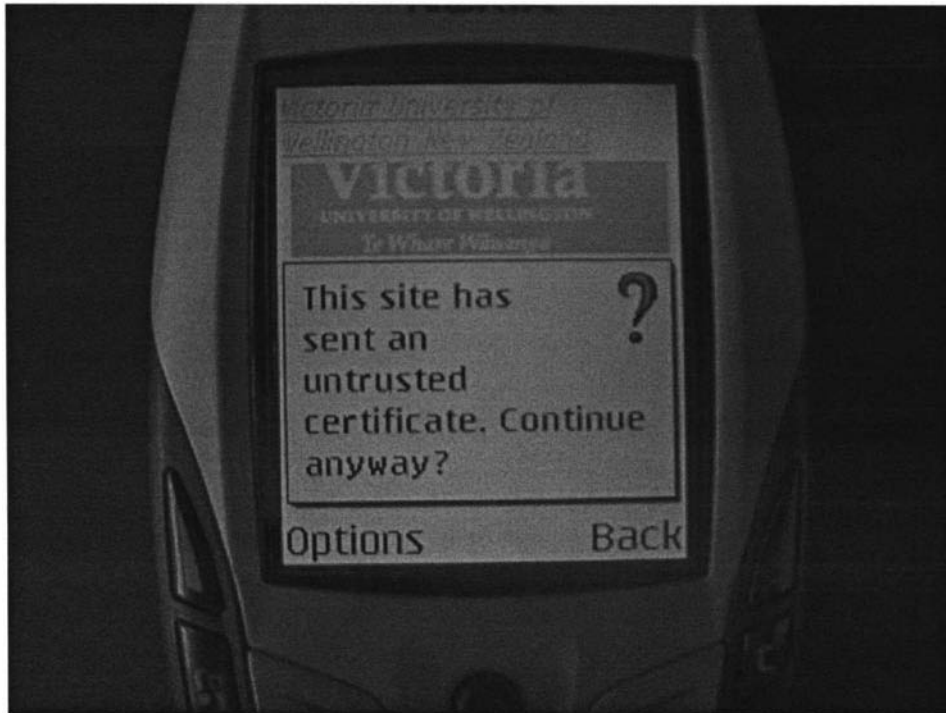


Figure 4.20 Nokia 6600 login continues

d. Learner navigates to course site

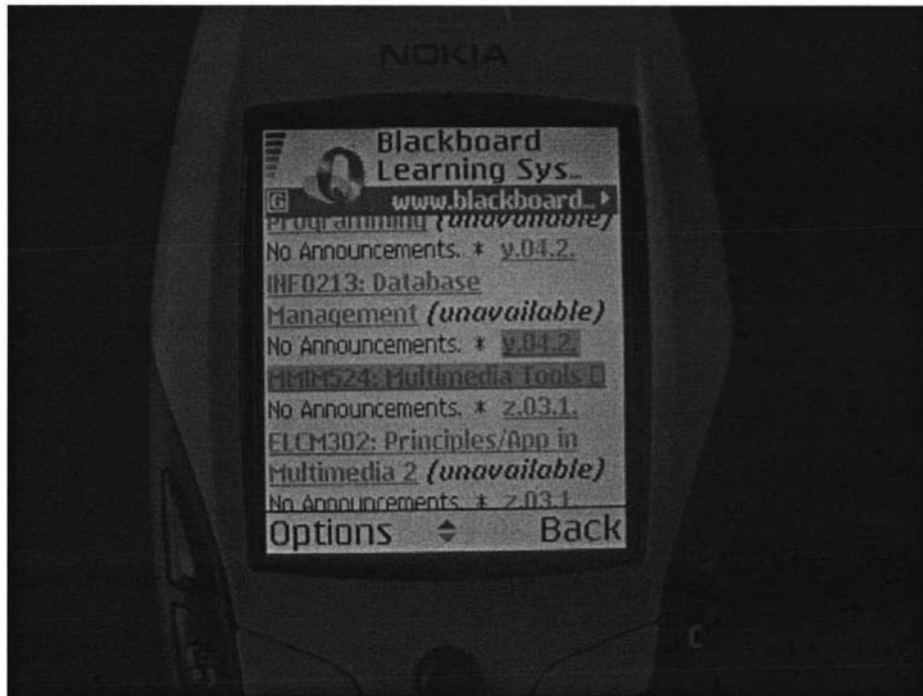


Figure 4.21 Navigate to PHYSICS 101 folder

- e. Learner navigates to PHYSICS 101 folder

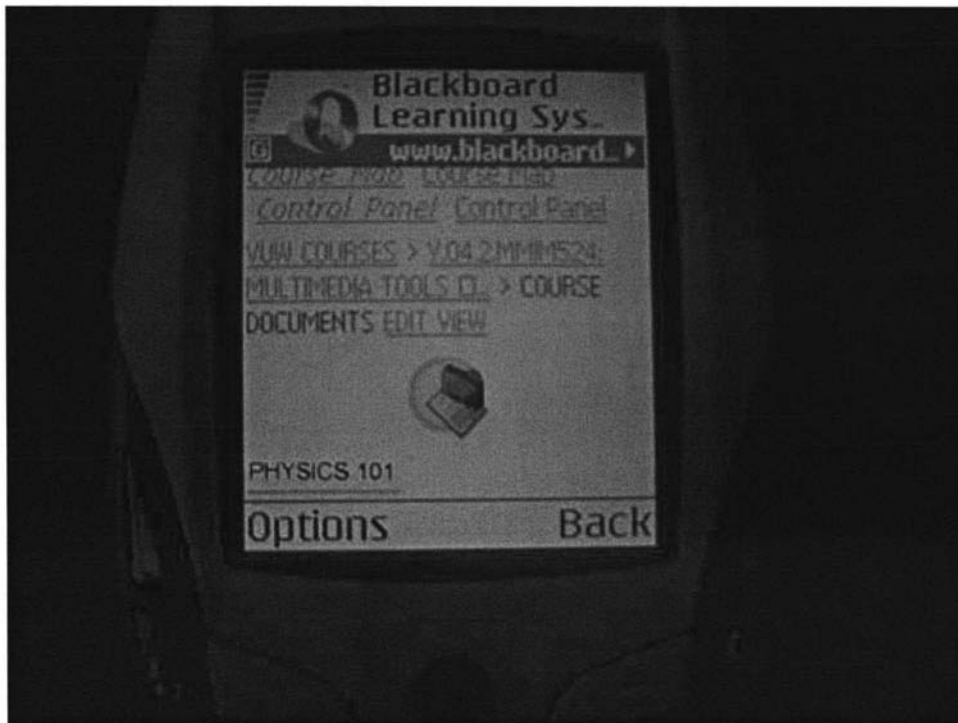


Figure 4.22 Access to PHYSICS 101 folder

- f. Learner navigates to module 3

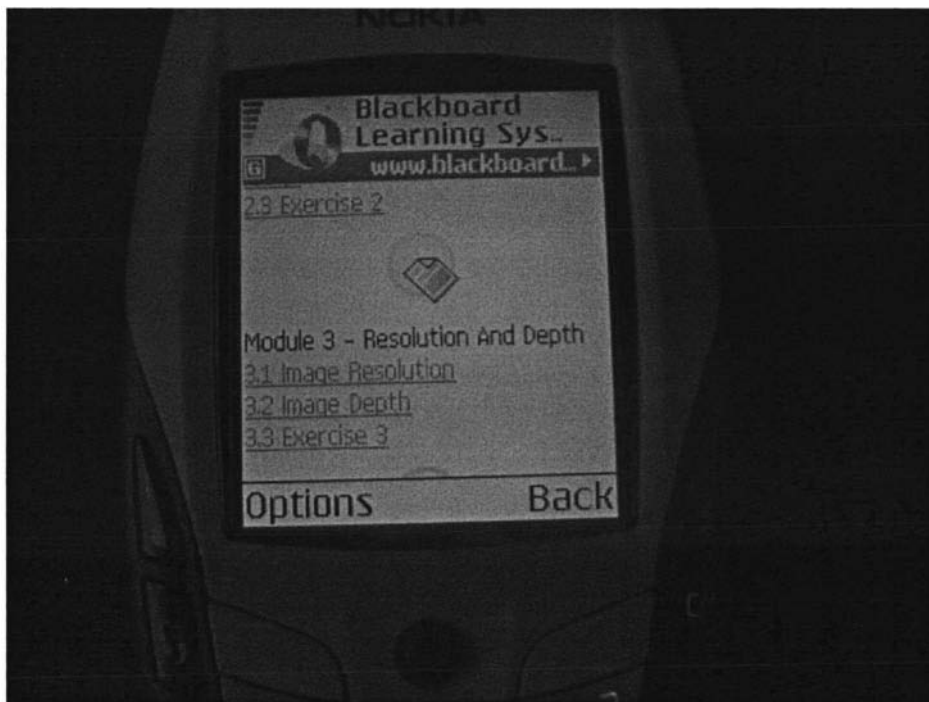


Figure 4.23 Access to module 3

- g. Learner navigates to module 3 - colour depth

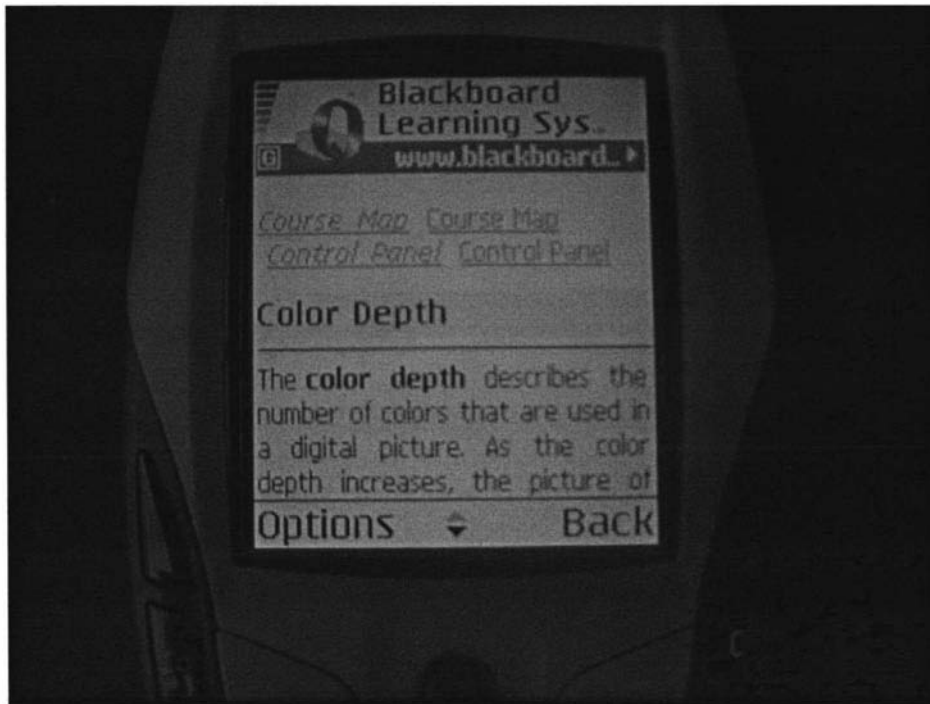


Figure 4.24 Access to module 3 content

- h. Learner accesses exercise 3

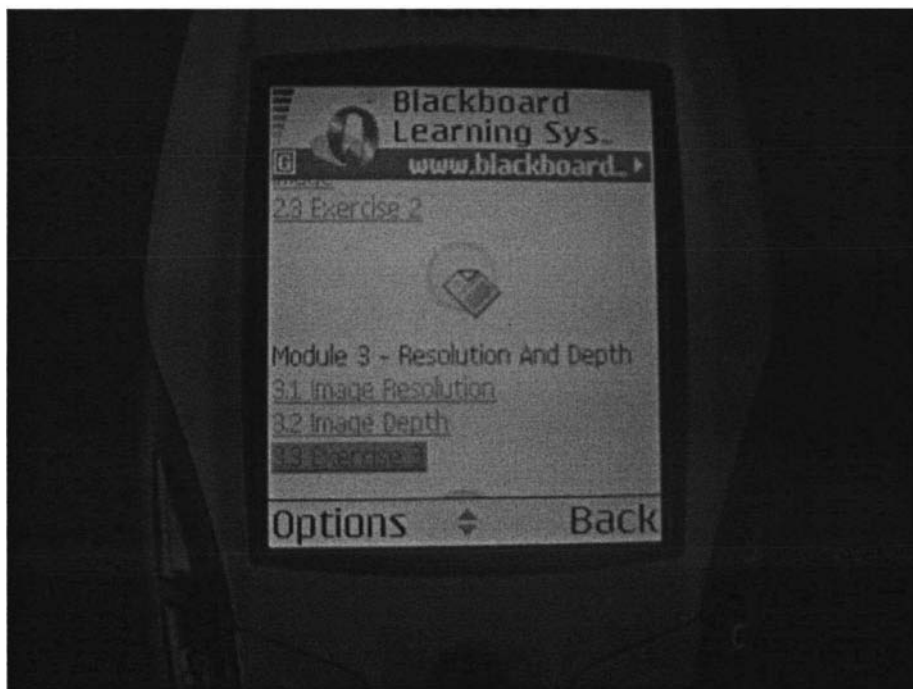


Figure 4.25 Access to module 3 exercise

i. Learner login to exercise

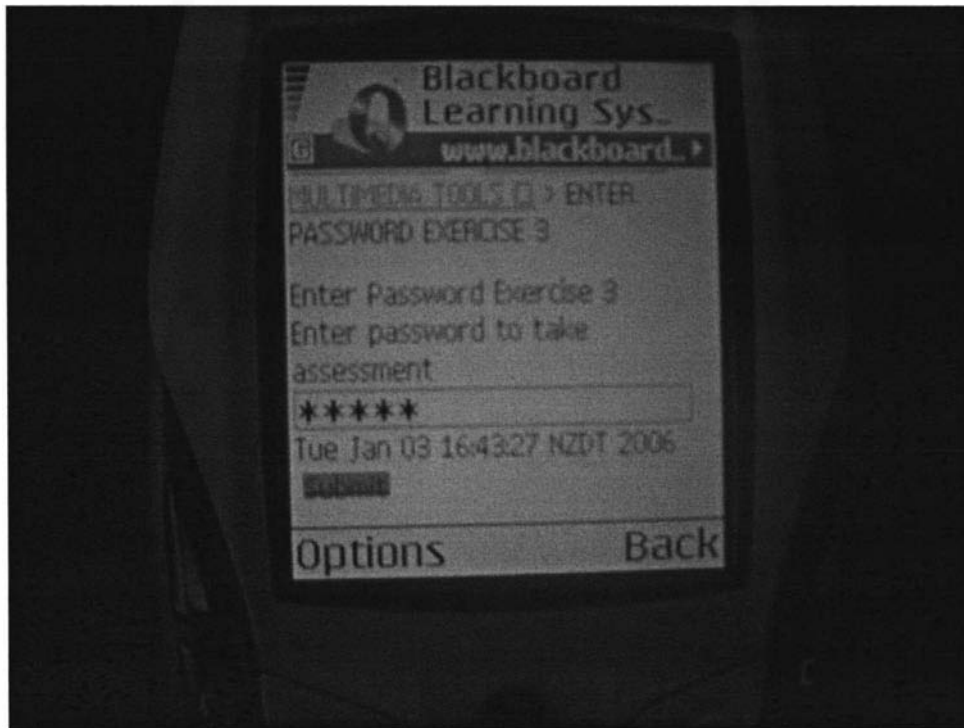


Figure 4.26 Log on to access exercise

j. Learner accesses exercise

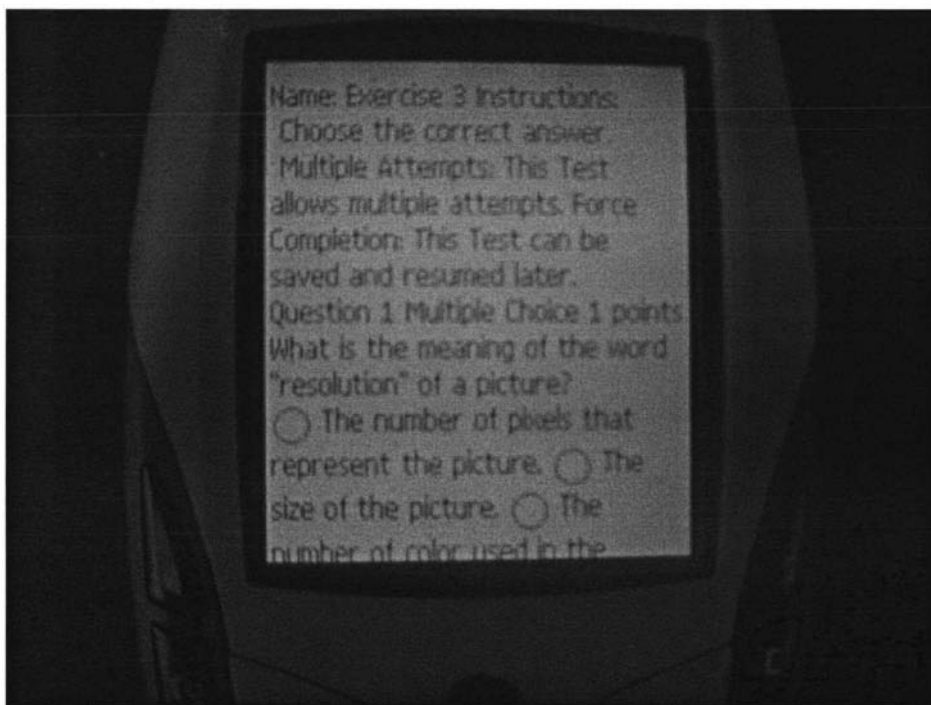


Figure 4.27 Format problems with e-learning system A

k. Learner navigates to end of exercise

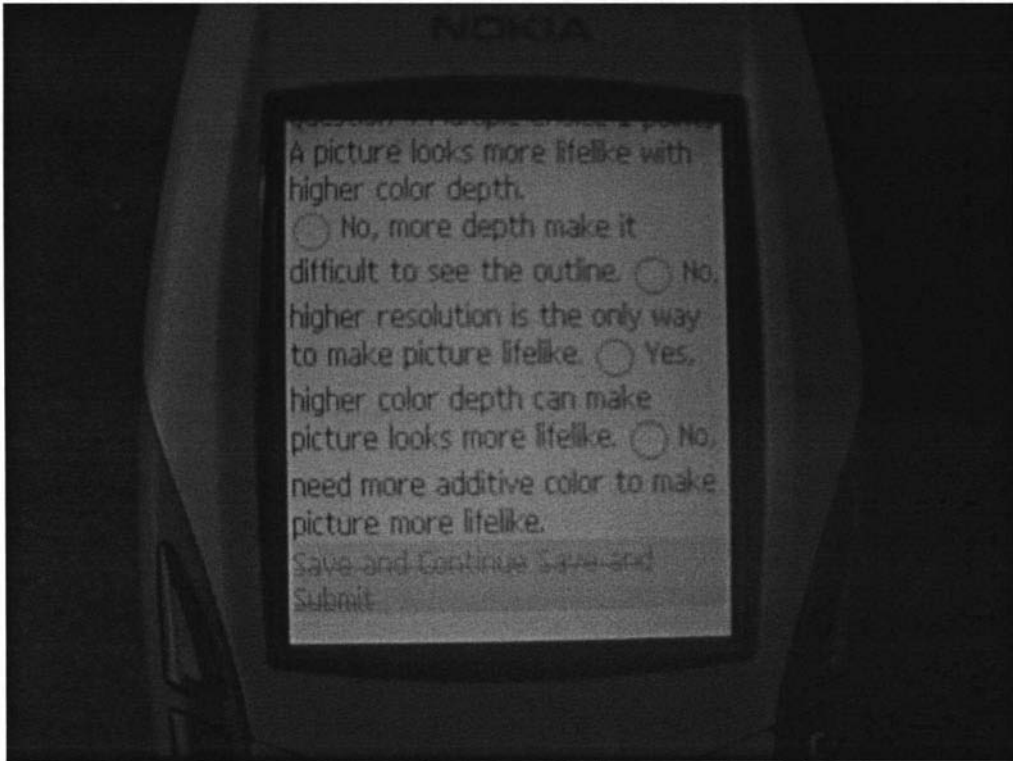


Figure 4.28 Anchor link problems with e-learning system A

4.6.4 Multiplatform e-learning system B - PC

a. Learner accesses PHYSICS 101 home page

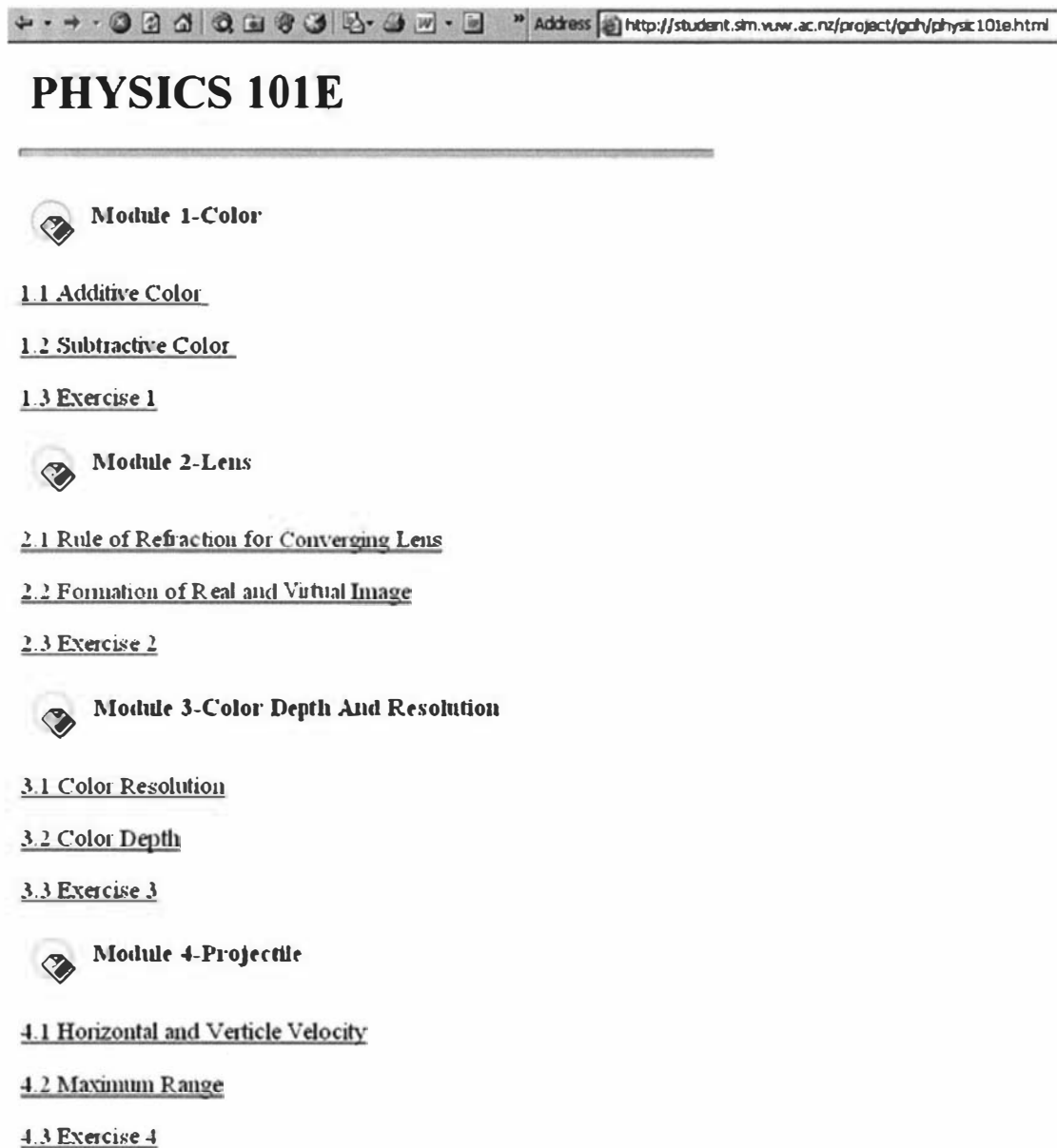


Figure 4.29 PHYSICS 101 in multiplatform e-learning system B

b. Learner accesses module 2 – lens

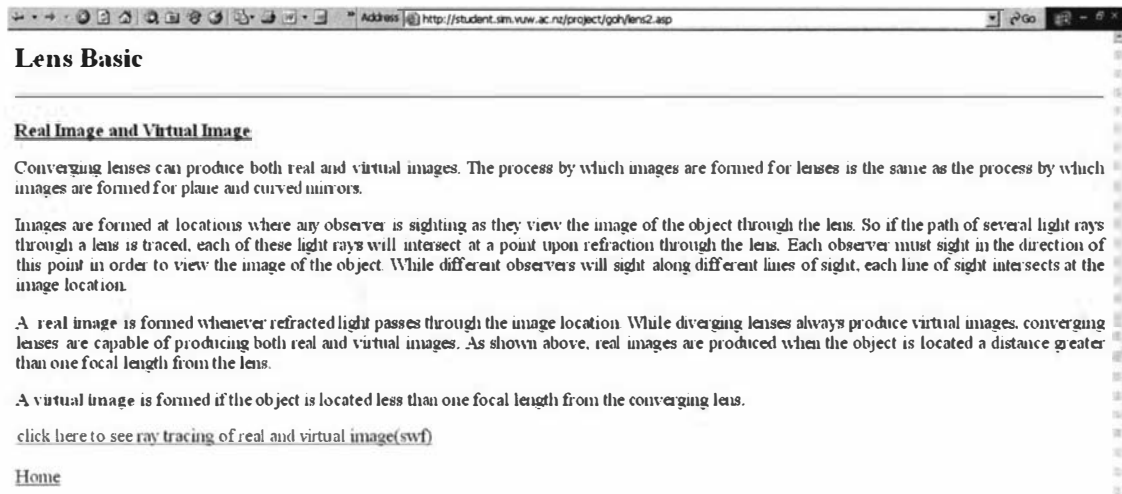


Figure 4.30 Content in module 2

c. Learner accesses interactive multimedia

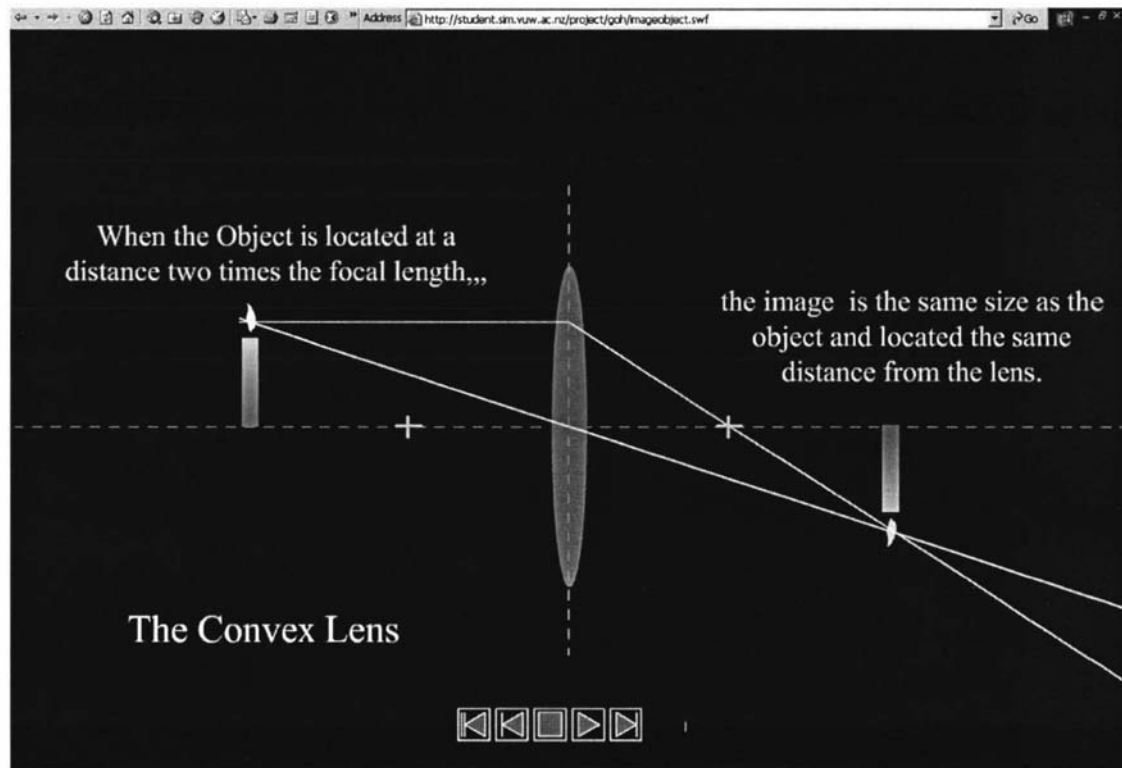


Figure 4.31 Same multimedia interactions for module 2

d. Learner accesses exercise – login

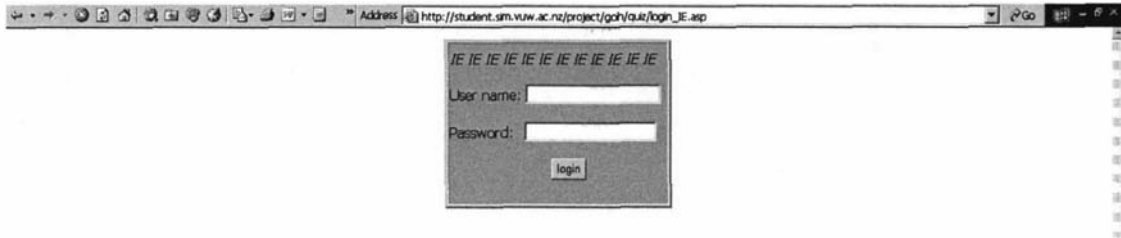


Figure 4.32 Access to assessment exercise login

e. Learner accesses exercise

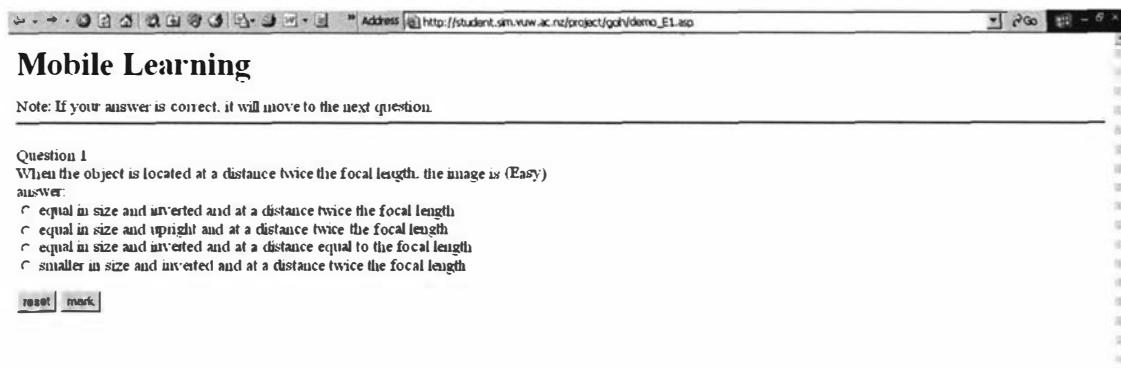


Figure 4.33 Assessment exercise in module 2

f. Learner completes exercise

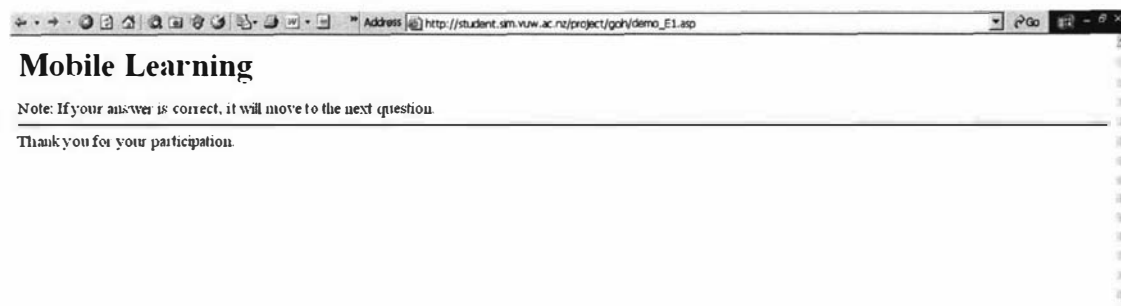


Figure 4.34 Assessment exercise completion

4.6.5 Multiplatform e-learning system B - PDA

a. Learner accesses PHYSICS 101 home page and login

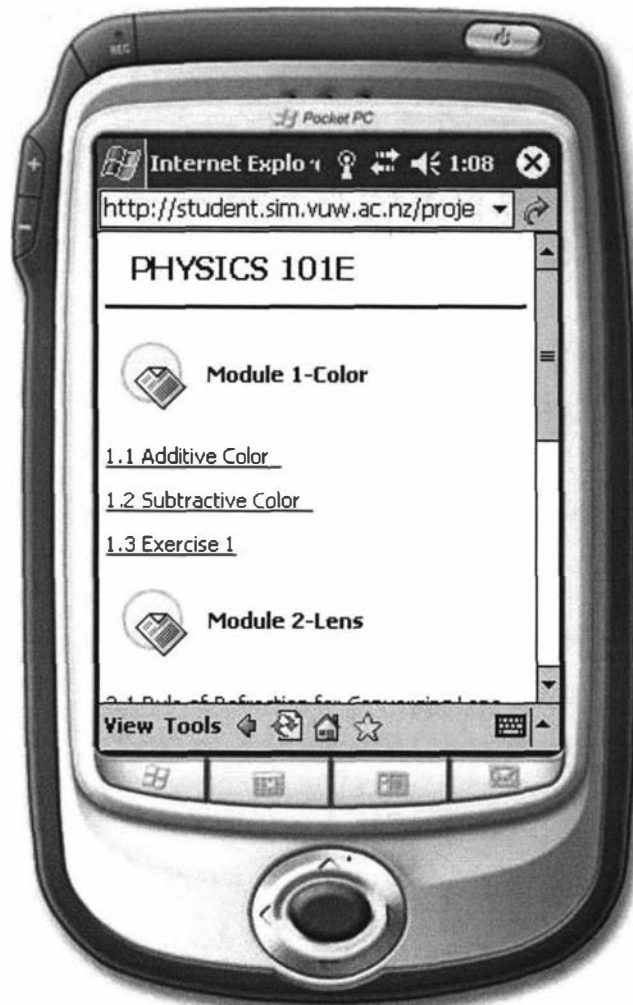


Figure 4.35 PDA access to PHYSICS 101 e-learning system B

b. Learner accesses module 1 – Colour

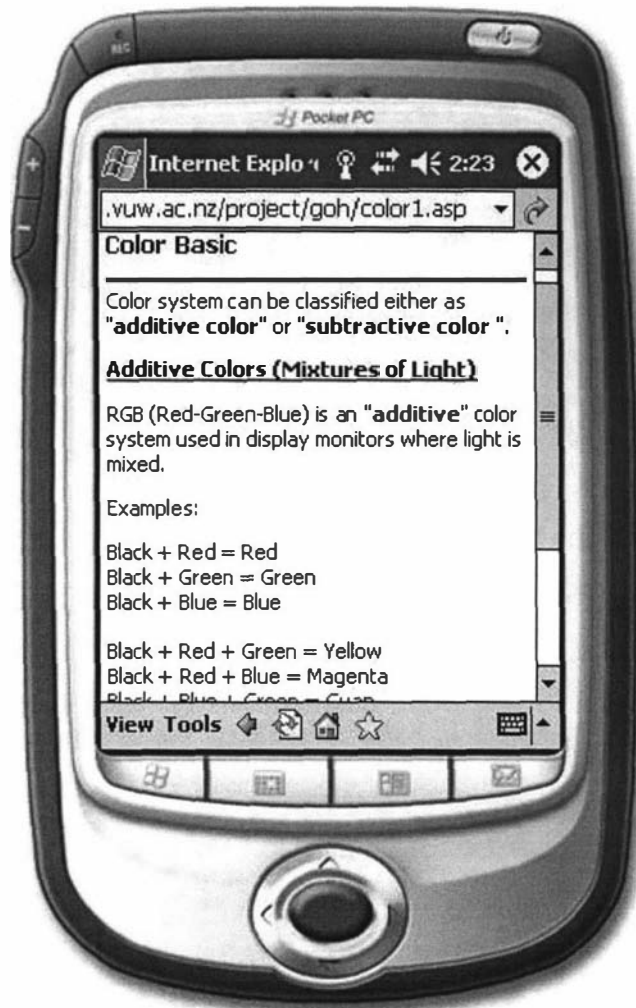


Figure 4.36 Content of module 1

c. Learner accesses interactive multimedia



Figure 4.37 Interactive multimedia for module 1

d. Learner accesses exercise

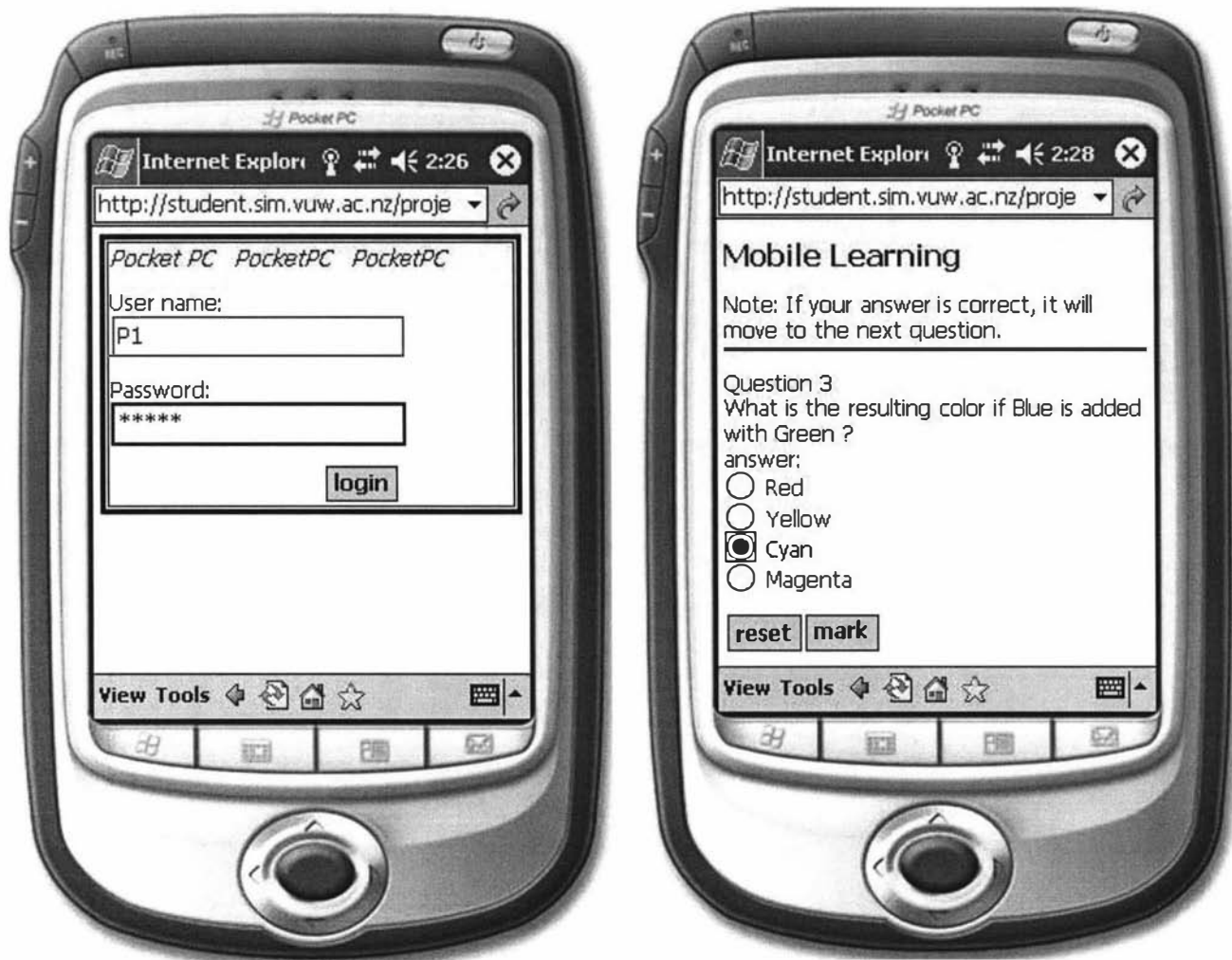


Figure 4.38 Accessing exercise login and adapted exercise content

4.6.6 Multiplatform e-learning system B - Mobile Phone

a. Learner accesses PHYSICS 101 home page

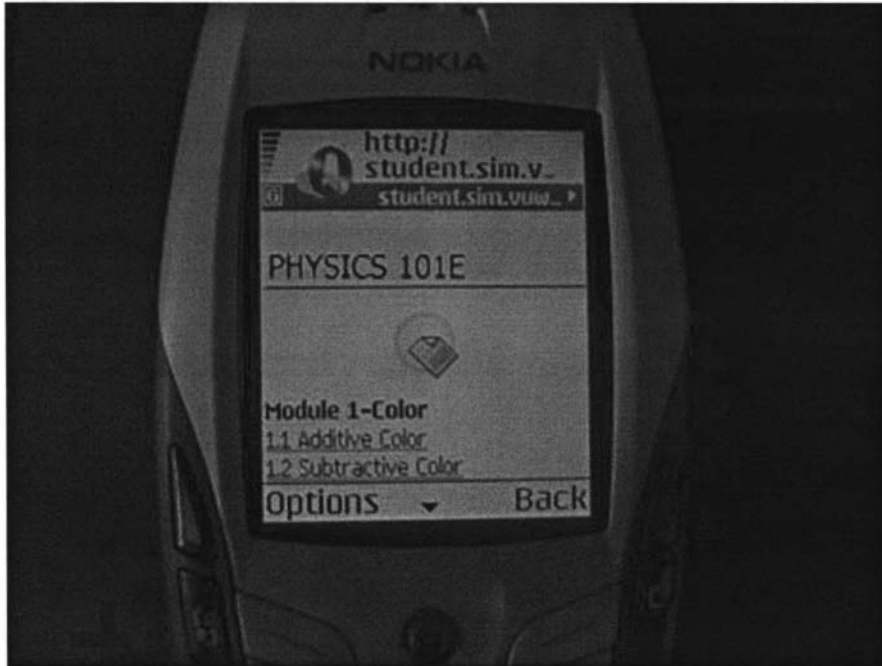


Figure 4.39 Nokia 6600 accessing multiplatform e-learning system B

b. Learner navigates to module 3

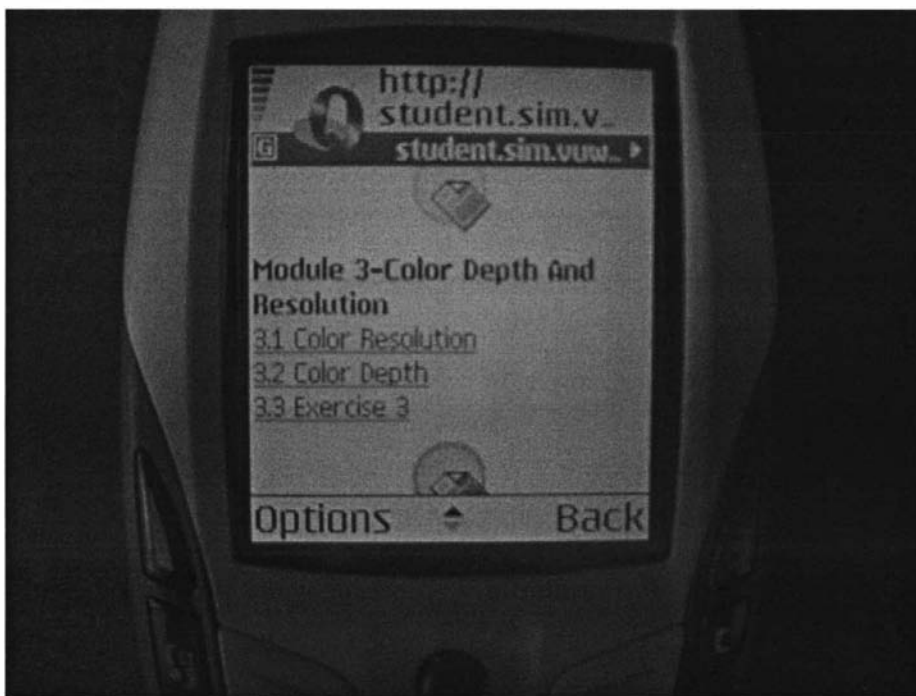


Figure 4.40 Easily navigate to module 3

- c. Learner accesses module 3 – resolution

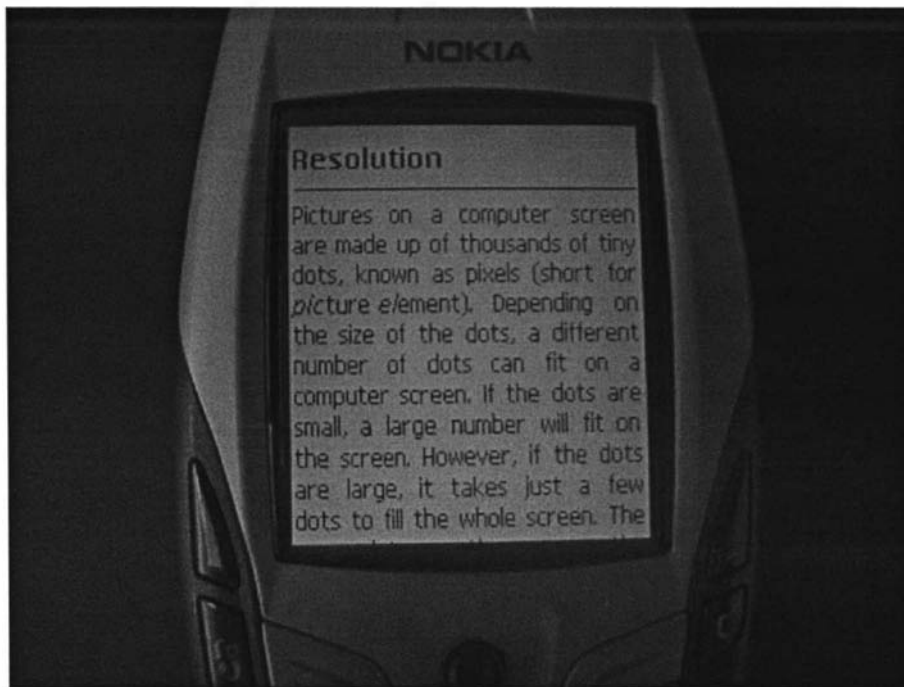


Figure 4.41 Accessing module 3 content

- d. Learner accesses interactive multimedia

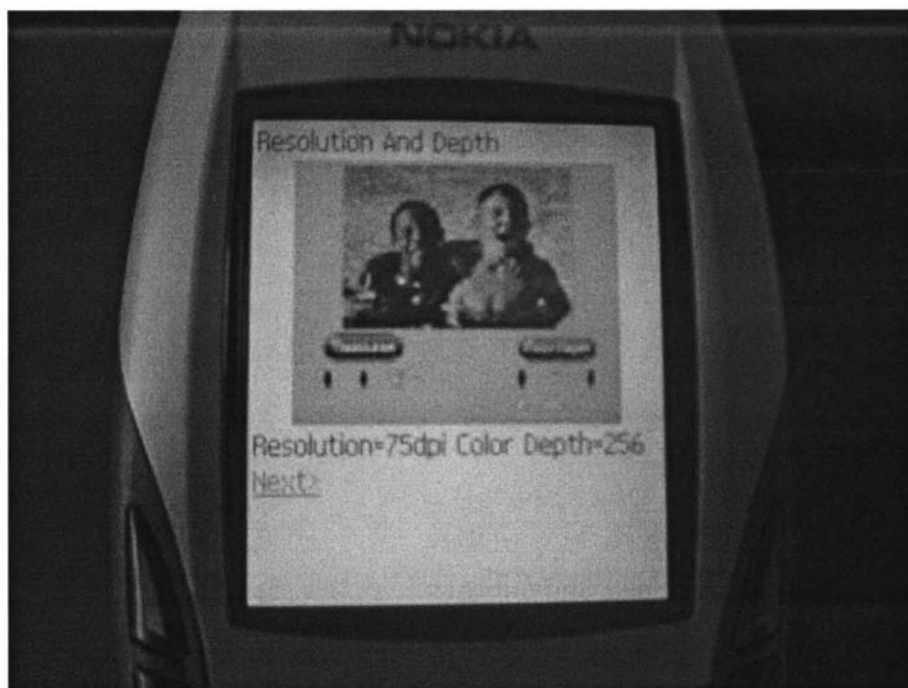


Figure 4.42 Adapted multimedia interactions for mobile phone (permission from OSIM)

- e. Learner continues to access interactive multimedia

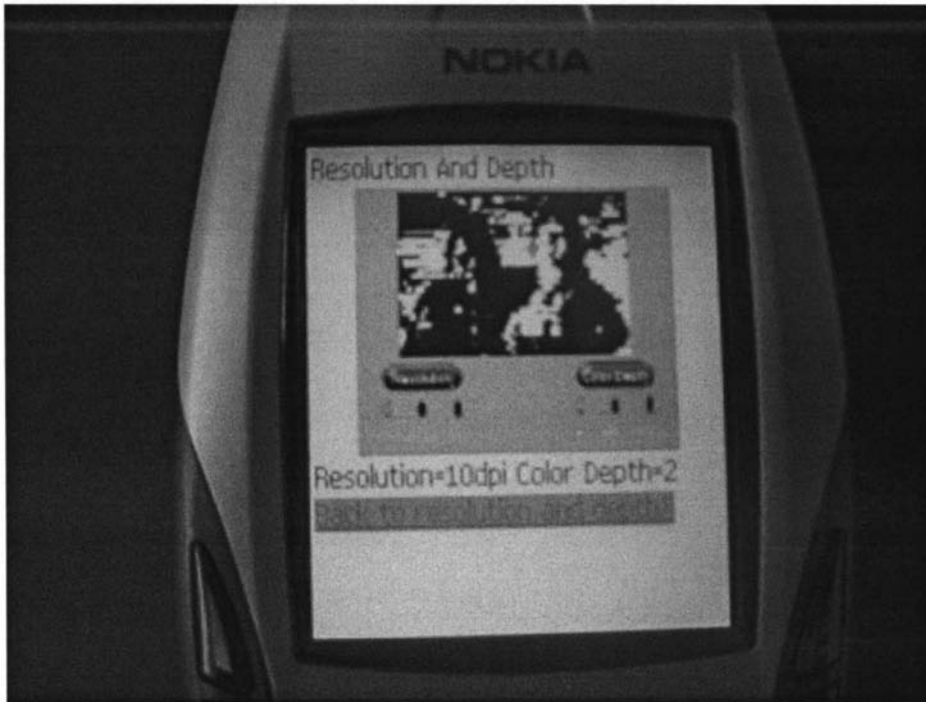


Figure 4.43 Next in sequence of multimedia interactions

- f. Learner login to exercise 3

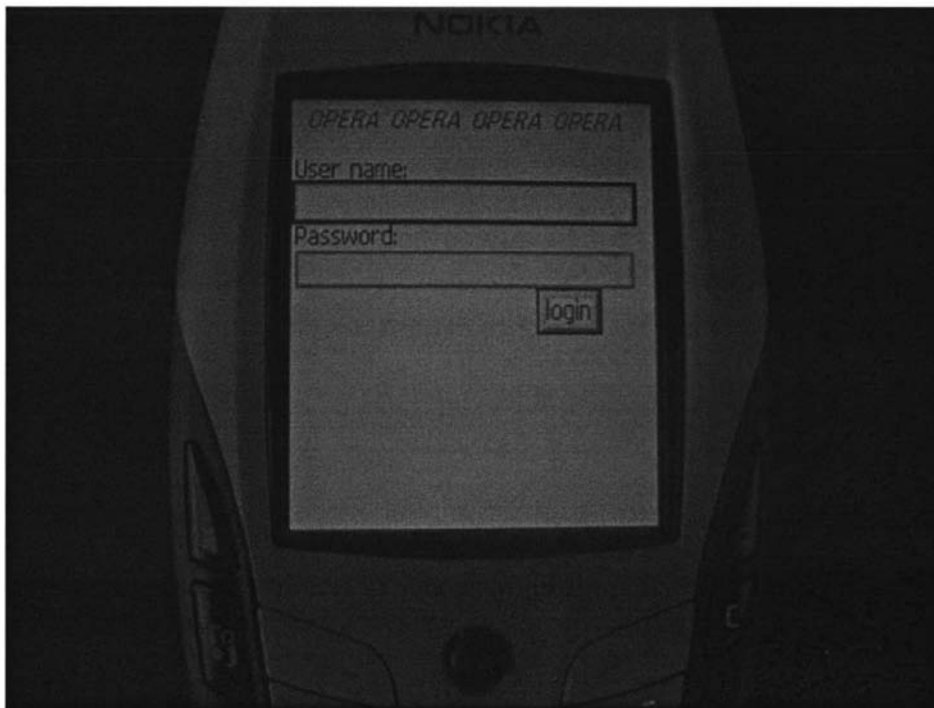


Figure 4.44 Login access to assessment exercise

g. Learner accesses exercise

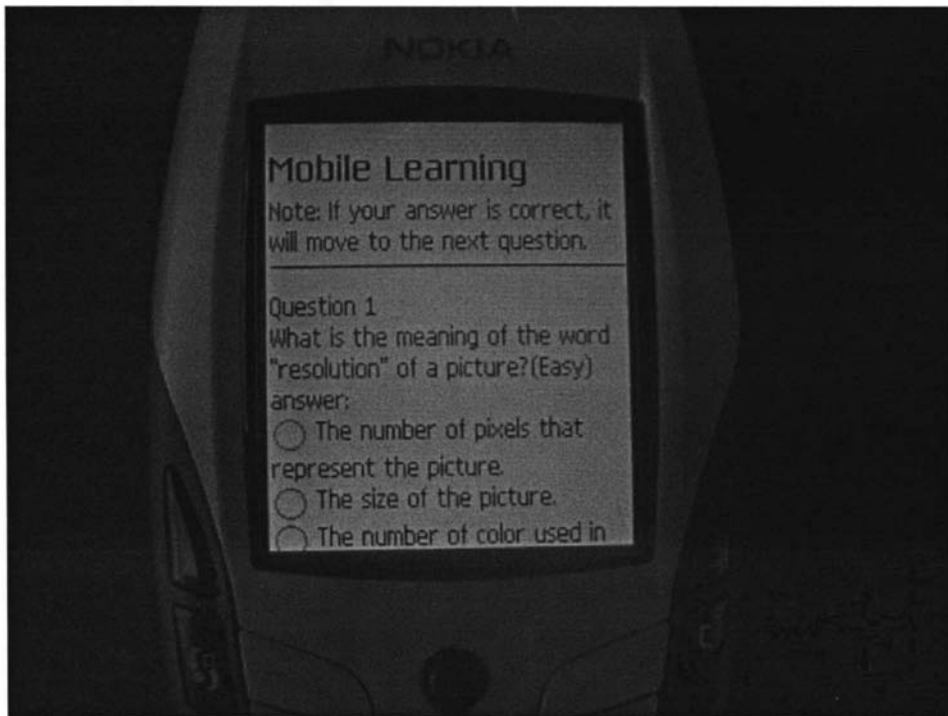


Figure 4.45 Adapted assessment content

h. Learner answered correctly and moved to next question

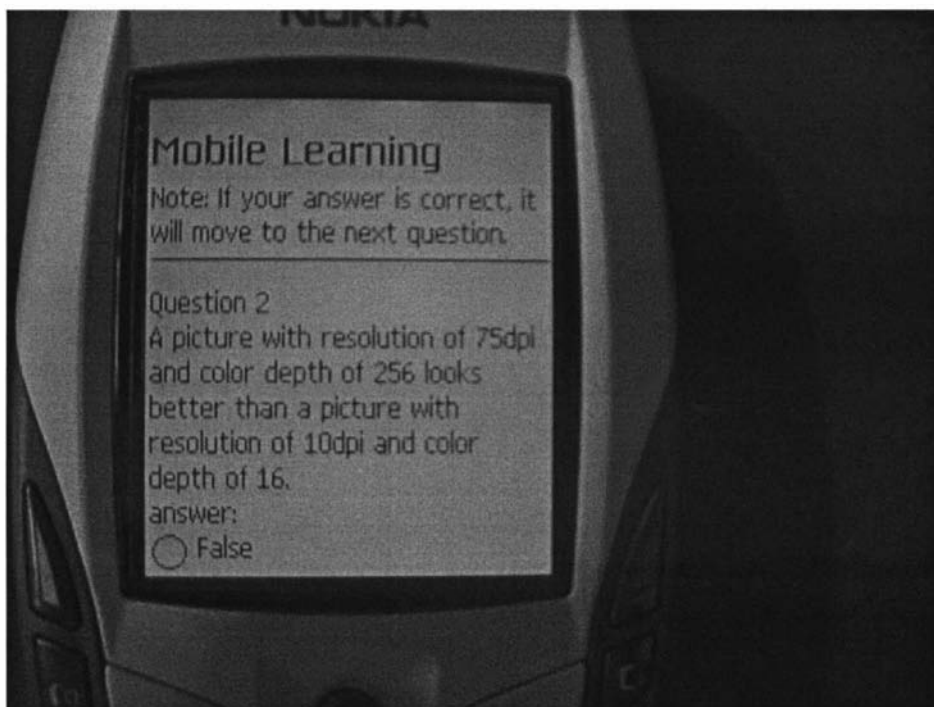


Figure 4.46 Next question in sequence

- i. Learner completed all questions

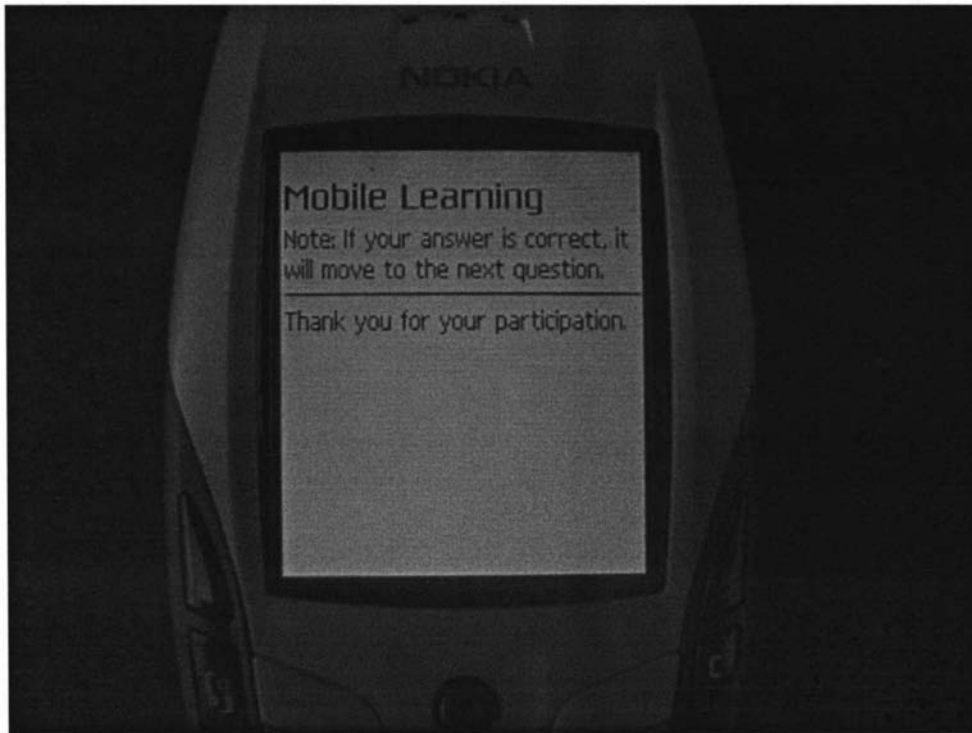


Figure 4.47 Feedback from completion of exercise

4.6.7 Openwave emulator

In the initial phase of the research, the Openwave SDK emulator was used as part of the system development. This content was also deployed in the pilot trial phase.

- a. Learner accesses module content



Figure 4.48 Openwave emulator accessing content

b. Learner accesses multimedia



Figure 4.49 Openwave emulator viewing animated gif

c. Learner accesses exercise



Figure 4.50 Openwave emulator accessing exercise

4.7 Summary of chapter 4

The technologies involved in the implementation of the multiplatform e-learning system have been highlighted in this chapter. A good understanding of all facets of the technologies involved is necessary to comprehend the required amount of work and knowledge needed for such an undertaking. Several factors contributed to the challenge. First, almost every technology involved is either very new or unstable and accompanied by poor documentation from vendors. For instance, Pocket PC JavaScript support is very limited. Second, style sheet transformation with MSXML and DOM is continuously evolving and there is no clear documentation on the supporting features. Third, mobile phone script support is also poorly documented. Vendors seldom provide detailed information on resolving bugs. Browsers are locked down with a specific type of browser in the mobile phone, making bypass extremely difficult. Surprisingly all these issues were resolved during the implementation stage. While the system is at a prototype stage, it is sufficient to undergo the usability evaluation to understand the basic factors that influence learner satisfaction while engaged in a multiplatform e-learning environment. Utilising the relevant technologies, the usefulness of the framework have been proven and validated and parts of the research goal have been answered. The next chapter covers the usability evaluation of the system and analyses the data through various statistical techniques such as correlation and structure equation modelling in order to explore the relationships among the factors that influence learner satisfaction.

Chapter 5A Methodology

5A.1 Evaluation methodology

Empirical evaluations were conducted to provide the necessary data for analysis. Two phases of evaluations were conducted. In phase one, a pilot evaluation was conducted and in phase two a full evaluation was performed. The evaluations were intended to provide a comparative study in which two e-learning systems were deployed. For e-learning system A, a traditional and familiar e-learning system, i.e. the Blackboard e-learning system was used. For e-learning system B, the multiplatform e-learning system that has been developed in this research was adopted. The multiplatform e-learning system was implemented according to the multiplatform e-learning systems framework described in chapter 4. A comparative study allows an investigation of the factors that influence learner satisfaction within the two e-learning systems. These factors can be very useful to the designer for quantifying the stability and acceptance of the multiplatform e-learning systems. The pilot evaluation was small in sample size as its main purpose was to provide insight into the multiplatform e-learning system and to fine tune the system for the subsequent full evaluation.

Based on the findings and various useful comments gathered in the pilot evaluation, the final evaluation was eventually conducted with some modifications. The objective of the final evaluation was to provide sufficient data to answer the research questions regarding the degree of each factor's influence and its relationship to other factors. By the final evaluation, the e-learning system B had been improved in relation to link navigation and included multimedia with interaction during the adaptation process. The PDA used was IPAQ5450 and Pocket PC Internet Explorer 2003 with a real time Bluetooth connection. The mobile phone used was Nokia 6600 with an Opera browser with Vodafone GPRS real time connection.

5A.2 Evaluation objectives

This research has identified several factors associated with the dimensions and sub-dimensions of the multiplatform e-learning systems framework. Through the formulation of the multiplatform e-learning systems framework in chapter 3, two main research questions have been answered. These research questions are:

What factors constitute a multiplatform e-learning system framework that will adapt to each learner's context and improve learner satisfaction? (RQ1)

And,

What are the factors influencing learner satisfaction in a multiplatform e-learning system? (RQ2)

Consequently the objective of the evaluation is to proceed with answering the associated research sub-questions:

How significant are the various factors in influencing learner satisfaction with respect to the multiplatform e-learning system? (SQ1)

What are the groupings (relationships) among the factors that influence learner satisfaction with respect to the multiplatform e-learning system? (SQ2)

And,

Is the multiplatform e-learning system achieving its goal of improving learner satisfaction? (RQ3)

To answer these questions, an evaluation instrument was developed and various statistical analysis techniques were deployed to explore the data.

5A.3 Evaluation instrument

A Questionnaire for User Interface Satisfaction (QUIS) was developed by Chin et al. (1988) at the University of Maryland. QUIS has been used for evaluating web-based e-learning systems and comparative studies of PDA based and paper based quizzes (Johnson et al., 2004, Segall et al., 2005). The original QUIS consisted of five scales, which show overall reactions to the software, screen, terminology and system information, learning and system capabilities. The first scale relating to overall reactions to the software consisted of 6 questions and the other four scales include a total of 21 questions. The scaling of items ranges from 1 to 9 and an additional “no answer” option is available. Compared to other instruments, such as the Purdue Usability Testing Questionnaire (PUTQ) (Lin et al., 1997), the Post Study System Usability Questionnaire (PSSUQ), and the Software Usability Measurement Inventory (SUMI) (Lewis, 2002), the QUIS is considered closer to the current evaluation objective. The learner questionnaire for evaluation of the multiplatform e-learning system (MELQ) in this study is modified and extended from the QUIS. This questionnaire consists of nine parts. Part 1 of the MELQ consists of capturing demographic information. Part 2 measures e-learning experience. Part 3 measures previous interaction experience and was modified to include more up-to-date and

relevant browsers, mobile games, SMS, PDA and mobile devices. Part 4 measures the overall learner satisfaction score (LSS) and the statements were modified to include the e-learning context for different accessing devices. Statement number 5 was changed to reflect meaningfulness of the system. Part 5 measures the content dimension (D1) with sub parts measuring organisation, granularity, multimedia objects, and pedagogy. Part 6 measures the learner dimension (D2) with sub parts measuring environment, available help, motivation, and preferences. Part 7 measures the device dimension (D3) with sub parts measuring presentation capability and ergonomic capability. Part 8 measures the communication dimension (D4) with sub parts measuring perceived response, perceived stability, and mode of delivery. Part 9 measures the coordination dimension (D5) with sub parts measuring navigation, interaction, and presentation.

5A.4 Evaluation conditions

Evaluating a system is a difficult task and it is even more difficult when the system is adaptive (Hook, 1998). Evaluation of adaptive systems remains a challenging issue (Weibelzahl, 2003). Most studies of adaptive systems are comparisons of the systems with and without adaptivity (Hook, 1998; Boyle, Craig, and Encarnacionj, 1994; Brusilovsky and Pesin, 1994; Meyer, 1994). The current evaluation is also a comparative study.

Six conditions were defined with the intention to vary the type of interaction between learner and the two e-learning systems. These conditions are described below.

For condition one, participants told to assume that they were in a classroom setting and that they had just purchased an IPAQ PDA and a Nokia mobile phone. They were keen to explore these devices to learn about a particular physics topic. The condition encouraged the participant to ask as many questions as possible during the evaluation process. The evaluation environment was made as relaxing as possible. The goal for the condition was to achieve the best measurement score possible for each device and each e-learning system.

Condition two also assumed a classroom setting. Participants used PCs, PDAs and mobile phones to explore the two e-learning systems. In condition two, participants were made to experience a low bandwidth connection. The adaptive

multiplatform e-learning system detected and estimated the delay and offered the participants offline content delivery while the Blackboard system delivered content as usual with delay. It should be stressed that both systems experienced the same delay.

In condition three, participants were made to experience an interruptive environment. Participants were required to read and close a randomly appearing popup window while performing the sequence of required tasks. The objective was to simulate a multi-tasking situation frequently encountered in a mobile environment. The adaptive multiplatform e-learning system made adaptive adjustments to the delivery of content to the learner by adjusting the length of assessment content while the Blackboard e-learning system remained the same.

In condition four, participants were made to experience a busy bandwidth connection but not as long a delay as the offline condition. The adaptive multiplatform e-learning system detected and estimated the bandwidth and presented a pre-fetch delivery solution while the Blackboard system delivered content as usual but with some delay.

In condition five, participants were assumed to be receiving a call from a friend who wanted help on a particular physics topic, and that the participant did not have much time because of an imminent appointment with a doctor. This condition simulated the condition of working under time constraint. An eight minute countdown clock was deployed to increase the urgency. The adaptive e-learning system provided adaptive content delivery by adjusting the length of the assessment.

In condition six, participants were made to self explore the e-learning systems without any help from the researcher. In addition they were warned that 10 points would be deducted for every question asked. The objective was to examine the factors influencing the learner when absolutely no help was given during self exploration. This condition is frequently encountered when learners use mobile devices to access e-learning systems outside of a class room environment.

It should be emphasised that in all these experiment conditions the multiplatform e-learning system was capable of identifying the accessing device, determining its capabilities, estimating its bandwidth and providing content adaptation through style sheet transformation. These activities rely extensively on the coordination dimension.

5A.5 Evaluation procedure

First the participants were recruited through public noticeboard within the university. The overall sample distribution was similar to the university students' population. Six participants were enlisted to take part in each condition. A new group of six participants was enlisted for each condition. Thus a total of 36 participants (6 conditions x 6 participants) were recruited. Before the actual experiment, the participants were briefed and trained on the use of the e-learning systems using module 4 for each accessing device (PC, PDA and mobile phone). The training session took about forty five minutes to an hour for each student. Because there was only one set of equipment available, the experiments were conducted for each participant one at a time. Throughout the experiment the researcher was taking notes and watching the participant at a distance. For each condition, each participant had to complete a total of six tasks. The six tasks consisted of three tasks on each e-learning system (e-learning system A and e-learning system B) for each of the three different accessing devices (PC, PDA, and mobile phone). The sequence of the experiments was PC on system A, PC on system B, PDA on system A, PDA on system B and mobile phone on system A followed by mobile phone on system B. The modules used for PC was module 2. Module 3 was used for PDA and Module 1 was used for mobile phone. The intention to use different modules was to reduce data dependency. Thus the evaluation can be viewed as repeated measures with $6 \times 2 \times 3$ (6 conditions, 2 e-learning systems, 3 different devices) uniquely different experiments. Repeated measures method is commonly used for before and after test comparison as it could minimise measurement error but may produce data dependency issues. The tasks performed by each participant include login to the respective e-learning systems, navigate to the respective folder, navigate to the contents pages, explore individual learning module, explore interactive multimedia, login to exercise, response to exercise, revisit content if necessary, view exercise feedback, and exit system. E-learning system A consists of learning and assessment modules implemented in the commercial Blackboard system without adaptive capabilities. E-learning system B consists of a multiplatform e-learning system with adaptive capabilities. To improve data independency and minimise familiarity, the experiments were designed such that participants accessed different modules on each different device. Upon completing each task, the participant would require to complete a MELQ form. Therefore a total of 6 MELQ data sets were generated for each participant. For 36 participants a total of

216 data sets were generated. Once all the tasks were completed, each participant was interviewed. The purpose of the interview was to cross check the comments made in the MELQ form. The duration of the experiment for each student took about 4 to 5 hours. Each student was given a \$20 supermarket voucher for their time and effort.

Subsequently the data were analysed using various techniques. Details findings will be reported in the next chapter.

Chapter 5B Analysis

5B.1 Introduction

This chapter will first present some background information regarding the samples distribution, participants' browser experience and interactions experience. Subsequently, this chapter will present findings based on quantitative and qualitative data analysis. Data analysis is done to support all the research questions (RQ1, RQ2, SQ1, SQ2, and RQ3) with emphasise on quantitative data. The rationale of using a particular statistical technique will be further justified and discussed.

5B.1.1 Participant information

A total of 36 students took part in the final evaluation. Six conditions were used to vary the interaction between the e-learning systems, accessing devices and learners. Out of the 36 participants 20 (55.6%) were female and 16 (44.4%) were male. The participants were mostly (80%) aged between 16 and 25, while 8% were aged between 26 and 30, and 12% between 31 and 45. The majority (89%) were doing an undergraduate degree while 11% were at post graduate level. The samples used were convenient samples and it matched the university's student population's distribution and profiles. Statistical test showed that there were no significant differences in response between male and female participants.

5B.1.2 Browsers experience

The Internet Explorer (IE) browser usage among the students was very high: 44% of the participants spent over 10 hours a week using IE; 28% of the participants spent 4-10 hours a week; 14% of the participants spent 1-4 hours a week; and the remaining 14% spent less than 1 hour a week using it. There were three participants who indicated they had limited experience in Palm OS, Pocket IE PDA and WAP which were not related to web e-learning. Thus all participants had less than one hour's experience in Pocket IE and Opera browser through the training session provided. Of the 36 participants, 9 (Nine, 25%) participants had only Internet Explorer browser experience, 16 (44.4%) participants had additional Netscape browser experience, 15 (41.6%) participants had additional Mozilla experience and 4 (11.1%) participants had additional Opera PC browser experience. Figure 5B.1 depicts the distribution of other browsers experience.

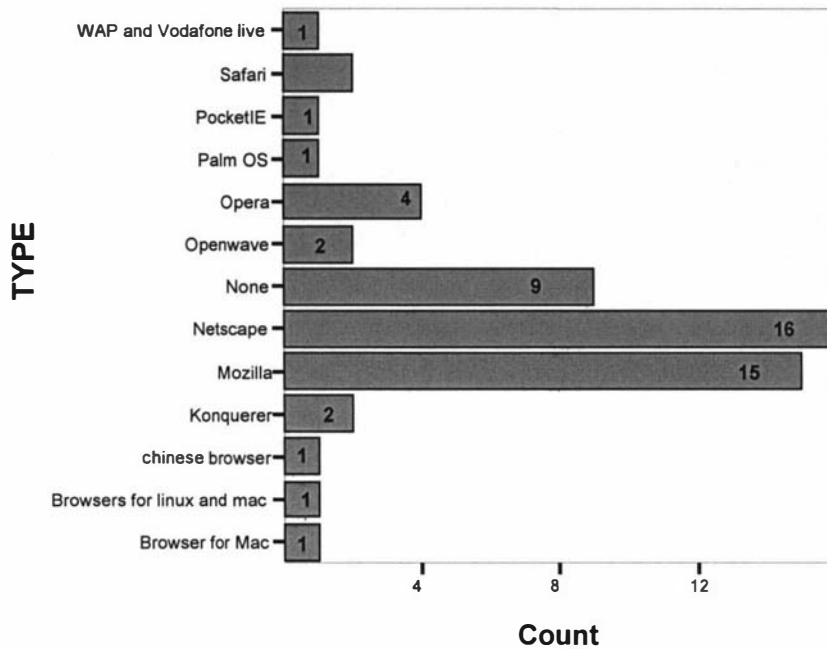


Figure 5B.1 Participants' browser experience

5B.1.3 Interactive experience

The questionnaire also asked participants to select which interactive experiences they are familiar with, out of 20 possibilities. The list of interactive experiences is shown in Figure 5B.2. The survey showed that almost all (35 or 97%) of the participants were familiar with sending short messages (SMS). Most (69% or 25) of the participants were familiar with mobile phone games. Half the participants were familiar with using a camera phone. Less than half (44% or 16) of the participants were familiar with a multimedia messages service (MMS). The same number had interaction experience as a personal tutor. Only 25% (9) of the participants were familiar with mobile phone browsing using WAP and only 16% (6) of the participants were familiar with PDA. A high proportion (75% or 25) of the participants was familiar with an e-learning system. This is because the university uses Blackboard as its e-learning system platform. Notice that the mobile phone and PDA responses regarding browsing experience differ from the interactive experience figures. This may be due to different interpretations from the participants. Nevertheless it indicates

that not many participants were experienced with PDA and mobile phone browsing for e-learning purposes.

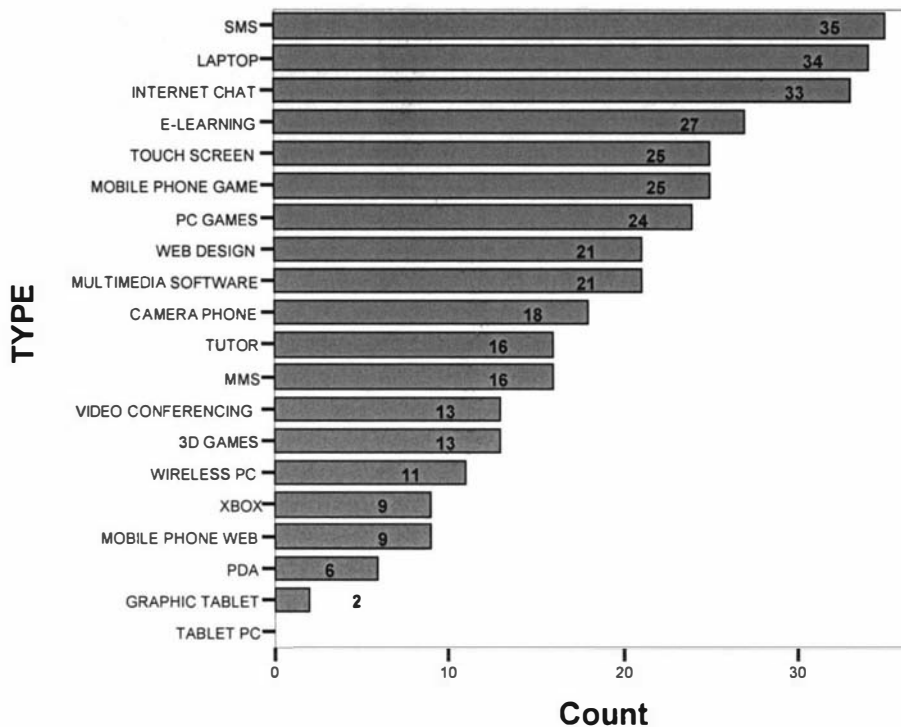


Figure 5B.2 Participants' interactive experience

5B.2 Data analysis

Data analyses were essential to validate the research questions. Various statistical techniques were deployed to allow different perspectives and depth to be explored from the human/system interaction data. First an overview of the pilot evaluation and its findings was provided. Second, the overall learner satisfaction score (LSS) organised according to the experiment conditions and different accessing devices were presented. The overall mean learner satisfaction score provided a quick overview of the differences between the two systems. A ranking technique was deployed to provide quick overview of the overall performance of the systems. Then a special case of the self-directed exploring condition where no assistance was rendered during the experiment was examined. Subsequently using Pearson's correlation technique the degree of influence on learner satisfaction scores from the factors within

the five dimensions was determined. Through comparisons and identifying trend, data analyses were able to identify grouped behaviours among the factors. The discovery of the grouped behaviours may have implications for future multiplatform e-learning development processes. Through analysing interview data and qualitative data specific issues faced by the participants during the experimental process were revealed. Finally ANOVA paired samples tests were conducted to validate the performance of the multiplatform e-learning system and describe the impact of adaptation processes due to three accessing devices. In reporting the results in the subsequent sections, the abbreviations in Table 5B.1 will be adopted.

Table 5B.1 Abbreviations

Dimensions	Factor	Factors Meaning
Content D1	CON-GR	Granule
	CON-MU	Multimedia
	CON-OR	Organization
	CON-PE	Pedagogy
Learner D2	LER-EN	Environment
	LER-HE	Help
	LER-MO	Motivation
	LER-PR	Preference
Device D3	DEV-ER	Ergonomic
	DEV-PR	Presentation
Communication D4	COM-DE	Delivery Mode
	COM-ST	Stability
	COM-RE	Response
Coordination D5	COO-IN	Interaction
	COO-NA	Navigation
	COO-PR	Presentation

5B.2.1 Pilot evaluation

The objective of the pilot evaluation was to provide content validation and to identify refinements in preparation for the full scale evaluation. The pilot evaluation was conducted initially with five participants. However one set of data was removed due to incorrect entry and as a result only four sets of valid data were available. Two e-learning systems were used in the pilot evaluation to provide a comparison. E-learning system A consisted of three learning and assessment modules implemented in the familiar Blackboard environment without adaptive capability. E-learning system B consisted of the same content implemented in a customised web site that can provide

adaptation. This is the multiplatform e-learning system. Three different browsers were used in the pilot evaluation. They were the Internet Explorer (IE) browser representing a desktop computer, a pocket 2003 Internet Explorer (PIE) emulator representing a PDA environment, and an Openwave mobile browser with emulator representing a mobile phone environment. During the pilot evaluation, each participant was asked to perform a total of five tasks with the two e-learning systems and three different browsers. Participants were not required to access e-learning system A using the Openwave browser emulator because Blackboard was unable to provide access to this browser without proper script support. Upon completion of each task with a specific browser and e-learning system, participants were asked to complete a set of questionnaires in response to the completed task.

Although the number of participants was small, the pilot evaluation provided useful insights about the interaction between e-learning systems, accessing devices and learners. Some useful findings from the evaluation were as follows:

- a. While interacting with Internet Explorer and a desktop computer, participants felt that e-learning system A could generate a higher overall learner satisfaction score (LSS) than e-learning system B. This might be due to the fact that learners were more familiar with e-learning system A (the Blackboard environment) than e-learning system B.
- b. While interacting with the PDA emulator, participants felt that e-learning system B could generate a higher overall learner satisfaction score (LSS) than e-learning system A. One possible reason might be the fact that e-learning system A did not provide any adaptation while e-learning system B provided appropriate adapted content. For example, an animated gif was delivered when a Flash player was not detected for e-learning system B.
- c. When using a mobile phone Openwave emulator to interact with e-learning system B, participants gave the lowest overall learner satisfaction scores even though adaptation had been provided. One possible reason might be that the screen size is too small for the learner. Moreover, navigating with the emulator can be unusual and tricky at times, as well as encountering a slower response from the emulator.
- d. Within the individual sub-dimension scores, the multimedia object with Openwave mobile phone browser had the lowest score. This perception again signals that content design for mobile phones with small screen display and

limited multimedia rendering capability may not be easy when trying to produce a significant learning experience that can satisfy learners.

Besides analysing quantitative data such as the overall learning satisfaction score (LSS), qualitative data were also collected from participants through written comments. These comments were useful in explaining some of the scores and how participants perceived the interaction using multiple accessing devices. Some of the comments written by participants are shown here:

- a. One participant commented on the response time. The participant suggested that “The emulators might not truly represent the real situation and hence some of the results might not be convincing. For example the response time might be slower in the actual situation than in the lab environment”. In the evaluation using real mobile devices, the response time was comparable with the emulators.
- b. Another participant commented on the mobility and portability features of the mobile devices. The participant suggested that “In the emulator environment, the learner is in a lookup mode and both hands are free while with an actual mobile phone, only one hand is free and this will affect how navigation can be done”. In the evaluation using real devices, the mobility and portability features were perceived very positively in the use and adoption of mobile devices for e-learning.
- c. With regards to multimedia design, one participant commented that “The animated gif did not convince me that it is useful because the learner is not able to interact with the animated gif as opposed to full Flash interaction. Using a sequence of images with some interaction might be helpful and no text in images for very small screen devices as it is difficult to read and doesn’t serve the purpose”. Animated images were replaced with a sequence of interactive images during the real devices evaluation.

The pilot evaluation pointed to the fact that emulators can have limitations and thus real devices should be used to conduct actual experiments. Secondly, providing adaptive content delivery to mobile phones may not necessarily satisfy learners due to small screen size and navigation problems. A more detail investigation shall be made in the final evaluation.

5B.2.2 Overall learner satisfaction score

This part of the analysis is to support research question three (RQ3). The statistical method intends to be simple. It provides the designer with a quick

understanding of the systems under investigation. Table 5B.2 depicts the overall learner satisfaction score with respect to different experiment conditions organised by accessing devices and e-learning systems. Each individual cell in the table is an average over six participants on the overall learner satisfaction score taken from part four of the multiplatform e-learning system questionnaires (MELQ). The overall learner satisfaction questions contain six items where the participants responded according to their learner satisfaction after each completed task. It provides an aggregate score on interacting with the e-learning systems without getting into detailed measures. From Table 5B.2, the following general observations can be made:

- a. From the overall ranking and scores, participants seemed to prefer multiplatform e-learning system B rather than e-learning system A, which is a traditional e-learning system based on the Blackboard e-learning system. The implication could be that the multiplatform e-learning system was capable of adapting to the experiment situations and managed to provide better content as perceived by the participants than e-learning system A.
- b. By comparing learner satisfaction scores according to accessing devices, participants seemed to accord higher learner satisfaction scores (LSS) for PCs than PDAs and for PDAs than mobile phones in that order within each e-learning system. The ordering of the accessing devices may suggest that participants perceive that smaller mobile accessing devices will not be more satisfying than bigger desktop devices unless the adaptation process can modify such perception.
- c. With an appropriate adaptation process, a mobile phone can achieve a better learner satisfaction score in multiplatform e-learning system B than a PDA device without adaptation in e-learning system A. Moreover a PDA device with appropriate adaptation can achieve a better overall learner satisfaction score than a PC without adaptation. Therefore it may imply that with the right adaptation process a learner's pre-perception can be altered.
- d. The best overall ranking is PC with multiplatform e-learning system B. It achieved number one ranking and attained a mean score of 6.7 out of 9. The worst ranking is mobile phone with e-learning system A. It achieved a mean score of 2.7 out of 9. Thus mobile phone access with no appropriate adaptation is unlikely to be successful.

Table 5B.2 Mean overall learner satisfaction score (LSS)

Conditions	PC		PDA		Mobile	
	A	B	A	B	A	B
S1: Benchmark	7.0	7.3	5.6	6.0	2.8	5.9
S2: Offline	6.9	7.5	6.3	7.0	2.1	5.2
S3: Interruption	5.7	6.3	4.9	6.1	2.7	5.2
S4: Pre-fetch	5.8	6.4	5.6	7.2	3.5	6.4
S5: Urgency	5.7	5.7	4.8	6.2	3.0	4.5
S6: Self Explore	7.5	7.5	5.0	6.4	2.2	6.4
Total Score	38.6	40.7	32.2	38.9	16.3	33.6
Mean score	6.43	6.78	5.37	6.48	2.72	5.60
Rank	3	1	5	2	6	4

5B.2.3 Analysing the self-directed exploring condition

Condition six represents the situation where no personal help was given to the participants during the experiment process. The analysis is intended to provide findings to support research question two (RQ2). The preliminary training procedure was identical to other experiment conditions. However, participants could only seek help if the experiment would not proceed without resolving the issues. In contrast, other experiments conditions encourage participants to seek help any time. This condition was intended to simulate the condition where a learner is likely to act alone, as is frequently the case in a mobile environment. Six participants took part in the evaluation. A total of 44 questions were asked either directly or indirectly. These questions were recorded and subsequently categorised according to the multiplatform e-learning systems questionnaires (MELQ). Of the 44 questions, activity 5 where participants used a mobile phone to access e-learning system A contributed to half of the queries. Another 32% of the questions were due to using a PDA, equally divided between e-learning systems A and B. A low 7% of the questions were due to activity 6. In total, these account for 89% of the questions participants asked due to mobile devices. Other aspects of the questions asked were minor as shown in Figure 5B.3. Some of the common questions were:

“How do you navigate in site A with a cell phone?”

“How to use textbox input with a cell phone?”

“How do you input the password ‘12345’ with a cell phone?”

“How do you navigate to the Physics101 folder in a cell phone?”

“How do you navigate and highlight links with a mobile in site A?”

As there was no video recording during the evaluation; the researcher observed the participants and the experiment process carefully at a distance. It was observed that while using a mobile phone to access it, participants tended to lose connection to e-learning system A by accidentally pressing the wrong keys on the cell phone (learners were not familiar with the exit and stop button). Further analysis also revealed that these participants had used at least three other browser types and had considerable interactive experience and all used SMS to send text messages. Therefore it is likely that the Opera/Nokia 6600 system had a substantial ergonomic problem with device navigation and browser capability when the e-learning system did not provide adaptations that matched the device capabilities. The device ergonomic issues contributed to 36% of the questions asked, as shown in Figure 5B.4.

Another factor that was likely to produce a lower overall learning satisfaction score was that participants were incapable of following the instructions that were written on the evaluation sheet. This contributed to 27% of the questions asked, as shown in Figure 5B.4. The consequence of not complying with the written instructions was that participants eventually got “lost” in the evaluation process and subsequently penalised the learning satisfaction by perceiving it negatively. This negative experience was further exacerbated in e-learning system A rather than in multiplatform e-learning system B. Some of the common questions associated with not complying with written instructions are listed below:

Why there was no response from the interaction link when using a PDA with e-learning system A?

(Participants did not follow instruction to cancel "steps".)

Which URL site should I access?

(Participants used "physics101.html" instead of physics101E.html.)

What is the password?

(The instruction says "12345")

Why can't I login using 'pl'?

(The instruction says capital "P")

Why I don't see any multimedia?

(Participants used module 2 instead of module 1 in PDA-site A)

While some of these problems could be minimised by re-structuring the instructions, one cannot totally ignore the fact that these problems and mistakes, which are related to the learner, will not disappear. These problems would have an inherent impact on the learner's assessment of the overall learning satisfaction under a multiplatform environment. It is envisaged that such problems will diminish as a learner gets used to the system.

Another factor that was closely related to device ergonomics was learners' inability to learn and operate the browser correctly with their knowledge, skills, experience and intuition. As shown in Figure 5B.4, this factor contributed to 20% of the queries. This lack of abilities on the part of the learner was manifested in use of both mobile and desktop devices, though in the case of the mobile device it was slightly more severe. For example, one participant asked how to open multiple windows in Internet Explorer to revisit content and how to complete exercises, although the participant had been using IE for many years. This incident suggests that the user might have been using IE for long enough but did not necessarily acquire the experience, knowledge and intuition to operate the browser effectively. In the case of a mobile browser, some of the most frequently encountered issues were as follows:

- a. Participants frequently navigated to the wrong links.
- b. Participants were not able to input into a text box and submit the password "12345" with e-learning system A.
- c. Participants were not able to use a cell phone to login to e-learning system A.
- d. Participants were not able to navigate and highlight in a text box, nor were they able to launch a web page from the Opera browser.

These observations strongly suggest that even though training and demonstrations were provided to all the participants, individual skills, knowledge, intuition and sense of operation had significant influence on their ability to operate the e-learning system successfully. Thus to achieve a better learning satisfaction and subsequently the adoption of a multiplatform e-learning system, learners must be trained in different conditions to the extent that they can achieve a specific level of skill, experience, confidence and capability prior to launching the multiplatform e-learning system.

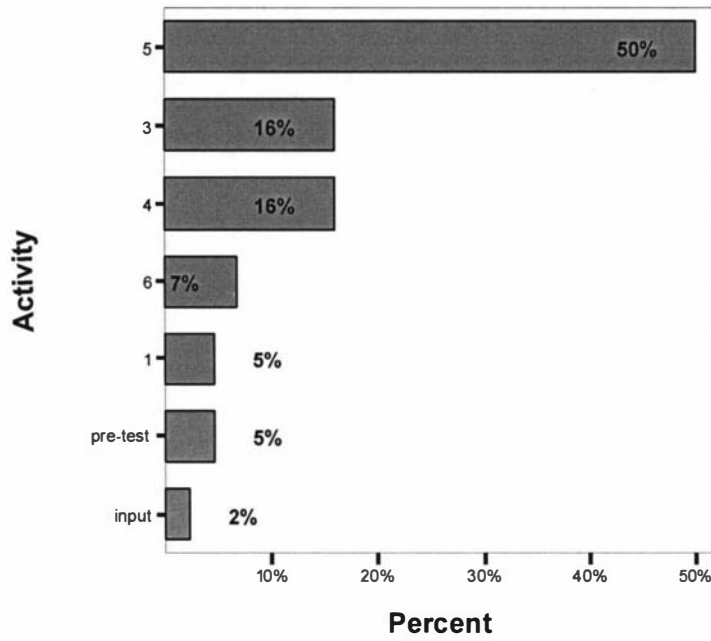


Figure 5B.3 Questions frequency distribution with respect to activities

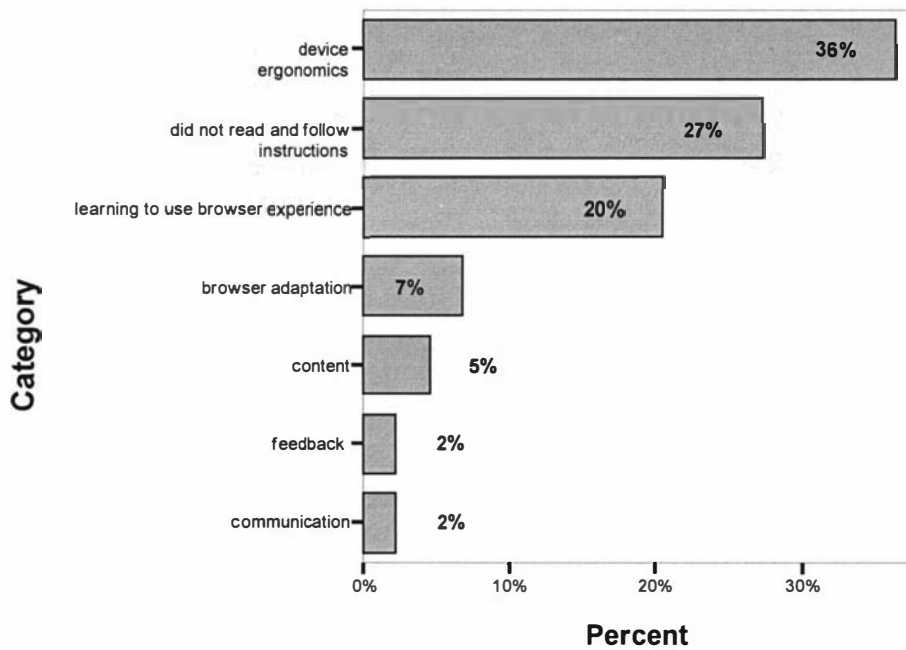


Figure 5B.4 Question frequency distribution with respect to category

5B.2.4 Degree of influence and relationships

One of the key research questions in this study is to examine and validate the degree of influence on overall learning satisfaction by the dimensions and sub-dimension factors identified in the multiplatform e-learning systems framework (SQ1). Another question is to examine the groupings (relationships) among these factors (SQ2). This section intends to achieve these objectives through the use of correlation technique to establish the required statistics and to avoid masking by strong factors (Hair et al., 1995, p. 191). Correlation technique is also common in measuring relationship between factors and user satisfaction score (B2B, 2005). Correlation analysis between all the factors and overall learner satisfaction produced a set of correlation coefficients and its significance level. The larger the coefficient value, the stronger the relationship is between the factor and the overall learner satisfaction measure (Hair et al., 1995, p.171; Garson, 1998). Upon generating the correlation coefficients using Pearson's correlation, each factor is ranked according to their values for the ease of visualisation. Subsequently all the coefficients were averaged within the content dimension (D1), learner dimension (D2), device dimension (D3), communication dimension (D4) and coordination dimension (D5) respectively to obtain an indicative value. The correlation analysis was performed independently for e-learning system A and multiplatform e-learning system B.

By examining the statistics that were generated in Table 5B.3, several assessments could be made. First, all the correlation coefficients were positive and statistically significant at 0.001 levels except LER-EN ($P < 0.05$). This implies that all the factors were positively and significantly influencing the overall learner satisfaction score. It also meant that the relationship between factors and overall learner satisfaction identified in the framework were all valid. Second, the degree of influence among the factors on the overall learner satisfaction score was not uniform. This meant that some factors can be more influential than others.

With reference to correlation statistics for e-learning system A in Table 5B.3 and the multiplatform e-learning system in Table 5B.3, the following observations can be made:

- a. In e-learning system A, the maximum correlation coefficient was due to content organisation (CON-OR, 0.86) while the minimum correlation coefficient was due to learner environment (LER-EN, 0.05). The spread was about 0.81. The correlation coefficient for multiplatform e-learning system B had a range from

0.76 (CON-OR) to 0.18 (LER-EN). The spread was about 0.58, which is lower than e-learning system A. A wider spread in a system is normally associated with more variation and less stability. Thus participants may have perceived multiplatform e-learning system B to be more stable than e-learning system A because of its adaptive capability. The consequence of a stable e-learning system is that it can facilitate better opportunities for learning.

- b. The mean correlation coefficients by dimension in multiplatform e-learning system B had a narrower spread than in e-learning system A. The implication is that all dimensions are treated equally. An equalisation effect has occurred.
- c. The top five factors perceived most influential for e-learning system A were organisation (CON-OR), delivery (COM-DE), navigation (COO-NA), ergonomics (DEV-ER), and response (COM-RE). The top five factors perceived most influential for multiplatform e-learning system B were organisation (CON-OR), delivery (COM-DE), navigation (COO-NA), interaction (COO-IN), and pedagogy (CON-PE). The pedagogy factor (CON-PE) in the content dimension and interaction (COO-IN) in the coordination dimension emerged and replaced perceived response (COM-RE) and ergonomics (DEV-ER) in e-learning system A as the influential factors in e-learning system B. As e-learning system B was perceived to be more stable than e-learning system A, several negative effects due to lack of adaptive capability would have been overcome. In e-learning system A, participants had expressed difficulty in manoeuvring especially using mobile devices. Moreover, content could be missing due to lack of adaptive capability. Once these obstacles had been overcome in multiplatform e-learning system B, participants could address higher e-learning issues such as pedagogy and interactions.
- d. In e-learning system A, the dimensions that had a stronger influence on overall learner satisfaction were the coordination dimension (D5), device dimension (D3), communication dimension (D4), content dimension (D1) and learner dimension (D2) in that order. The learner dimension (D2) remained the least influential dimension. In multiplatform e-learning system B, the dimensions that had stronger influence on overall learner satisfaction were the coordination dimension (D5), content dimension (D1), device dimension (D3), communication dimension (D4), and learner dimension (D2) in that order. This order is distinctly different from the order of e-learning system A. The significant difference was that the content

dimension (D1) was the second most influential factor and the device dimension (D3) was the third most influential. Though the learner dimension (D2) remained the least influential dimension the mean correlation coefficient improved significantly. The reason for the content dimension to be more significant in system B is probably that adaptive capability had allowed participants to consider higher learning issues which are not possible in e-learning system A, where participants were busy dealing with device issues.

5B.2.5 Grouping behaviour in factors

The analysis so far has shown that the factors within the multiplatform e-learning system were valid and statistically significant in influencing overall learner satisfaction through correlation analysis. This section intends to provide support for research sub-question two (SQ2). By comparing these coefficients of multiplatform e-learning system B and e-learning system A and using simple trend analysis, one noticed that the correlation coefficients had been equalised in multiplatform e-learning system B. Equalisation (EQ, 2005) means that the coefficient values are closer to each other and the spread is smaller. This effect may imply that these factors were becoming equally influential and important as perceived by learners. This effect can only be noticed if two systems were used in the experiment instead on just the multiplatform e-learning system. Thus comparative study can provide such insight while studying a single system alone cannot unless the experiment is repeated after enhancement. Table 5B.3 showed the differences in correlation coefficients between multiplatform e-learning system B and e-learning system A. A positive value indicates that the correlation coefficient is higher in e-learning system B and a negative value indicates otherwise. With reference to Table 5B.3, the factors of environment (LER-EN), help (LER-HE), motivation (LER-MO) and preference (LER-PR) in the learner dimension (D2) and granularity (CON-GR) and pedagogy (CON-PE) in the content dimension (D1) improved their correlation coefficients. While the improvements may not all be significant, the improvement in the values may indicate that learners had the opportunity to assess these factors as influential. This could happen provided the ergonomic obstacles in e-learning system A have been resolved or reached a threshold level of satisfaction. Thus the factors LER-EN, LER-HE, LER-MO, LER-PR, CON-GR and CON-PE are termed secondary factors as they appeared more influential and relevant once the primary factors reached a

threshold. Conversely the factors in D3, D4 and D5 all have lower correlation coefficients in e-learning system B than in e-learning system A. These are the dominant factors that influence overall learner satisfaction in the traditional e-learning system A. These dominant factors are termed primary factors as they provided the main influences. Primary factors are indicated as a negative sign and secondary factors are indicated as a positive sign in the last column of Table 5B.3. A high positive value indicates a strong secondary factor while a high negative value indicates a strong primary factor. In multiplatform e-learning system B, correlation coefficients of primary factors decreased while secondary factors increased.

Thus far two groups of factors have been identified among the correlation coefficients. Primary factors were dominated by D3, D4 and D5 while secondary factors were dominated by D1 and D2. Designers can take advantage of the features by observing the emergence of the equalisation effect and secondary factors as an indication of a stable and well adapted e-learning system. This is likely to happen when the multiplatform e-learning system overcomes the threshold dominated by primary influencing factors.

Table 5B.3 Dimensions Ranking, Factors Ranking and Correlation Coefficients

Dimensions	Factor	Factors Meaning	System A				System B				Changes in Correlation Coefficient	Primary and secondary factor
			Factor Correlation Coefficient	Factor Rank	Average Coefficient By Dimension	Dimension Rank	Factor Correlation Coefficient	Factor Rank	Average Coefficient By Dimension	Dimension Rank		
Content D1	CON-GR	Granule	0.50	13	0.67	4	0.61	10	0.66	2	0.11	+
	CON-MU	Multimedia	0.74	6			0.58	11			-0.16	-
	CON-OR	Organization	0.86	1			0.76	1			-0.09	-
	CON-PE	Pedagogy	0.58	12			0.67	5			0.09	+
Learner D2	LER-EN	Environment	0.05*	16	0.33	5	0.18*	16	0.44	5	0.13	+
	LER-HE	Help	0.27	15			0.45	15			0.18	+
	LER-MO	Motivation	0.39	14			0.51	14			0.12	+
	LER-PR	Preference	0.60	11			0.62	9			0.02	+
Device D3	DEV-ER	Ergonomic	0.80	4	0.75	2	0.65	8	0.65	3	-0.15	-
	DEV-PR	Presentation	0.69	9			0.65	6			-0.04	-
Communication D4	COM-DE	Delivery Mode	0.84	2	0.74	3	0.73	2	0.62	4	-0.11	-
	COM-ST	Stability	0.63	10			0.57	13			-0.06	-
	COM-RE	Response	0.74	5			0.57	12			-0.18	-
Coordination D5	COO-IN	Interaction	0.72	8	0.75	1	0.69	4	0.69	1	-0.02	-
	COO-NA	Navigation	0.81	3			0.71	3			-0.10	-
	COO-PR	Presentation	0.72	7			0.65	7			-0.07	-

***P<0.05, all others P<0.001**

5B.2.6 Analysing interview data

Apart from quantitative data, qualitative data were also collected through interviewing and observing participants. Some comments from the participants are provided below. In general, interviews can discover more specific details. This section intends to provide support to research question two (RQ2). It also provides a mean to cross check the comments written in the MELQ form. The comments were also aligned with the analysis from the MELQ questionnaire. When the participants were asked what they disliked about e-learning system A, one participant commented as follows:

“I dislike that the e-learning system as it is often confusing and hard to navigate using the tools on the side bar, it has quite frequent disruptions and has either not enough information to get you where you want to go in a hurry, or it takes a while to get there through many steps”. Thus, using a side bar for navigation may not necessarily be preferred in a multiplatform e-learning system. The comments also signalled that good navigation design and understanding learner preferences can influence learner satisfaction.

When the participants were asked what they disliked about multiplatform e-learning system B, one participant commented as follows:

“The only thing that I was unsure of was that it wasn’t immediately clear if one had answered all the questions correctly at the end as no ‘final score’ was given. The style of testing meant that there could technically be no competition aspect to the test. While you would know straight away if you had something wrong, you would still be able to ‘pass’ simply by trying each answer until you got the right one”. The participant was clearly concerned with the teaching strategy as included in the pedagogy sub-dimension that affected his learning satisfaction.

When asked what they liked about e-learning system A, one participant commented as follows:

“I like the learning style, it allows you to learn at your own pace and go over information as necessary”. The participant clearly expressed his acceptance of the “revisit” teaching strategy as included in the pedagogy sub-dimension.

When asked what they liked about multiplatform e-learning system B, one participant commented as follows:

“I liked the look very much; it was much simpler and clearer to read than the Blackboard site (e-learning system A). While looking at the information on

Blackboard I found my eyes skimming over information a bit, it was hard to concentrate on all the words. I would probably prefer a more rounded font as it's easier to look at. But the layout was good, the home button is helpful and it took me where I expected it to take me". This comment appeared to reflect that content organisation, layout and learner preference were affecting the participant's learner satisfaction.

Other participants had similar comments and in general found multiplatform e-learning system B much more satisfying than e-learning system A. Participants also commented negatively on the navigation aspect of e-learning system A with mobile phone access. These comments coincided with the findings in the questionnaire.

With respect to PDAs, participants expressed difficulty with the device interface. They did not find it easy to use. A participant commented about the "zooming" and "show all" features of the PDA while exploring the embedded Flash animation as follows:

"While I liked both the Flash demonstrations in this, I found it hard to use the pen to change the settings on them and had to resort to zooming in up close to make the pen move the animations, then move the whole screen around to see the result. It was hard to navigate and I couldn't see the entire effect too clearly always..." This comment signalled that while Flash animation was included as part of the learning content to improve learning, the inability to use it satisfactorily was likely to adversely influence the learner satisfaction and subsequently result in negative satisfaction overall. Conversely, the capabilities of "zooming" and "show all" in PDA may not be perceived as a useful tool for interactive multimedia thus affecting the ergonomic sub-dimension in the device dimension.

Overall the interviews were very useful and informative in reaffirming the findings derived from the MELQ questionnaire. Through interviews specific areas in content organisation, pedagogy, navigation, and ergonomics were identified. These specific items such as navigation bar, "zooming", and fonts would be useful for designer to enhance the usability of the final system if required.

5B.2.7 Analysing qualitative data

During the evaluation, participants were asked to document what they liked and disliked about the e-learning systems, the different accessing devices and the interactions. The questions were asked after each completed task. Subsequently, the responses were coded according to the dimensions and sub-dimensions as they appeared in the MELQ questionnaire. Again this section is to further support research question 2 and research sub-question two (RQ2 and SQ2). Each statement was examined for the factors that best matched the participant's qualitative responses. A total of 502 responses were subsequently coded. Table 5B.4 depicts a summary of positive and negative responses with respect to e-learning system A and multiplatform e-learning system B, categorised according to three different accessing devices. Table 5B.5 depicts a summary of positive and negative responses organised according to devices and dimensions. From these results, the previous findings regarding multiplatform e-learning systems and the factors influencing overall learner satisfaction can be reaffirmed. A summary of findings is provided below:

- a. Overall, e-learning system A collected 169 (34%) negative responses while multiplatform e-learning system B collected 117 (23%) negative responses. For positive responses, e-learning system A collected 84 (17%) responses while e-learning system B collected 132 (26%). There were more positive responses and less negative responses for multiplatform e-learning system B. Participants seemed to perceive multiplatform e-learning system B better than e-learning system A. The adaptive capability of the multiplatform e-learning system seemed to perform well.
- b. Using a mobile phone with e-learning system A achieved a mere 2% positive responses while 8% positive responses were achieved by multiplatform e-learning system B. For PDAs, e-learning system A collected 6% positive responses while multiplatform e-learning system B collected 8% positive responses. For negative experience responses, e-learning system A collected 11% while multiplatform e-learning system B collected 8%. These numbers again showed that with respect to mobile devices multiplatform e-learning system B was perceived to be better than e-learning system A.
- c. To get more details, factors which were being perceived positively in both e-learning systems were determined. From Figure 5B.5(a), the ergonomic factor in the device dimension (DEV-ER) and the pedagogy factor in the content dimension

(CON-PE) were two main items liked by learners in e-learning system A with a positive occurrence of 22 and 16 times respectively. From Figure 5B.5(b), the perceived response factor (COM-RE) in the communication dimension, ergonomic factor in the device dimension (DEV-ER), pedagogy factor in the content dimension (CON-PE) and navigation factor (COO-NA) in the coordination dimension were the major items liked by the learners in e-learning system B with occurrences of 24, 24, 21, and 17 times respectively.

- d. From Figure 5B.6(a), learners seemed to dislike perceived response in the communication dimension (COM-RE), presentation in the device dimension (DEV-PR), navigation in the coordination dimension (COO-NA), presentation in the coordination dimension (COO-PR) and ergonomics in the device dimension (DEV-ER) when interacting with e-learning system A. These factors had occurrences of 37, 30, 29, 19, and 18 times respectively. From Figure 5B.6(b) learners disliked device presentation in the device dimension (DEV-PR), ergonomics in the device dimension (DEV-ER), navigation in the coordination dimension (COO-NA), perceived response in the communication dimension (COM-RE) and preference in the learner dimension (LER-PR) while interacting with e-learning system B. These factors had occurrences of 27, 18, 17, 15 and 10 times respectively.
- e. Close examination of these factors revealed that some of them appeared both in the positive and negative response lists which may imply that these factors were perceived as more relevant to the participants under the multiplatform e-learning system environment. These factors were also similar to the earlier findings through correlation analysis and interviews.
- f. With respect to PCs, DEV-ER and CON-PE were the two main factors viewed positively in e-learning system A as shown in Figure 5B.7(a) while CON-PE, DEV-ER and COM-PR were the main factors viewed positively in e-learning system B as shown in Figure 5B.7(b). During the evaluation conditions learners experienced a faster response in multiplatform e-learning system B than e-learning system A, hence a positive comment on perceived response COM-PR is no surprise. The content dimension (D1) and device dimension (D3) for both e-learning systems were the main focus of the participants.
- g. With respect to PCs, the negative responses from e-learning system A were mainly COO-NA, COM-PR, LER-PR, and CON-OR as shown in Figure 5B.8(a)

while the negative responses from e-learning system B were mainly LER-PR and COO-NA as shown in Figure 5B.8(b). Learners were concerned with most of the dimensions in e-learning system A except the device dimension with which participants were very familiar. For multiplatform e-learning system B, learners were mainly concerned with the coordination dimension (D5) and learner dimension (D2).

- h. With respect to PDAs, the positive comments with respect to e-learning system A were due to DEV-ER as shown in Figure 5B.9(a) while the positive comments with respect to e-learning system B were due to COO-PR, DEV-ER, COM-PR, CON-PE, and CON-OR as shown in Figure 5B.9(b). The focus in e-learning system A with PDAs was mainly on the ease of use of the device and browser (DEV-ER) while the focus in e-learning system B was the presentation of content (COO-PR). It seemed that content and its presentation in e-learning system A did not succeed in getting the learners' attention as the adaptation from Pocket IE was not really favoured by learners. The device dimension (D3) and content dimension (D1) were of concern for learners for e-learning system A while the device dimension (D3) and coordination dimension (D5) were the main concerns of learners for e-learning system B.
- i. With respect to PDAs, the negative comments with respect to e-learning system A were due to DEV-PR, COM-RE, COO-PR and COM-ST as shown in Figure 5B.10(a). The negative comments with respect to e-learning system B were due to DEV-ER, DEV-PR and COO-IN as shown in Figure 5B.10(b). Device capability issues contributed to most of the negative responses. Interaction issues were raised in e-learning system B due to some difficulties interacting with the multimedia object. The communication dimension (D4), coordination dimension (D5) and device dimension (D3) contributed to the negative responses.
- j. With respect to mobile phones, there were no significant positive responses for e-learning system A. For e-learning system B, the positive responses were mainly from COM-PR and COO-NA as shown in Figure 5B.11(b). E-learning system A was disliked by learners as it was not able to adapt to mobile phones with meaningful presentation and navigation. Compared to e-learning system A, e-learning system B is able to adapt to mobile phones with faster response and organisation and thus makes navigation easier. The coordination dimension (D5)

and communication dimension (D4) contributed to most of the positive responses in e-learning system B.

- k. With respect to mobile phones, the negative comments with respect to e-learning system A were COM-PR, COO-NA, DEV-PR, DEV-ER and COO-PR as shown in Figure 5B.12(a). The negative comments with respect to e-learning system B were DEV-PR, COM-PR, COO-NA, and DEV-ER as shown in Figure 5B.12(b). The device dimension (D3), coordination dimension (D5) and communication dimension (D4) contributed to most of the negative comments.

In summary, positive responses were due mainly to the content dimension (D1), device dimension (D3) and coordination dimension (D5) while negative responses were due mainly to the device dimension (D3), communication dimension (D4) and coordination dimension (D5) as shown in Table 5B.6. These findings seemed to imply that if adaptation were less than perfect and ideal, as in e-learning system A and especially for mobile devices, accessibility problems would be encountered before content problems. Learners would be likely to focus their attention and blame on the device dimension (D3), coordination dimension (D5) and communication dimension (D4). On the other hand if the adaptations were more successful, and when learners managed to cross the hurdle of accessibility and were subsequently able to interact with the content, then learners can assess the content dimension (D1). The successful adaptation also resulted in favourable responses for D3 and D5. Thus one can conclude that these observations seem to suggest that there are two levels of responses. The first level of response consists of the device dimension (D3), communication dimension (D4) and coordination dimension (D5) and the second level of response consists of the content dimension (D1) and learner dimension (D2). Learners must cross the first level before entering into the second level to have meaningful interaction experiences and responses on D1 and D2. These findings are consistent with the primary and secondary factor findings earlier.

Table 5B.4 Positive and negative responses

	e-learning system A				e-learning system B			
	Positive	%	Negative	%	Positive	%	Negative	%
PC	47	9%	39	8%	50	10%	29	6%
PDA	29	6%	56	11%	42	8%	41	8%
Mobile	8	2%	74	15%	40	8%	47	9%
Total	84	17%	169	34%	132	26%	117	23%

Table 5B.5 Positive and negative responses organised by dimensions and devices

	Dimensions	e-learning system A				e-learning system B			
		Positive	%	Negative	%	Positive	%	Negative	%
PC	D1	24	5%	8	2%	21	4%	4	1%
	D2	2	0%	8	2%	0	0%	9	2%
	D3	14	3%	4	1%	13	3%	3	1%
	D4	2	0%	9	2%	11	2%	3	1%
	D5	5	1%	10	2%	5	1%	10	2%
PDA	D1	8	2%	3	1%	13	3%	3	1%
	D2	0	0%	1	0%	0	0%	1	0%
	D3	13	3%	16	3%	7	1%	21	4%
	D4	1	0%	20	4%	6	1%	7	1%
	D5	7	1%	16	3%	16	3%	9	2%
Mobile	D1	1	0%	5	1%	8	2%	3	1%
	D2	1	0%	0	0%	0	0%	1	0%
	D3	1	0%	28	6%	5	1%	21	4%
	D4	2	0%	17	3%	10	2%	14	3%
	D5	3	1%	24	5%	17	3%	8	2%
Total		84	17%	169	34%	132	26%	117	23%

Table 5B.6 Positive and negative responses organised by dimensions

Dimensions	e-learning system A				e-learning system B				Sub Total	
	Positive	%	Negative	%	Positive	%	Negative	%	Positive	Negative
D1	33	7%	16	3%	42	8%	10	2%	15%	5%
D2	3	1%	9	2%	0	0%	11	2%	1%	4%
D3	28	6%	48	10%	25	5%	45	9%	11%	19%
D4	5	1%	46	9%	27	5%	24	5%	6%	14%
D5	15	3%	50	10%	38	8%	27	5%	11%	15%
Total	84	17%	169	34%	132	26%	117	23%	43%	57%

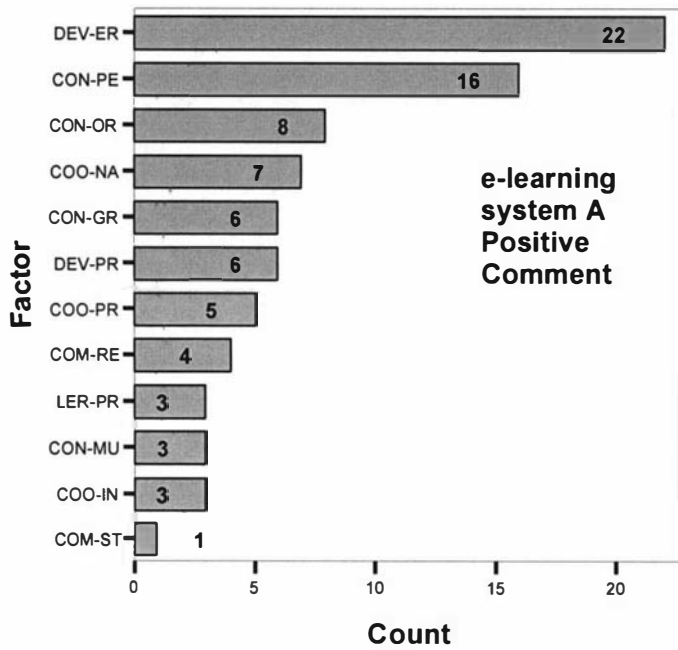


Figure 5B.5(a) Detailed factors – e-learning system A positive responses

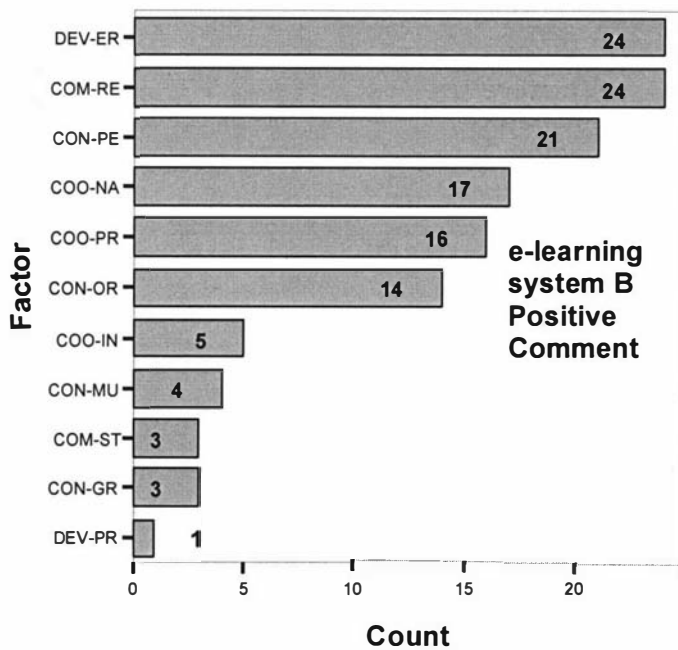


Figure 5B.5(b) Detailed factors – e-learning system B positive responses

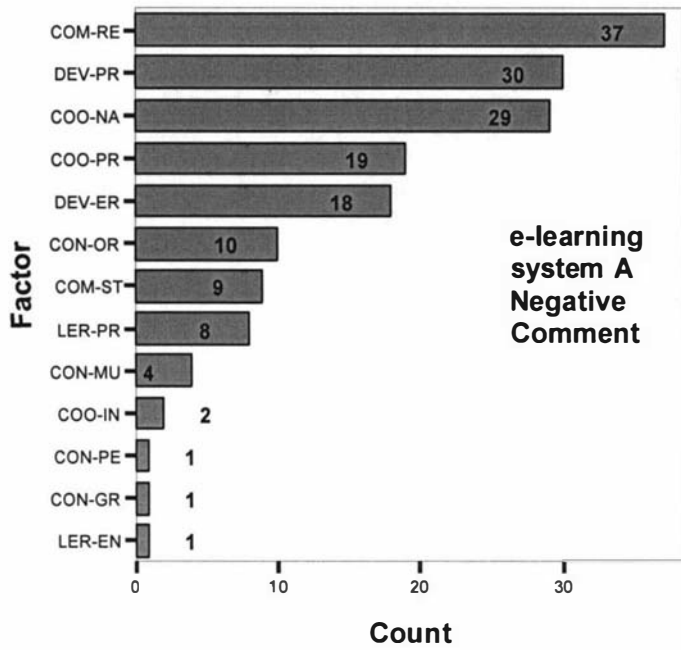


Figure 5B.6(a) Detailed factors – e-learning system B negative responses

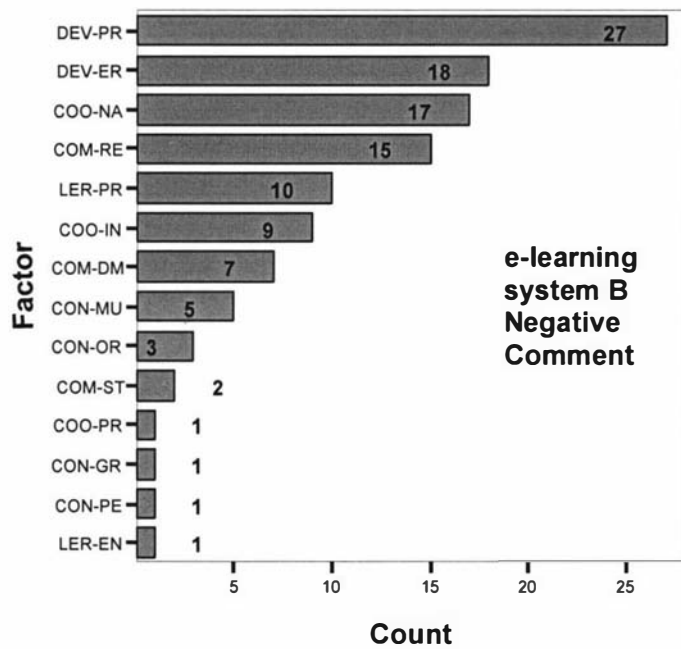


Figure 5B.6(b) Detailed factors – e-learning system B negative responses

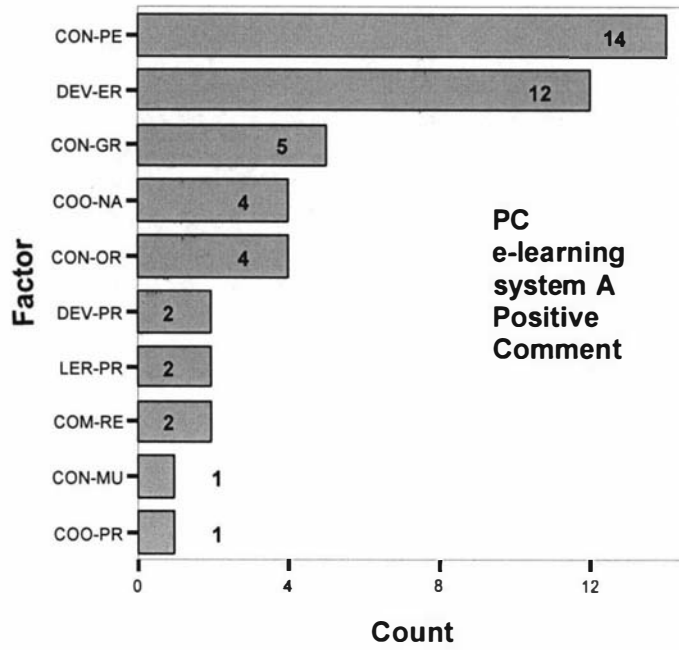


Figure 5B.7(a) Detailed factors – PC, e-learning system A positive responses

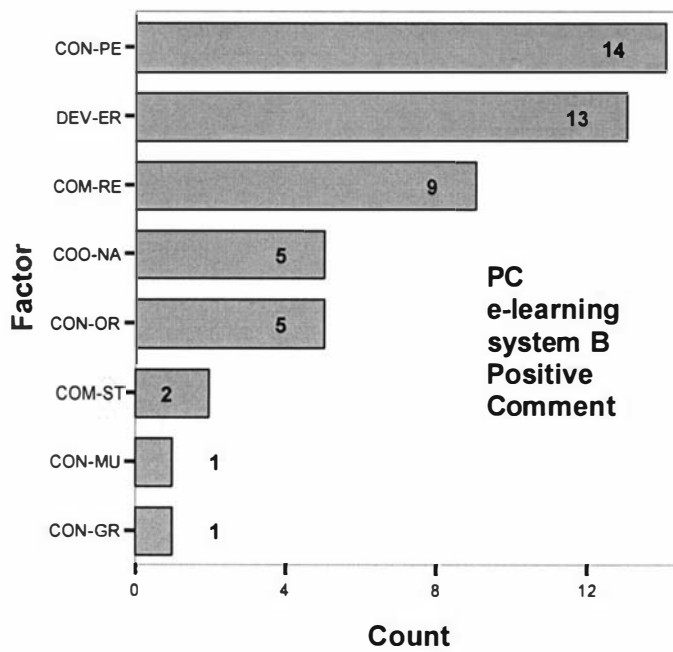


Figure 5B.7(b) Detailed factors – PC, e-learning system B positive responses

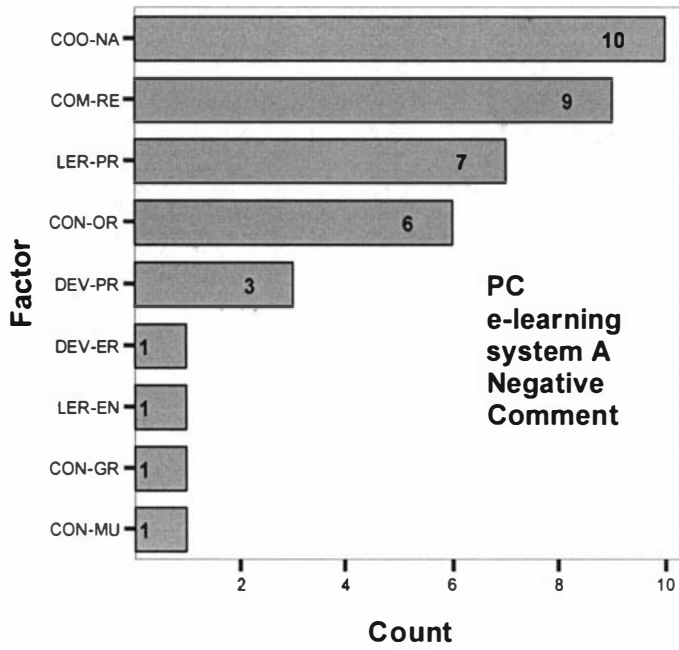


Figure 5B.8(a) Detailed factors – PC, e-learning system A negative responses

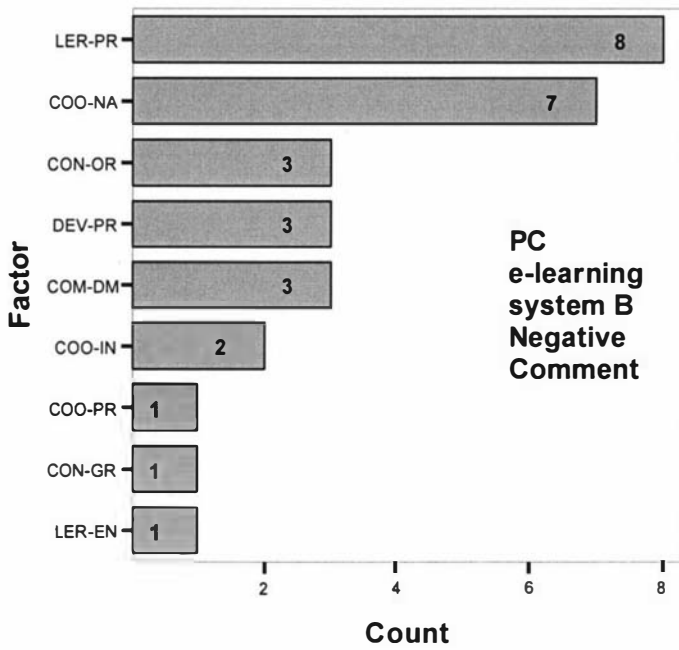


Figure 5B.8(b) Detailed factors – PC, e-learning system B negative responses

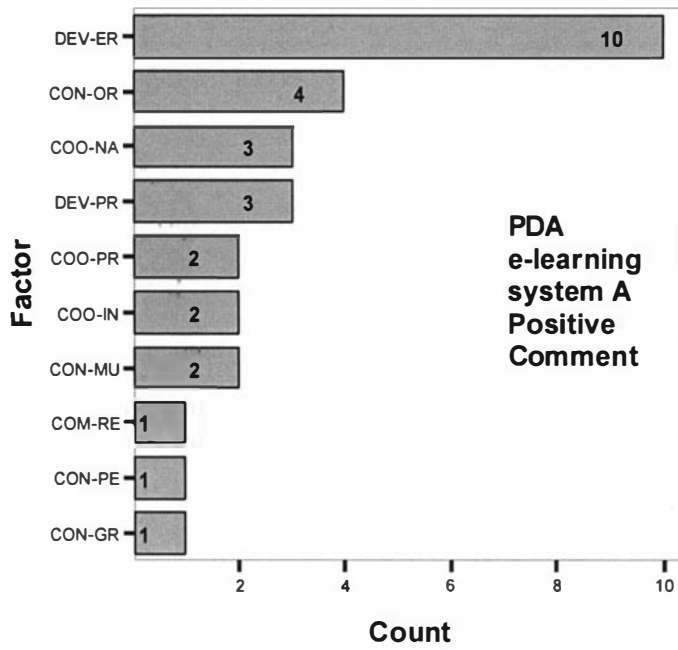


Figure 5B.9(a) Detailed factors – PDA, e-learning system A positive responses

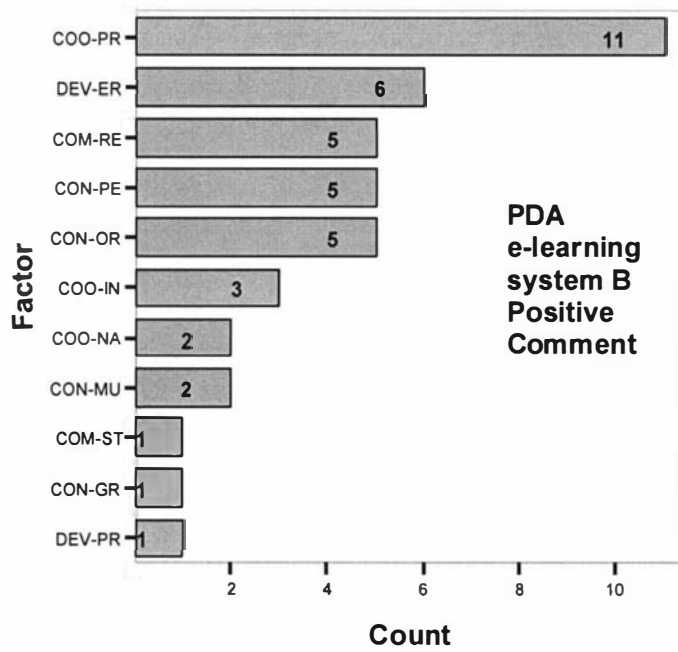


Figure 5B.9(b) Detailed factors – PDA, e-learning system B positive responses

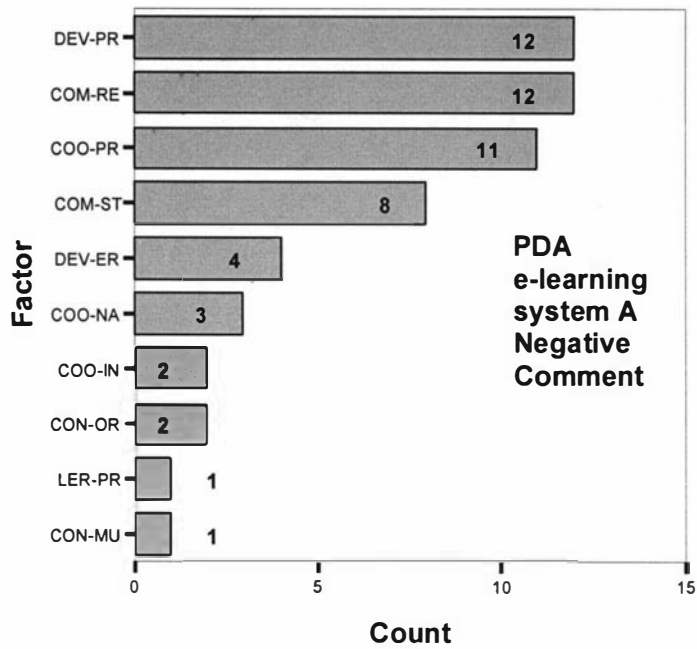


Figure 5B.10(a) Detailed factors – PDA, e-learning system A negative responses

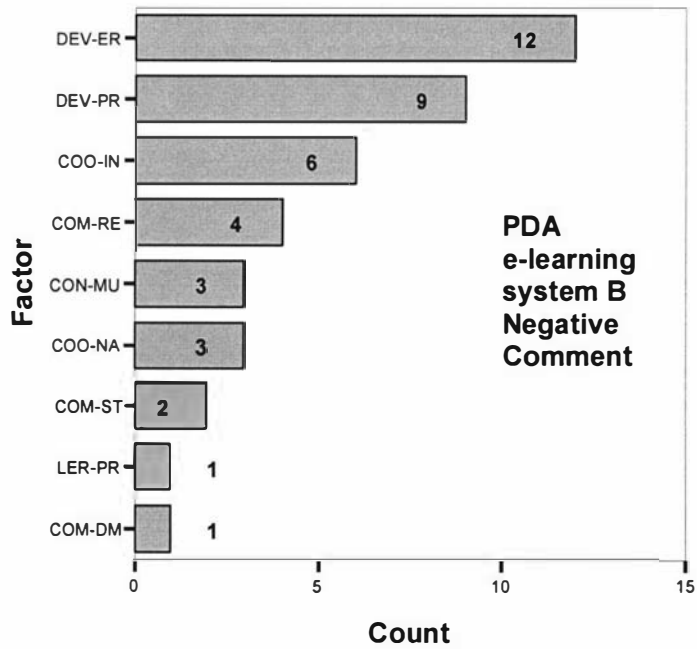


Figure 5B.10(b) Detailed factors – PDA, e-learning system B negative responses

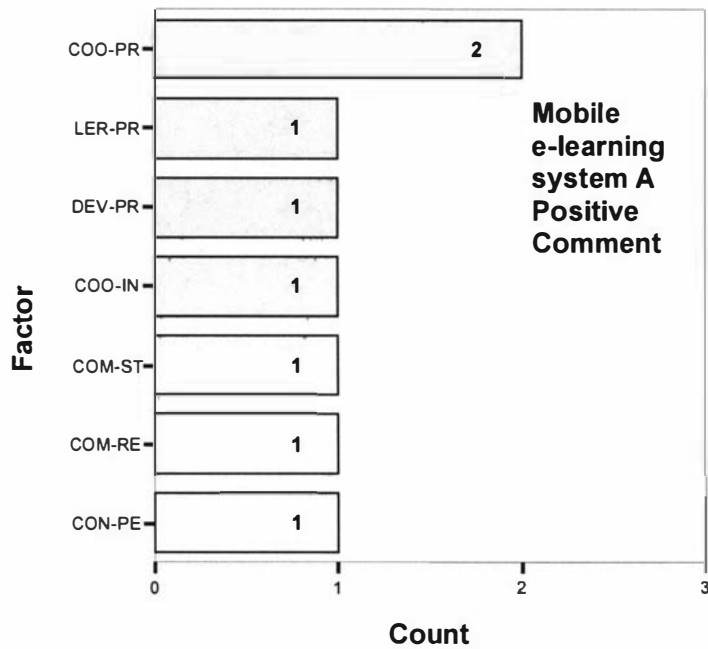


Figure 5B.11(a) Detailed factors – mobile phone, e-learning system A positive responses

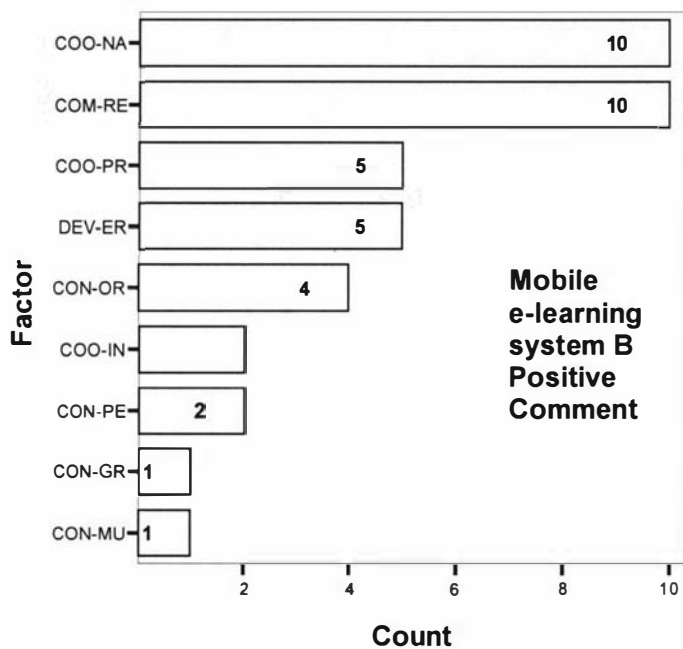


Figure 5B.11(b) Detailed factors – mobile phone, e-learning system B positive responses

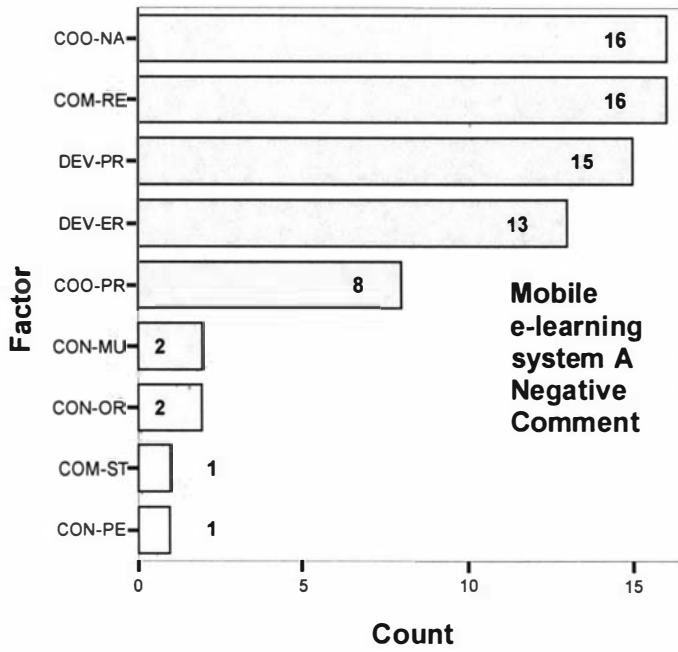


Figure 5B.12(a) Detailed factors – mobile phone, e-learning system A negative responses

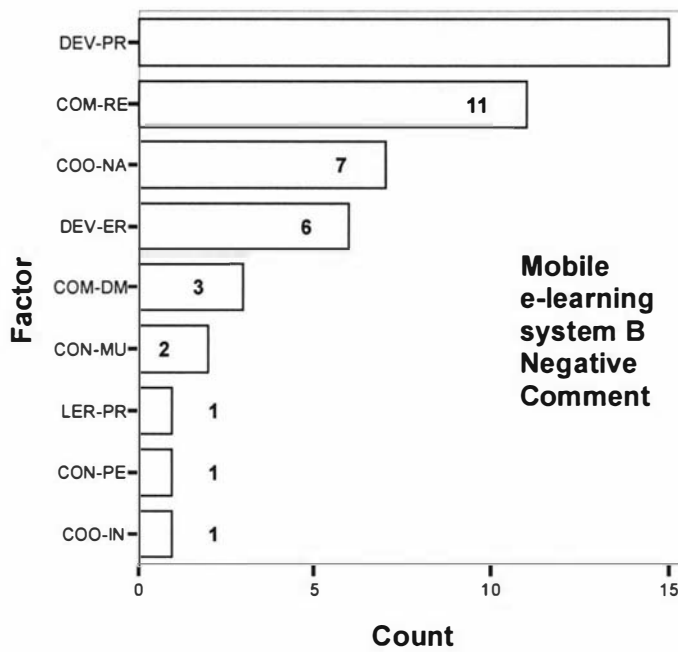


Figure 5B.12(b) Detailed factors – mobile phone, e-learning system B negative responses

5B.2.8 Comparison test between e-learning systems

The multiplatform e-learning systems framework emphasised five dimensions for which adaptation can be implemented to improve overall learner satisfaction. One of the research questions is to determine whether the multiplatform e-learning system actually achieves its goal of improving learner satisfaction (RQ3). This section intends to provide support for research question three (RQ3). To validate this claim, ANOVA paired samples test was conducted between the two systems under evaluation. Paired samples test is commonly used for repeated measures data such as before and after measurements for the same group (segall et al., 2005). The overall learner satisfaction score (LSS) was assigned as the dependent variable for the two e-learning systems. All LSS scores were used irrespective of accessing devices and the ANOVA test was performed. The test supported the claim that multiplatform e-learning system B can achieve its goal of enhancing overall learner satisfaction scores over e-learning system A.

Table 5B.7 depicts the mean difference in overall learner satisfaction score with respect to e-learning system A and multiplatform e-learning system B. The $t(107, -8.114)$ test indicates that there is a significant difference between the mean scores of e-learning system A and B. From Table 5B.7 the mean score of e-learning system B is higher than e-learning system A (6.329 and 4.897). Hence there is evidence that the multiplatform e-learning system B can enhance overall learner satisfaction over the traditional e-learning system A.

Table 5B.7 Paired samples test between systems

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
e-learning system A – e-learning system B	-1.4318	1.8338	.1765	-1.7816	-1.0820	-8.114	107	.000

5B.2.9 Gain in multiplatform e-learning system

Previous analysis had determined that overall the multiplatform e-learning system B can enhance learner satisfaction scores over traditional e-learning system A. RQ3 has effectively being answered. However, to dig further could it be possible that the statistics were biased by a particular accessing device? Thus this section intends to further support research question three (RQ3) by looking into specific device types. With this objective, the system gain is defined as the difference in mean learner satisfaction scores between system B and system A over that of system A, as shown below:

$$Gain = \frac{LSS_B - LSS_A}{LSS_A}$$

To determine if the difference was statistically significant, separate ANOVA paired samples test was performed between system A and system B with the overall learner satisfaction score as the dependent variable for the two e-learning systems over three different accessing devices. Table 5B.8 depicts the respective system gain factors. The results of the ANOVA test clearly indicated that mobile phones achieved the highest gain of 103% and was significant at the 95% confidence level over all the evaluation conditions. This was followed by PDAs with a gain of 20% and was also significant at the 95% confidence level. These results also provided a good indication that content adaptation for mobile device access could achieve a very good return in learner satisfaction scores and that increased the likelihood for adoption. On the other hand, PCs achieved a mere gain of 5% and this was not significant at the 95% confidence level. Therefore, the overall performance result obtained earlier was likely to be biased by the contribution from the mobile devices. This small gain also indicated that adaptation processes on PCs did not achieve as much as desired. One possible explanation is that the PC is already the most familiar system and the learner is capable of adjusting to the system. Another possible reason might be that the experiment conditions did not trigger many significant differences between the two systems with PC access. It may also suggest that the adaptation process may not be uniformly applied across different devices and more specific device dependent adaptation processes may be required.

Table 5B.8 System gain comparison

Device	System A Mean LSS	System B Mean LSS	Gain %	t-value	df	Sig. of the difference (2-tailed)
PC	6.4	6.8	5	-1.928	35	0.062
PDA	5.4	6.5	20	-3.921	35	0.000
Mobile Phone	2.7	5.6	103	-19.076	35	0.000

5B.3 Structure equation modeling

With the use of correlation analysis, the strength and significant of the relationship between the factors and learner satisfaction and the aggregated contribution of each dimension had been examined and validated. The findings may well have already answered all the relevant research questions (SQ1 and SQ2). However by looking deeper into the research questions, a further relevant question could be explored. Are there any interrelationships or interactions between the dimensions that could have an impact on learner satisfaction? This question is also relevant to research questions SQ1 and SQ2. Understanding these interrelationships can be beneficial, for example, designers can establish criteria and priorities for design guidelines to improve the system to achieve better overall learning satisfaction and boost system adoption by modifying dimensions that have strong total impact. Therefore a statistical technique that could reveal such interrelationships is needed. To achieve the objective, structure equation modeling (SEM) at the dimensional level can be used. Structure equation modeling has a number of advantages over other multiple regression techniques, including more flexible assumptions (particularly allowing interpretation even in the face of multicollinearity) (SEM, 2006), the ability to estimate multiple and interrelated dependence relationships and correct for measurement error (Hair et al., 1995). The dimensional level SEM approach involves analysing the interrelationships between the five main dimensions. Thus SEM is suitable for this situation. A two steps approach using measuring model and structural model is adopted (Hair et al., 1995; Anderson and Gerbing, 1988). In addition a comparison between e-learning system A and multiplatform e-learning system B can reveal the transition and evolution effects of the interrelationships.

5B.3.1 Measurement model

First, the independence of the samples was tested for the two e-learning systems. Durbin-Watson values for e-learning system A was 1.753 and 2.127 for e-learning system B. These values are within the guideline of Durbin-Watson statistic (Durbin-Watson, 2005) so the samples can be considered independent. Correlational statistics for the dimensions were generated from the final evaluation data. The correlations indicated discriminant validity for the dimensions. Discriminant validity was assessed by determining the confidence interval around the correlation for each pair of factors. The confidence interval is equal to plus or minus two standard errors of the respective

correlation coefficient. If the confidence interval does not include -1.0 then discriminant validity is demonstrated (Anderson and Gerbing, 1988 p416). The test indicated a good level of discriminant validity for the measures. Table 5B.9 depicts the correlation coefficient, standard error and t-values between dimensions.

Next a separate confirmatory factor analyses for both e-learning systems were further conducted to test their reliability. Table 5B.10 shows the path loadings, error variance, t-values, composite reliability, mean, number of sample and standard deviation for each indicator and dimension. Reliability was assessed by computing the composite reliability coefficients for the dimensions (Hair et al., 1995); composite reliability values greater than 0.6 are desirable (Bagozzi and Yi, 1988). In structural equation modeling composite reliability is a common approach rather than using coefficient alpha (Hair et al., 1995). As indicated in Table 5B.10, the factor loadings for each of the dimensions was rather high except for multimedia (CON-MU) in e-learning system A, and motivation (LER-MO) and preference (LER-PR) in both e-learning systems. A slightly low loading suggested that these measures did not capture the dimension fully and did not behave in the same direction as other measures within the dimension. The loadings were high for other measures which translated into a high and acceptable composite reliability except for LER-MO, LER-PR and CON-MU in e-learning system A. The overall analysis showed good reliability which is consistent with QUIS (Chin et al., 1988).

Convergent validity was established from a review of the t-tests for the factor loadings. All the t-tests were significant, which suggest that all indicators measured the same dimension (Anderson and Gerbing, 1988). Table 5B.10 shows that all of the t-values were greater than 2.0 and significant at $P < 0.01$ (Steenkamp and Van Trijp, 1991) except for CON-MU due to missing data. The missing data for e-learning system A were due to the fact that e-learning system A was not capable to produce the appropriate multimedia during the experiment. For theoretical reason (Chin et al., 1988), these items were kept in the model.

Table 5B.9 Correlation coefficients, standard errors and t-values between dimensions

	LSS	D1	D2	D3	D4	D5
LSS	1					
D1 Content	0.858 (0.021) 40.24	1				
D2 Learner	0.348 (0.064) 5.472	0.496 (0.056) 8.921	1			
D3 Device	0.789 (0.029) 27.416	0.92 (0.014) 64.441	0.416 (0.06) 6.895	1		
D4 Communication	0.813 (0.026) 31.71	0.84 (0.023) 36.316	0.364 (0.063) 5.823	0.865 (0.02) 43.148	1	
D5 Coordination	0.864 (0.02) 43.014	0.901 (0.016) 55.562	0.456 (0.058) 7.917	0.87 (0.02) 44.148	0.856 (0.021) 41.443	1

Table 5B.10 Standardised loading, error variance, t-value, and composite reliability

e-learning system A									e-learning system B								
	Path	Θ	T	CR		Mean	N	SD	Path	Θ	T	CR		Mean	N	SD	
LSS1	0.95	0.10	13.08	0.95		4.7	108	2.3	0.91	0.17	12.17	0.92		6.4	108	1.6	
LSS2	0.95	0.10	13.16			4.5	108	2.4	0.92	0.16	12.22			6.2	108	1.6	
LSS3	0.88	0.22	11.64			4.8	108	2.4	0.84	0.30	10.56			6.2	108	1.7	
LSS4	0.88	0.22	11.54			5.1	108	2.5	0.77	0.41	9.30			6.6	108	1.6	
LSS5	0.67	0.55	7.78			5.5	107	2.0	0.69	0.52	8.03			6.4	108	1.5	
LSS6	0.86	0.26	11.14			4.7	108	2.5	0.74	0.45	8.85			6.1	108	1.8	
					D1								D1				
CON-OR1	0.91	0.17	12.04	0.92	0.93	5.4	108	2.7	0.86	0.27	10.80	0.89	0.97	6.5	108	1.9	
CON-OR2	0.97	0.05	13.51			5.1	108	2.7	0.85	0.28	10.70			6.4	108	1.8	
CON-OR3	0.80	0.37	9.82			5.6	108	2.3	0.87	0.25	11.06			6.8	108	1.6	
CON-GR1	0.79	0.38	8.99	0.75		6.1	108	2.0	0.89	0.21	10.89	0.77		6.9	108	1.5	
CON-GR2	0.88	0.23	10.34			5.8	108	2.4	0.79	0.38	9.27			7.0	108	1.6	
CON-GR3	0.42	0.82	4.26			6.4	107	1.7	0.46	0.79	4.71			6.7	107	1.6	
CON-MU1	0.41	0.83		0.69		6.6	56	1.9	0.89	0.20	11.56	0.95		6.0	102	2.0	
CON-MU2	0.52	0.74				6.7	55	1.8	0.90	0.19	11.83			5.9	103	2.0	
CON-MU3	0.25	0.94				6.5	55	1.9	0.83	0.31	10.27			5.8	103	1.9	
CON-MU4	0.68	0.54				6.4	43	2.5	0.81	0.35	9.14			6.2	81	2.3	
CON-MU5	0.02	1.00				6.9	39	2.2	0.79	0.38	8.75			6.3	79	2.2	
CON-MU6-	0.39	0.85				6.2	52	2.3	0.73	0.46	8.46			5.2	100	2.5	
CON-MU7	0.16	0.98				4.9	17	3.3	0.84	0.30	6.60			4.1	27	3.2	
CON-MU8	0.22	0.95				4.1	16	3.1	0.79	0.38	5.52			3.8	24	3.0	
CON-MU9	0.79	0.38				6.4	65	1.7	0.81	0.34	10.04			5.9	106	2.0	
CON-MU10-	0.57	0.67				6.4	67	2.0	0.76	0.42	9.15			5.9	107	2.2	
CON-MU11-	0.38	0.86				5.2	60	2.5	0.62	0.61	6.90			5.5	103	2.3	
CON-PE1	0.75	0.43	8.98	0.89		6.6	108	1.9	0.76	0.43	9.04	0.90		6.9	108	1.5	
CON-PE2	0.91	0.16	12.07			6.1	108	2.3	0.95	0.10	12.95			6.6	108	1.7	
CON-PE3	0.93	0.13	12.43			6.2	108	1.9	0.90	0.19	11.87			6.6	108	1.7	
CON-PE4	0.67	0.55	7.43			5.7	100	2.2	0.72	0.49	8.27			6.4	103	1.9	
					D2								D2				
LER-EN1	0.82	0.33	10.20	0.94	0.96	7.1	106	1.9	0.82	0.33	10.13	0.94	0.96	7.3	106	1.8	
LER-EN2	0.89	0.20	11.73			7.0	108	2.0	0.88	0.23	11.40			7.2	108	1.9	
LER-EN3	0.92	0.15	12.40			6.9	108	2.2	0.88	0.22	11.52			7.2	108	2.0	
LER-EN4	0.88	0.22	11.52			6.6	108	2.1	0.90	0.20	11.82			6.8	108	1.9	
LER-EN5	0.79	0.37	9.70			6.4	107	2.1	0.88	0.23	11.45			6.8	108	2.0	
LER-HE1	0.92	0.15	12.32	0.91		7.3	107	1.7	0.92	0.15	12.41	0.92		7.3	108	1.7	
LER-HE2	0.94	0.11	12.91			7.1	108	1.7	0.94	0.12	12.71			7.3	108	1.6	
LER-HE3	0.78	0.40	9.46			7.2	108	1.8	0.81	0.35	10.01			7.4	108	1.5	
LER-HE4	0.69	0.52	8.05			6.8	107	1.9	0.68	0.54	7.80			7.1	107	1.8	
LER-HE5	0.77	0.41	9.31			6.8	108	2.0	0.77	0.40	9.36			7.0	108	1.8	
LER-MO1	0.98	0.04	9.46	0.72		7.4	104	2.3	0.80	0.36	8.27	0.65		7.9	105	1.7	
LER-MO2	0.51	0.74	5.09			6.9	107	2.4	0.43	0.81	4.23			7.1	108	2.1	
LER-MO3	0.50	0.75	5.08			6.1	108	2.4	0.60	0.65	6.08			6.7	108	2.0	
LER-PR1	0.67	0.55	6.70	0.73		5.2	108	2.2	0.81	0.35	9.32	0.82		5.9	108	2.0	
LER-PR2	0.65	0.58	6.40			5.3	108	2.1	0.83	0.32	9.65			5.7	108	2.1	
LER-PR3	0.53	0.72	5.07			5.9	107	2.0	0.57	0.67	5.99			6.0	107	1.9	
LER-PR4	0.67	0.55	6.69			5.5	108	2.4	0.71	0.50	7.84			6.3	108	2.1	
					D3								D3				

DEV-PR1	0.90	0.20	11.83	0.94	0.97	5.5	108	2.2	0.87	0.25	11.17	0.94	0.970	5.9	108	2.0
DEV-PR2	0.90	0.19	11.74			5.7	100	2.1	0.89	0.22	11.58			5.7	108	2.3
DEV-PR3	0.92	0.16	12.37			5.8	108	2.1	0.87	0.24	11.24			5.8	108	2.1
DEV-PR4	0.86	0.26	10.83			5.7	100	2.4	0.88	0.22	11.33			5.9	101	2.2
DEV-PR5	0.79	0.37	9.58			6.2	103	2.3	0.86	0.27	10.86			6.3	104	2.1
DEV-PR6	0.79	0.38	9.42			5.2	100	2.2	0.78	0.39	9.31			5.6	100	2.0
DEV-PR7	0.68	0.53	7.93			4.8	108	2.8	0.66	0.56	7.56			5.0	108	2.7
DEV-ER1	0.82	0.32	10.35	0.96		6.4	107	2.5	0.86	0.25	11.10	0.94		6.8	107	2.1
DEV-ER2	0.86	0.26	11.15			5.8	108	2.5	0.83	0.30	10.51			6.4	108	2.1
DEV-ER3	0.90	0.19	11.96			6.2	107	2.4	0.88	0.22	11.46			6.9	107	1.8
DEV-ER4	0.91	0.17	12.24			5.9	107	2.5	0.88	0.23	11.35			6.5	107	2.1
DEV-ER5	0.91	0.18	12.08			5.5	108	2.5	0.86	0.27	10.96			6.1	108	2.2
DEV-ER6	0.91	0.18	12.08			6.0	107	2.3	0.83	0.31	10.36			6.5	106	1.9
					D4								D4			
COM-RE1	0.97	0.06	13.66	0.98	0.98	4.6	105	2.7	0.98	0.05	13.82	0.98	0.974	6.2	105	2.5
COM-RE2	0.99	0.02	14.23			4.8	107	2.6	0.98	0.04	13.93			6.4	107	2.4
COM-RE3	0.94	0.12	12.85			4.9	104	2.6	0.94	0.11	12.98			6.4	104	2.3
COM-ST1	0.92	0.15	11.79	0.86		5.3	108	2.5	0.93	0.14	12.09	0.86		6.4	108	2.0
COM-ST2	0.66	0.56	7.41			5.5	108	2.3	0.64	0.59	7.20			6.0	108	2.2
COM-ST3	0.85	0.28	10.34			5.5	105	2.6	0.86	0.25	10.73			6.6	103	2.2
COM-DE1	0.97	0.06	13.69	0.96		5.2	108	2.4	0.94	0.11	12.96	0.93		6.3	108	2.0
COM-DE2	0.99	0.03	14.21			5.3	108	2.4	0.97	0.07	13.52			6.4	108	2.0
COM-DE3	0.85	0.28	10.97			5.2	108	2.5	0.81	0.34	10.16			6.3	108	2.0
					D5								D5			
COO-NA1	0.89	0.22	11.58	0.93	0.97	5.1	108	2.6	0.89	0.21	11.64	0.91	0.964	6.5	108	1.9
COO-NA2	0.83	0.31	10.50			5.7	108	2.4	0.85	0.27	10.88			6.8	108	1.9
COO-NA3	0.72	0.48	8.53			5.7	108	2.3	0.75	0.44	8.95			7.0	108	1.9
COO-NA4	0.85	0.28	10.86			5.7	107	2.3	0.77	0.40	9.34			6.6	108	1.7
COO-NA5	0.85	0.29	10.34			5.2	93	2.5	0.75	0.43	8.55			6.3	93	1.9
COO-NA6	0.83	0.31	10.34			5.7	105	2.5	0.77	0.41	9.12			6.7	104	1.9
COO-IN1	0.90	0.19	11.85	0.91		5.6	108	2.4	0.91	0.17	12.04	0.87		6.8	108	1.8
COO-IN2	0.81	0.34	10.05			5.9	108	2.3	0.82	0.32	10.21			6.6	108	2.0
COO-IN3	0.88	0.23	11.33			6.2	108	2.1	0.82	0.34	10.06			6.9	108	1.5
COO-IN4	0.81	0.34	10.00			5.8	105	2.5	0.61	0.63	6.77			6.6	108	1.8
COO-PR1	0.88	0.22	11.54	0.94		5.2	108	2.5	0.80	0.36	9.87	0.93		6.1	108	2.0
COO-PR2	0.88	0.23	11.49			4.7	108	2.5	0.91	0.17	12.17			5.8	108	2.1
COO-PR3	0.97	0.05	13.70			4.9	108	2.4	0.98	0.04	13.71			6.1	108	2.0

5B.3.2 Dimensional level SEM

Unlike correlation analysis, structural equation modeling allowed the entire dimension's relationships to be simultaneously formulated (Hair et al., 1995). At the dimensional level SEM is used to determine the interactions among the five main dimensions and the impact on learner satisfaction. The following hypotheses derived from the research questions (SQ1 and SQ2):

H1: The content dimension (D1) has a direct impact on LSS.

H2: The learner dimension (D2) has a direct impact on LSS.

H3: The device dimension (D3) has a direct impact on LSS.

H4: The communication dimension (D4) has a direct impact on LSS.

H5: The coordination dimension (D5) has a direct impact on LSS.

The followings hypotheses derived from theories and findings gained from previous data analysis:

H6: D1 has a direct impact on D2.

H7: D3 has a direct impact on D1.

H8: D3 has a direct impact on D5.

H9: D4 has a direct impact on D3.

H10: D5 has a direct impact on D4.

To establish a neutral structural model so that it will not bias either system A or system B, the model is first fitted using Analysis of Moment Structures software (AMOS) with all the data combined. Repeated measures data can be used in structural equation modelling (SEM, 2006; MLM, 2006). Using multi-level analysis or aggregation is normally recommended (MLM, 2006). However, multi-level analysis would imply more paths and more samples would be needed. Thus the multi-level approach was not adopted because of limited sample size and an aggregated approach was adopted. In essence aggregation creates a composite indicator that has psychometric and model advantages (Little et al., 2002; McDonald et al., 2005, p3). For each dimension, aggregations were done on all the sub-dimension scores to produce a single dimension score. As the sample size was not very large compared to the number of paths, aggregation helped to reduce system noise and make distribution becomes more normally distributed (Little et al., 2002; McDonald et al., 2005, p3). The fit indexes from the combined model achieved a χ^2 (chi-square) = 1.917 with DF (Degree of freedom) = 5, N=216 at P=0.861. The ratio of χ^2 /DF = 0.38 which is less

than the recommended 3:1. Other fitness indicators were found to be GFI (Goodness of fit index) =0.997, AGFI (Adjusted goodness of fit index) =0.987, NFI (Normed fit index) =0.999, TLI=1.07, and RMSEA (Root mean square error of approximation) =0. Note that because $\chi^2/DF < 1$ thus RMSEA was set to zero in the formula. These indexes provided further support that the overall model fits very well within the established fitness guideline. In the combined model, the path from D3 to LSS was only -0.03 and was not significant. This path was deleted from the model. Once the overall model fitted well with all the data, a group comparison of the model using data from system A and system B was performed. The resulting model is shown in Figure 5B.13 and their fit indexes are shown in Table 5B.11. All paths were significant at the 0.001 level unless otherwise stated.

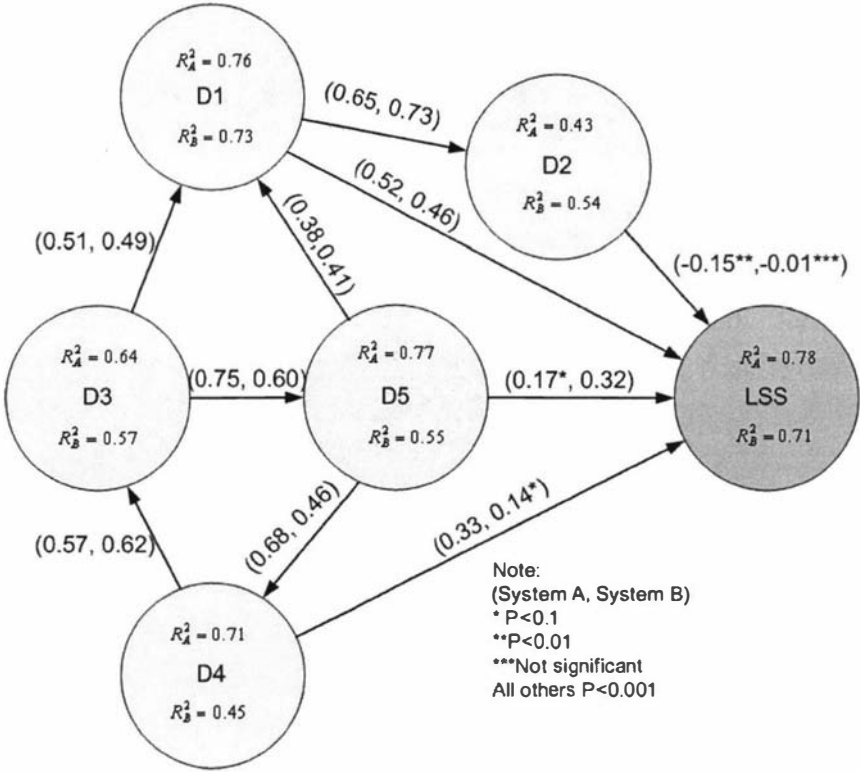


Figure 5B.13 Dimensional level SEM (standardized)

Table 5B.11 Fit indexes for dimensional level SEM

System	CMIN	DF	P	CMIN/DF	RMR	GFI	NFI	RFI	RMSEA
combine	1.91	5	0.86	0.38	0.01	0.99	0.99	0.99	0.00
A	2.95	5	0.71	0.59	0.03	0.99	0.99	0.99	0.00
B	0.94	5	0.97	0.19	0.01	1.00	0.99	0.99	0.00

Table 5B.12 Summary of hypotheses

Hypothesis	System A	System B
H1: The content dimension (D1) has a direct impact on LSS.	Supported	Supported
H2: The learner dimension (D2) has a direct impact on LSS.	Supported at 0.01 level	Not supported
H3: The device dimension (D3) has a direct impact on LSS.	Not supported	Not supported
H4: The communication dimension (D4) has a direct impact on LSS.	Supported	Supported at 0.1 level
H5: The coordination dimension (D5) has a direct impact on LSS.	Supported at 0.1 level	Supported
H6: D1 has a direct impact on D2.	Supported	Supported
H7: D3 has a direct impact on D1.	Supported	Supported
H8: D3 has a direct impact on D5.	Supported	Supported
H9: D4 has a direct impact on D3.	Supported	Supported
H10: D5 has a direct impact on D4.	Supported	Supported

*Supported at 0.001 levels unless otherwise stated.

Table 5B.13 Impact on LSS

Dimension	System A			System B		
	Direct	Indirect	Total	Direct	Indirect	Total
D1	0.524	-0.102	0.422	0.467	-0.013	0.454
D2	-0.155	0	-0.155	-0.017	0	-0.017
D3	0	0.92	0.92	0	0.694	0.694
D4	0.333	0.529	0.862	0.143	0.435	0.578
D5	0.179	0.754	0.932	0.32	0.456	0.776

5B.3.3 Findings on dimensional level SEM

From the structure equation model, only H1 and H5-H10 were supported at the 0.001 level whereas H4 was supported at the 0.1 level for multiplatform e-learning system B. These results demonstrated that interactions and interrelationships among

dimensions were strong and significant, implying indirect impacts on LSS were strong and significant as well. Direct impacts were due mainly to D1 and D5. Direct impact due to device dimension D3 can not be supported in both systems. Direct impact from D2 was supported in system A at the 0.05 level and not supported in system B. From observations it is likely that both D2 and D3 (the direct path was -0.03) have similar characteristics. A summary of the hypotheses is shown in Table 5B.12.

Both system A and system B SEM appeared to fit well and with good fit statistics as shown in Table 5B.11. The fit statistics seem slightly better for system B than system A. Because system A is a non adaptive system, this may suggest that data from system A has a wider variance than that of system B. Nevertheless both models can satisfactorily explain the effect of all the dimensions on overall learner satisfaction.

For system B the direct impact on overall learner satisfaction due to the learner dimension (D2) has been reduced to statically insignificant with a path estimate of -0.01 while for system A the direct impact due to the learner dimension (D2) on overall learner satisfaction is significant at the 0.05 level with a path estimate at -0.15. The learner dimension has become less negative (more positive) and the content dimension (D1) has improved in total impact on multiplatform e-learning system B compared to e-learning system A. All other dimensions D3, D4, D5 had reduced their total impact as well. This effect is similar to the previous findings.

The direct impacts in system A were contributed mostly by the content dimension (D1) and communication dimension (D4) while the direct impacts in system B were contributed mostly by the content dimension (D1) and coordination dimension (D5). It is likely that in system B the communication dimension (D4) was perceived positively. An acceptably fast response in system B allowed learners' attention to focus on D5 and experience the interactions, navigations and presentation aspects of the system. Conversely in system A the response was slow and the communication dimension (D4) is perceived negatively and its impact is felt. Learners did not get the necessary chance to experience the interaction, navigation and presentation contributed by the coordination dimension (D5).

The coordination dimension (D5) had a strong impact on the communication dimension (D4) in system A than in system B. The implication may be that in system B the learner has experienced more consistency in navigation, presentation and interaction and is likely also to be associated with a stable system and suitable form of delivery. Similarly the impact of the device dimension (D3) on the coordination

dimension (D5) was also very strong in system A than in system B. A more consistency experience in D3 was likely to be associated with a consistency experience in coordination dimension (D5). Among all the interactions between various dimensions, content dimension (D1) had the greater impact on learner dimension (D2).

Referring to Table 5B.13, the total impact from each dimension on LSS had been equalised with less spread in system B compared to system A. The implication was that the outcome of the adaptation process allows learners to have better opportunities to experience all the other factors instead of being dominated by a single dimension as in the device dimension (D3) or coordination dimension (D5) of system A.

Surprisingly, the learner dimension (D2) has a negative path value in both systems. This suggests that D2 might be a suppressor. According to Cohen and Cohen (1975, p. 91), there are three kinds of suppressors. If the predictor variable in question has a zero or very small correlation with the criterion variable, the situation is one of classical suppression. If its beta weight is of opposite sign from its correlation with the criterion, it is serving as a net suppressor. If its beta weight exceeds its correlation with the criterion and is of the same sign, cooperative suppression is indicated.

Further, Darlington (1968) defined a negative suppressor as a variable that has a positive correlation with the dependent variable, but negative beta weight in the regression model. Further analysis shows that D2 itself has a positive correlation with LSS but a negative weight in the full model. This suggests that D2 is a net suppressor. According to Thomson (1998) suppressor variables are important within a regression model because they increase the effect size which shows the extent, strength or effect of a relationship and accounts for the total variance. Further investigation showed that the overall model fit index improved when D2 is present. The suppressing effect was greater in system A than in system B. Thus it is likely that the adaptation process has minimised the suppression, making it more positively correlated.

In summary the model suggests that there are two types of factors—a suppressor and a non suppressor. D1, D4 and D5 were non suppressors whereas D2 (and possibly D3) was a suppressor. The suppressor effect was minimised in system B. The model also suggested that interactions between dimensions were significant in both systems, whereas the direct impact from factors to LSS was not at all significant. Hypotheses H2 and H3 were not supported at the 0.001 level whereas H4 was only supported at

the 0.1 level for system B. Primary and secondary factors were also revealed in the model.

5B.4 Summary of chapter 5

The relationships of the factors constituting the multiplatform e-learning system have been thoroughly examined. Through empirical evaluation and six different experiment conditions, the interactions between learners and the e-learning systems were varied. Data gathered from the experiments were analysed through ten different approaches and findings are depicted in Table 5B.14. Analysing these sets of data further identified, confirmed, validated, and cross validated the findings with regards to the research questions. Several appropriate evaluations and analyses allowed these goals to be achieved. First, the pilot evaluation played an important role in fine tuning the initial system for the final evaluation. Next, the final evaluation and statistical tests confirmed that the multiplatform e-learning system achieved a higher overall learner satisfaction score than the non adaptive e-learning system. The mean overall learner satisfaction score was higher for multiplatform e-learning system B than traditional e-learning system A. Third, the correlation analysis confirmed the significance of the factors influencing overall learner satisfaction. While not all factors carried equal strength, the most influential factors were identified to be content organisation (CON-OR), delivery mode (COM-DE), navigation (COO-NA), and device ergonomics (DEV-ER). In addition, similar findings were revealed while analysing the interview and qualitative data. Correlation analysis revealed that D5, D3 and D4 were strong dimensions affecting overall learning satisfaction in e-learning system A. D5, D1 and D3 were strong dimensions affecting overall learning satisfaction in the multiplatform e-learning system B. Further analysis revealed two different groupings of factors. Primary factors, also known as hygiene factors, dominated in the non adaptive e-learning system, and secondary factors, also known as motivation factors, emerged in adaptive e-learning system, due to equalisation effect. Lastly, the use of structure equation modelling revealed more detailed relationships between dimensions which were not possible with the correlation technique. SEM validated the existence of interrelationships among dimensions. The dimensional level structure equation modeling indicated that direct impact due to the device dimension (D3) on LSS was not supported. SEM also identified D2 (possibly D3) as a suppressor and cross validated the findings regarding primary factors and secondary factors.

Table 5B.14 Summary of main findings

Analysis	Main findings for multiplatform e-learning system
1. Pilot evaluation	<ul style="list-style-type: none"> a. Exposed limitations of emulators. b. Exposed weakness in animated images over interactive images. c. Exposed mobility and portability deficiency. d. Showed content design with mobile devices can be difficult to satisfy.
2. Overall learner satisfaction score (RQ3)	<ul style="list-style-type: none"> a. Identified multiplatform e-learning system satisfaction score to be higher than e-learning system A. b. Identified LSS for PC > PDA > mobile phone within each system. c. Highest mean learner satisfaction score was only 6.7/9 or 74.45%.
3. Self-directed exploring condition (RQ2)	<ul style="list-style-type: none"> a. Mobile devices generated 89% of the queries. b. Ergonomic issues with mobile phones can be aggravated. c. Identified the need to ensure participants comply with written instructions. d. Identified the need to ensure learners acquired the acceptable skill level.
4. Degree of influence and relationship (SQ1)	<ul style="list-style-type: none"> a. Validated all factors as relevant, valid and significant. b. Not all factors contributed equally but were more equally distributed in the multiplatform e-learning system. c. Identified the most influential factors as CON-OR, COM-DE, COO-NA, COO-IN, and CON-PE d. Identified the most influential dimensions in order as D5, D1, D3, D4 and D2.
5. Grouping behaviour (SQ2)	<ul style="list-style-type: none"> a. Identified secondary factors as CON-GR and CON-PE in D1 and LER-EN, LER-HE, LER-MO and LER-PR in D2. b. Identified primary factors as D3, D4 and D5.
6. Interview data (RQ2, SQ1)	<ul style="list-style-type: none"> a. Identified CON-PE, CON-OR to be influential. b. PDA stylus can create ergonomic issues. c. Content design for multimedia object with small screen size can be difficult. d. "Zooming" and "show all" feature can be difficult to use in PDAs.
7. Qualitative data (RQ2, SQ1)	<ul style="list-style-type: none"> a. Multiplatform e-learning system is preferred with PCs, PDAs and mobile phones. b. Identified the most liked factors as COM-RE, DEV-ER, CON-PE, and COO-NA. c. Identified the most disliked factors as DEV-ER, COO-NA, DEV-PR, COM-RE, and LER-PR d. Identified dominant primary dimensions as D3, D4, D5 and secondary factors as D1 and D2.
8. Satisfaction test (RQ3)	<ul style="list-style-type: none"> a. Validated multiplatform e-learning system as perceived to be more satisfying.
9. Gain in multiplatform e-learning system (RQ3)	<ul style="list-style-type: none"> a. Validated gain biased toward mobile devices. b. Adaptation process need not necessarily be uniformly applied. c. Device dependent adaptation process may be required.
10. Structure equation modelling (SQ1, SQ2)	<ul style="list-style-type: none"> a. Validated interrelationships among dimensions. b. Identified D1 and D2 as secondary factors, D3, D4, and D5 as primary factors. c. Identified that D1 and D5 have strong direct impact and D3 and D5 have strong indirect impact. d. Identified D2 (possibly D3) as a suppressor.

Chapter 6 Discussion and implications

6.1 Implications

One of the major contributions of the present research is the development of the multiplatform e-learning system framework. Through this framework, experiments were conducted to determine learning satisfaction as perceived by learners. Findings through statistical data analysis provided several implications for implementation on multiplatform e-learning systems. First there is an implication for improving multiplatform e-learning systems. The success of the present research and evaluation can be duplicated in system improvement through the use of multiplatform e-learning system questionnaires (MELQs) and the experiment process. Second, the research identified several key system characteristics such as the spreading effect, equalisation effect, suppressor effect and grouping effect. The implication is that these effects can serve as useful determinants to quantify the stability and acceptance level of the multiplatform e-learning systems. Third, similar findings on the relationship between learner dimension (D2) and learning satisfaction which were also shared by other researchers. The implication for improving learning satisfaction is that designers should first focus on other critical dimensions rather than considering the learner dimension as their first priority.

6.1.1 System improvements

The evaluation experiments, measuring instrument and statistical data analysis techniques can provide a systematic methodology that is useful for identifying issues for multiplatform e-learning systems improvement. Although the mean score gathered from MELQ questionnaire can normally be used to identify factors that have a lower score with respect to a benchmark situation, it does not necessarily mean that the factor will have a strong impact on overall learner satisfaction. With resource constraints, factors with the lowest score and which have the highest total impact on LSS should be identified. Use of these factors will provide an effective way for improving the system. A heuristic algorithm is provided here to demonstrate the process of improving overall learning satisfaction. First the bottom five factors for each accessing device from the MELQ questionnaire were identified. Second, using dimensional level SEM one can identify and rank the dimensions according to their total impact on overall learning satisfaction. Next, assign these rankings to the five factors found in step 1. In the event that some of the factors have identical rankings,

the correlation coefficients ranking can be used to allocate priority. Factors ranked as high priority should be looked into closely for enhancement. Once all the improvements have been made, experimental tests can be repeated to gather new data. The process is repeated until improvement is marginally within an acceptable value. For example, in the present case the dimensional level SEM indicates that coordination dimension (D5) has the highest total impact on LSS and device dimension (D3) has the second highest total impact on LSS. Table 6.1 depicts the bottom five factors with their total impact ranking and correlation ranking. These factors should therefore be considered for further improvement according to their ranking criteria. For PCs, presentation in the device dimension (DEV-PR) should be considered first and environment in the learner dimension (LER-EV) should be considered last. Similarly in PDAs, presentation in the coordination dimension (COO-PR) should be considered first and multimedia in the content dimension (CON-MU) should be considered last. Lastly in mobile phones, presentation in the device dimension (DEV-PR) should be considered first and multimedia in the content dimension (CON-MU) should be considered last.

An alternative approach to improve learner satisfaction in multiplatform e-learning systems is to use a two dimensional visualisation method (B2B, 2005). This method uses the correlation coefficients on the X-axis and the specific items (factors) score on the Y-axis. Items with high score and high correlation coefficients are desirable. Items with high correlation coefficients and low score will need to be improved. In essence this method is similar to the recommended heuristic approach.

Table 6.1 Heuristic approach for system improvement

	Factors, impact rank and correlation rank				
PC	DEV-PR 2(6)	CON-GR 4(10)	CON-MU 4(11)	LER-PR 5(9)	LER-EN 5(16)
PDA	COO-PR 1(7)	DEV-PR 2(6)	COM-RE 3(12)	COM-ST 3(13)	CON-MU 4(11)
Mobile Phone	DEV-PR 2(6)	DEV-ER 2(8)	COM-DE 3(2)	COM-RE 3(12)	CON-MU 4(11)

Comparing the SEM method and correlation coefficient method, one can see that the correlation method can also provide indications of the dimensions with potentially

large total impact. With the correlation method it is difficult to tell how much impact these indicators have and how they are affected by other factors. The correlation method cannot provide the causal inter-relation among dimensions. While correlation methods can provide a list of parameters for improvement, the effect of each dimension and sub dimension on overall learning satisfaction is difficult to establish. SEM is able to reveal the total impact at the expense of computation and model fitting.

6.1.2 System characteristics

Through statistical analysis, the inter-relationships between each dimension (D1, D2, D3, D4, and D5) were observed to behave according to the following effects:

- a. Spreading effect—when an e-learning system is not designed for a multiplatform accessing environment such as e-learning system A in this study (based on commercial BlackBoard system), the factors influencing overall learning satisfaction could have a larger spread. Some factors will be highly correlated while some factors will be lowly correlated. The resulting effect is that standard deviation of correlation coefficients between factors and LSS is much higher than in the case of a multiplatform e-learning system. It also indicates that the learner perceived the system to be less stable and less consistent.
- b. Equalisation effect—when an e-learning system is designed for a multiplatform accessing environment such as system B in this study (the multiplatform e-learning system with adaptivity features), the factors influencing overall learning satisfaction will be equalised. The spreading effects will be reduced to give all factors the opportunity to contribute to the LSS. Due to the equalising effect the standard deviation of the correlation coefficient between LSS and factors is much smaller.
- c. Grouping effect—two groups have been identified. Primary factors and secondary factors exist within the list of factors influencing learner satisfaction. A higher degree of influence from secondary factors emerges only when primary factors are perceived to be satisfactory. D3, D4, and D5 are associated with primary factors while D1 and D2 are associated with secondary factors.
- d. Suppressor effect—learner dimension D2 has been identified to be a suppressor. A suppressor reduces the impact on learner satisfaction. In a multiplatform e-learning system, the suppressor effect is minimised.

The implication is that these system characteristics can serve as useful determinants to quantify the stability and acceptance level of multiplatform e-learning systems. For example, if the suppressor effect is reduced after a few design iterations, it is likely that the system is reaching stability. If equalisation effect exists to the extent that correlation coefficients become a weak indicator, designer would have to adopt other techniques to identify factors or dimensions that have greater impact on learner satisfaction. The structure equation modelling technique will be very useful.

6.1.3 Learning theories

The evaluation results showed a lower degree of relationship between learner dimension D2 and overall learning satisfaction in e-learning system A. These results were revealed by both correlation analysis and the structure equation model. Kearsley (2000) and Kim and Moore (2005) in their studies reported that learning styles did not seem to have any significant impact on the level of satisfaction with web-based courses. While the current findings seemed similar, caution must be taken as the current research involved multiple accessing devices and a short duration when participants were exposed to the e-learning system for data collection. However, the current findings showed a strong relationship between interaction in coordination dimension (COO-IN), navigation in coordination dimension (COO-NA) and overall learning satisfaction scores which is similar to the findings of Kearsley (2000) and Kim and Moore (2005). Thus interaction can be a significant factor affecting learner satisfaction in single as well as multiplatform e-learning systems. The implication for improving learning satisfaction is that designers should first focus on dimensions with strong relationships rather than giving the learner dimension first priority.

6.2 Limitations

The evaluation and findings come with some limitations. First, the evaluation was conducted with learners having short term usage of the e-learning systems. Though e-learning system A represents a familiar site with longer term usage its content was somehow not familiar to most learners. Thus further evaluation would need to determine the long term effect when learners were familiar with the e-learning system and content. Second, the experience with mobile devices and browsers is another area that needs further investigation into its long term effect. While almost all learners were familiar with sending SMS and had had other interactive experiences, these

experiences did not make it any easier for them to use mobile browsers. The long term effect of using a specific device and browser would expose learners to potential problems and give them the opportunity to resolve the problems much earlier. It is envisaged that some of the issues with regards to device ergonomics and delivery mode may be neutralised after the learner has spent sufficient time with the device. These experiences would have an impact on learner satisfaction and need further investigation. Third, the evaluation was performed using high school level physics as the subject. Learners spent a short time (minutes) trying to understand the content during the evaluation process. Thus if learners were exposed to the content in the classroom for a longer time frame (weeks), there might be some impact on the content dimension and its overall learner satisfaction as perceived by the learners. Fourth, while the experiments were intended to vary the interactions between the learner and the system as much as possible, there is no guarantee that all the factors will be equally affected. It is also unlikely that one can control only one particular factor at a time to capture the effect independently as these factors act together. Fifth, the pedagogy of the implemented e-learning system consists of first exposing learners to theory and principles, then multimedia simulation, followed by exercises. During the exercises, learners were encouraged to revisit the content and multimedia interaction. The evaluation is based on such pedagogy. Sixth, the design for experiment and data analysis can be improved to provide data independence and longitudinal comparison. Lastly, the current research used three different types of accessing devices. The results can only be generalised to devices with similar capabilities. New devices with very different interaction potential can be tested with the same instrument.

Chapter 7 Conclusion

This research began by asking the question, what constitutes to a multiplatform e-learning system. In order to answer this question, the factors influencing learner satisfaction in multiplatform e-learning systems were explored. Through the extensive and multidisciplinary literature review presented in chapter 2, a framework for multiplatform e-learning systems was successfully constructed and developed. The framework constituted five core competency dimensions: content dimension, learner dimension, devices dimension, communication dimension and coordination dimension. Within each dimension various sub-dimensions exist as depicted in Table 3.1. Five competency principles were also identified to necessitate the adaptive capability of the e-learning systems. Chapter 3 detailed the construction of the framework. The framework was further operationalised to validate its usefulness through an implementation. Chapter 4 provided details of the implementation of a prototype e-learning system based on the adaptive multiplatform e-learning system framework and the five competency principles. Chapter 4 also presented a conceptual layered architecture mapped from the multiplatform e-learning system framework. The implementation was based on several technologies such as XML, XSLT, DOM, ASP, detection and estimation algorithms and Flash multimedia. In chapter 5A and 5B, learner satisfaction was evaluated through six experiments. The evaluation showed that in e-learning system A, there was a spreading effect on factors, while multiplatform e-learning system B exhibited equalisation and suppressor effects. Grouping effects such as primary factors and secondary factors clearly emerged from e-learning system A to e-learning system B. The final evaluation and statistical tests confirmed that the multiplatform e-learning system achieved a higher overall learner satisfaction score. The correlation analyses confirmed the significance of the factors influencing overall learner satisfaction. The most influential factors were identified to be content organisation (CON-OR), delivery mode (COM-DE), navigation (COO-NA), and device ergonomics (DEV-ER). The significance and relationship of the factors allow designers to set criteria and further improve the e-learning system to achieve a better experience in the adoption of multiplatform e-learning systems. A heuristic approach for system improvement was presented in chapter 6. Chapter 6 also discussed some of the limitations in this research.

For the benefits of future research, several areas can be explored further. First, with respect to technology implementation, there is a need to investigate other emerging technologies to implement the multiplatform e-learning systems. For example, comparing the implementation using autonomous agents and web services with respect to performance, adaptivity and extensibility may generate a more robust multiplatform e-learning system. Second, current research used Flash technology as the main component for interactive multimedia objects. With the advent and adoption of SVG-tiny, future implementations should explore this technology from both server and client sides. Third, with respect to framework extension, there might be a need to study non web based accessing platforms with very low similarity in content factors. One such example would be to explore short message services (SMS) and multimedia messages services (MMS) as additional accessing channels. Another possibility is to explore iPod devices as a delivery channel. Whether the popularity and ergonomic factors could overcome its limitations in content design and delivery will be an interesting area to explore. Fourth, with respect to learning theory, there are some relationships between adaptive multiplatform e-learning systems and multiple representation theory but they are not fully understood. One question is whether delivering slightly different content in different platforms constitutes a different representation? Another issue is to quantify the effect and impact of multiple representations in multiplatform e-learning systems on the learner. These questions will have implications for the theory of multiple representations. Fifth, with respect to system evaluation, resource constraints can be a major factor in how evaluations can be conducted and this factor certainly affects the size of the sample. Sample size will have implications on the type of analysis tool able to support the evaluation. For example, structure equation modeling is a powerful tool that requires a large sample size. The current evaluation focused on basic issues of factors influencing learner satisfaction based on the adaptive framework and modified QUIS instrument. There are other equally important perspectives such as Keller's attention, relevance, confidence and satisfaction (ARCS) motivational model (Small 1997; Dempsey et al. 1997) and website motivational checklist WEBMAC (Small & Arnone, 1999), and the technology acceptance model (TAM) (Davis 1989, 1993) that could facilitate evaluation. An integrated and comparative approach to these evaluation instruments can be useful in predicting the adoption and effectiveness of the system. Finally, the current research focused on the tertiary education level but adaptive multiplatform e-

learning systems should be available to all levels of learning. Future research can investigate how multiplatform e-learning systems, especially mobile platforms, can address the needs of learners at different levels.

To conclude, with the successful development of the multiplatform e-learning systems framework, developers and adopters can now adopt the framework to systematically capture relevant requirements for the construction or acquisition of multiplatform e-learning systems. The current framework is not restrictive. It can be expanded to cater for new technologies, access devices, services, learning environments and context of use. Because the multiplatform e-learning systems framework looked at generic and fundamental issues by focusing on several aspects such as mobile learning, content adaptation, and learner satisfaction, researchers can scaffold on the current framework to conduct further research into other aspects of multiplatform e-learning systems as suggested earlier. Through condition-based usability experiments and several data analysis techniques such as correlation and structure equation modelling, this research was able to identify each factor, its relationships with other factors and its level of influence over learner satisfaction. The research also validated the assertion that adaptive systems can provide better learner satisfaction than non-adaptive systems in the context of multiplatform e-learning systems. Thus developers and researcher can use the evaluation methodology devised in this study to measure the relationships and validate future multiplatform e-learning systems enabling them to investigate, verify, enhance and invest in factors that have significant impact on learner satisfaction. This understanding will help institutions and educators to make the right investment decision in the eventual adoption of multiplatform e-learning systems and to a greater extent provide sound technology for students to embark on lifelong learning anytime, anywhere and through a variety of devices.

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Appendix A

Scripts and codes

Listing 1 Main learning content

```
<?xml version="1.0" standalone="no"?>
<?xml-stylesheet type="text/xsl" href="M3.xsl"?>
<module_content>
  <New_module ID="1">
    <mtitle>Color Basic</mtitle>
    <sub_module>
      <stitle>Additive Color</stitle>
      <line>Color system can be classified either as "additive" color or
"subtractive" color.</line>
      <line>Additive Colors (Mixtures of Light)</line>
      <line>RGB (Red-Green-Blue) is an "additive" color system used in display
monitors where light is mixed.</line>
      <line>Examples:</line>
      <line>Black + Red = Red</line>
      <line>Black + Green = Green</line>
      <line>Black + Blue = Blue</line>
      <line>Black + Red + Green = Yellow</line>
      <line>Black + Red + Blue = Magenta</line>
      <line>Black + Blue + Green = Cyan</line>
      <line>Black + Red + Green + Blue = White</line>
      <line>RED +GREEN = YELLOW</line>
      <line>Click here to see a color mixing interaction</line>
    </sub_module>
    <sub_module>
      <stitle>Subtractive Color</stitle>
      <line>Color system can be classified either as "additive color" or
"subtractive color".</line>
      <line>Subtractive Colors (Mixtures of Pigments)</line>
      <line>CMY (Cyan-Magenta-Yellow) and CMYK (Cyan-Magenta-Yellow-
black) are "subtractive" color systems used in printing where inks or pigments are
mixed.</line>
      <line>Examples:</line>
      <line>White - Red = Cyan</line>
      <line>White - Green = Magenta</line>
      <line>White - Blue = Yellow</line>
      <line>White - Red - Green = Blue</line>
      <line>White - Red - Blue = Green</line>
      <line>White - Blue - Green = Red</line>
      <line>White - Red - Green - Blue = Black </line>
      <line>click here to see a color mixing interation</line>
    </sub_module>
    <sub_module>
      <stitle>Exercise</stitle>
    </sub_module>
  </New_module>
</module_content>
```

```

</New_module>
<New_module ID="2">
  <mtitle>Lens</mtitle>
  <sub_module>
    <stitle>Lens Basic(physics, 2005)</stitle>
    <line>A lens is merely a carefully ground or molded piece of transparent
material which refracts light rays in such a way as to form an image.</line>
    <line>Lenses can be thought of as a series of tiny refracting lenses, each of
which refracts light to produce their own image. When these prisms act together, they
produce a bright enough image focused at a point.</line>
    <line>There are a variety of types of lenses. Our focus will be upon lenses
which are symmetrical across their horizontal axis - known as the principal axis. In
this module, we will study converging lens. </line>
    <line>A converging lens is a lens which converges rays of light which are
traveling parallel to its principal axis. Converging lenses can be identified by their
shape; they are thicker across their middle and thinner at their upper and lower edges.
</line>
    <line>Refraction Rule for a Converging Lens </line>
    <line>Any incident ray traveling parallel to the principal axis of a
converging lens will refract through the lens and travel through the focal point on the
opposite side of the lens. </line>
    <line>Any incident ray traveling through the focal point on the way to the
lens will refract through the lens and travel parallel to the principal axis. </line>
    <line>An incident ray which passes through the center of the lens will in
effect continue in the same direction that it had when it entered the lens.
</line>
    <line>Click here to see ray tracing of converging lens</line>
  </sub_module>
  <sub_module>
    <stitle>Lens Basic</stitle>
    <line>Real Image and Virtual Image</line>
    <line>Converging lenses can produce both real and virtual images. The
process by which images are formed for lenses is the same as the process by which
images are formed for plane and curved mirrors. </line>
    <line>Images are formed at locations where any observer is sighting as they
view the image of the object through the lens. So if the path of several light rays
through a lens is traced, each of these light rays will intersect at a point upon
refraction through the lens. Each observer must sight in the direction of this point in
order to view the image of the object. While different observers will sight along
different lines of sight, each line of sight intersects at the image location. </line>
    <line>A real image is formed whenever refracted light passes through the
image location. While diverging lenses always produce virtual images, converging
lenses are capable of producing both real and virtual images. As shown above, real
images are produced when the object is located a distance greater than one focal
length from the lens. </line>
    <line>A virtual image is formed if the object is located less than one focal
length from the converging lens. </line>
    <line>Click here to see ray tracing of converging lens</line>
  </sub_module>
</sub_module>

```

```

    <style>Exercise</style>
  </sub_module>
</New_module>
<New_module ID="3">
  <mtitle>Color Depth And Resolution</mtitle>
  <sub_module>
    <style>Resolution</style>
    <line>Pictures on a computer screen are made up of thousands of tiny dots,
known as pixels (short for picture element). Depending on the size of the dots, a
different number of dots can fit on a computer screen.</line>
    <line> If the dots are small, a large number will fit on the screen. However,
if the dots are large, it takes just a few dots to fill the whole screen. The more dots on
the screen, the clearer the picture will be.</line>
    <line>How many dots?</line>
    <line>The word "resolution" describes the number of dots that make up an
image. A high-resolution image is made up of a large number of tiny dots. High-
resolution images are very clear and show a lot of detail. </line>
    <line>A low-resolution image is made up of fewer, larger dots, so the
picture is less clear. By making the dots smaller, we can see smaller things in the
picture, but we need more dots to cover the same picture. It takes more space and time
inside the computer to keep track of more dots.
</line>
    <line>click here to see resolution interaction</line>
  </sub_module>
  <sub_module>
    <style>Color Depth </style>
    <line>The color depth describes the number of colors that are used in a
digital picture. As the color depth increases, the picture of the two boys playing
becomes more lifelike. </line>
    <line>In the 2-color picture, each pixel can only be black or white, making
the image difficult to interpret, especially at lower resolutions. </line>
    <line>With 256 colors, each pixel can be any one of 256 colors. It might
seem that 256 colors is a lot, but most photographs are made up of many more colors
than this. Limiting the colors to 256 usually means losing some image detail. </line>
    <line>With millions of colors, the picture has the highest color depth. The
picture is very lifelike as it is closest to how we see things in the real world.</line>
    <line>click here to see a color depth interation</line>
  </sub_module>
  <sub_module>
    <style>Exercise</style>
  </sub_module>
</New_module>
<New_module ID="4">
  <mtitle>Projectile </mtitle>
  <sub_module>
    <style>Projectile Basic (Projectile,2005;Harrison,2005) </style>
    <line>The projectiles we study here are ones unaffected by air resistance.
Only two things affect their motion: Inertia and Gravity. </line>

```

The only force they feel is straight down due to the pull of gravity. We discover that motion in the horizontal direction can be treated totally independent of the motion in the vertical direction.

A projectile moves at a constant speed in the horizontal direction while experiencing a constant acceleration of 9.8 m/s^2 downwards in the vertical direction.

To be consistent, we define up or upwards to be the positive direction. Therefore the acceleration of gravity is properly -9.8 m/s^2 .

Horizontal

The speed in the horizontal direction is v_x and this speed doesn't change. The equation which predicts the position at any time in the horizontal direction is simply

$$x = v_x t \quad \text{equ. 1}$$

Vertical

Because gravity is pulling, the vertical velocity changes constantly. To predict the vertical velocity at any time v_y , we need the following equation:

$$v_y = v_{oy} + a t \quad \text{equ. 2}$$

The v_{oy} is simply the original velocity in the vertical or y-direction.

To calculate the position in the y-direction, the full distance formula must be used. Note that I have included a term, y_o , which represents the original position in the y-direction.

$$y_f = y_o + v_{oy} t + \frac{1}{2} a t^2 \quad \text{equ. 3}$$

Acceleration for projectiles near the Earth's surface is -9.8 m/s^2 . We don't re-write the equation with a negative sign; rather, we use the negative acceleration value when solving problems.

When a projectile is launched horizontally - a ball rolls off a table, a car runs off the edge of a cliff, etc. - the original y-velocity is zero. Your choice of which position to consider $y = 0$ does not change the final calculation. For example, if the projectile drops 10 meters, you could set the $y_o = 0$ and $y_f = -10 \text{ m}$. Or you could set $y_o = 10 \text{ m}$ and $y_f = 0$. Either works out the same.

[click here to experiment](#)

Projectile Basic

Velocity

To determine the total velocity of a projectile, we combine the horizontal velocity (v_x) and the vertical velocity (v_y) using the Pythagorean Theorem:

$$v = (v_x^2 + v_y^2)^{1/2} \quad \text{equ. 4}$$

At the Top

At the top of its path, the projectile no longer is going up and hasn't started down, yet. Its vertical velocity is zero ($v_y = 0$). The only velocity it has is just its horizontal velocity, v_x . Remember, the horizontal speed stays constant throughout the projectile path.

A common misconception occurs at the top of a projectile's arc. When asked what the acceleration of the projectile is at this point, many people answer

"zero". If it were zero, the projectile would simply keep going in a straight line. However, gravity is still acting, pulling it down, accelerating it towards the earth. Thus the acceleration at the top is still -9.8 m/s^2 , just as it's been all along.

<line>Range </line>

<line>For a projectile that is launched at an angle and returns to the same height, we can determine the range or distance it goes horizontally using a fairly simple equation. However, we will focus on the results of studying that equation rather than solving it here. </line>

<line>When the projectile is launched at a steep angle, it spends more time in the air than it does when launched at a shallow angle. </line>

<line>When the projectile is launched at a shallow angle, it goes faster in the horizontal direction than if it is launched at a steep angle. . </line>

<line>The ideal combination of time in the air and horizontal speed occurs at 45° . Thus the maximum range or distance occurs when the projectile is launched at this angle. This applies to long jumpers and soccer balls for two good examples..

</line>

<line>click here to experiment</line>

</sub_module>

<sub_module>

<stitle>Exercise</stitle>

</sub_module>

</New_module>

</module_content>

Listing 2 Schema for the main learning content

```
<?xml version="1.0" encoding="UTF-8"?>
<!--W3C Schema generated by XMLSPY v5 rel. 3 U (http://www.xmlspy.com)-->
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
elementFormDefault="qualified">
  <xs:element name="New_module">
    <xs:complexType>
      <xs:sequence>
        <xs:element ref="mtitle"/>
        <xs:element ref="sub_module" maxOccurs="unbounded"/>
      </xs:sequence>
      <xs:attribute name="ID" use="required">
        <xs:simpleType>
          <xs:restriction base="xs:NMTOKEN">
            <xs:enumeration value="1"/>
            <xs:enumeration value="2"/>
            <xs:enumeration value="3"/>
            <xs:enumeration value="4"/>
          </xs:restriction>
        </xs:simpleType>
      </xs:attribute>
    </xs:complexType>
  </xs:element>
  <xs:element name="line" type="xs:string"/>
  <xs:element name="module_content">
    <xs:complexType>
      <xs:sequence>
        <xs:element ref="New_module" maxOccurs="unbounded"/>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
  <xs:element name="mtitle" type="xs:string"/>
  <xs:element name="stitle" type="xs:string"/>
  <xs:element name="sub_module">
    <xs:complexType>
      <xs:sequence>
        <xs:element ref="stitle"/>
        <xs:element ref="line" minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
</xs:schema>
```

Listing 3 XSL for transforming index page

```
<?xml version="1.0"?>
<xsl:stylesheet xmlns:xsl = "http://www.w3.org/1999/XSL/Transform" version =
"1.0" >
<!--9/7/03-->

<xsl:param name="cmax" select="1" />
<xsl:template match="/">

<html>
<P align="left"><font size="6" face="Tahoma"><STRONG>PHYSICS
101E</STRONG> </font>
  </P>
  <P><FONT face="Tahoma"></FONT></P>
  <FONT face="Tahoma">
    <HR style="WIDTH: 536px; HEIGHT: 6px; BACKGROUND-COLOR:
lightgrey" align="left" />
  </FONT>
</body>

<!--check if reaches max=4 modules-->
<xsl:if test="$cmax< 4">

<xsl:for-each select="module_content/New_module">

<!--xsl:value-of select="position()"/-->
<!--Construct the module number-->
<xsl:variable name="MU" select="concat(position(),'.')"/>

<P><IMG alt="" src="folder_on.gif" align="middle"/>
<FONT face="Tahoma" color="darkblue"><STRONG> Module <xsl:value-of
select="@ID"/> - <xsl:value-of select="mtitle"/></STRONG></FONT>
</P>
<!--Construct the link for connecting page-->
<xsl:variable name="MD" select="concat('M_',@ID)"/>
<xsl:variable name="file1" select="concat('Browser.asp?Exercise',@ID)"/>

<xsl:for-each select="sub_module">
<xsl:variable name="file" select="concat($MD,position(),'.html')"/>

<xsl:choose>
<!--position 3 link to exercise-->
  <xsl:when test="position()='3'">
    <P><A href="{ $file1 }"><FONT color="darkblue" face="Tahoma"><xsl:value-of
select="$MU"/><xsl:value-of
select="position()"/><xsl:text>&#x20;</xsl:text><xsl:value-of
select="stitle"/></FONT></A></P>
  </xsl:when>

```

```
<xsl:otherwise><P><A href="{ $file }"><FONT color="darkblue"
face="Tahoma"><xsl:value-of select="$MU"/><xsl:value-of
select="position()"/><xsl:text>&#x20;</xsl:text> <xsl:value-of
select="stitle"/></FONT></A></P>
</xsl:otherwise>
</xsl:choose>

</xsl:for-each>
<br/>
</xsl:for-each >
</xsl:if>
</body>
</html>
</xsl:template>
</xsl:stylesheet>
```

Listing 4 XSL for transforming learning content

```
<?xml version="1.0"?>
<xsl:stylesheet xmlns:xsl = "http://www.w3.org/1999/XSL/Transform" version =
"1.0" >

<!--parameters send from asp, module and page-->
<xsl:param name="cmodule" select="2" />
<xsl:param name="cpage" select="1" />
<xsl:template match="/">
<html>
<body>
<xsl:for-each select="module_content/New_module">
<xsl:if test="@ID=$cmodule">
  <FONT face="Tahoma" color="darkblue" size="5"><STRONG> <xsl:value-of
select="mtitle"/></STRONG></FONT><p/>
<hr/>
<xsl:for-each select="sub_module">
<!--xsl:value-of select="position()"/><br/-->
  <xsl:if test="$cpage=1 and position()=1">
<!--P align="left"><FONT face="Tahoma"><U><STRONG><xsl:value-of
select="stitle"/></STRONG></U></FONT></P-->

    <xsl:for-each select="line">
      <!--xsl:value-of select="position()"/><br/-->

      <xsl:if test="position()=5">
        <u><strong><FONT face="Tahoma"><xsl:value-of
select="."/><p/></FONT></strong></u>
        </xsl:if>

        <xsl:choose>
          <xsl:when test="position()=last()">
            <P><A href="imageobject.swf"><FONT color="darkblue"
face="Tahoma"><xsl:value-of select="."/></FONT></A></P>
            </xsl:when>
          <xsl:otherwise>
            <xsl:if test="position() != 5">
              <FONT face="Tahoma"><xsl:value-of select="."/><p/></FONT>
            </xsl:if>
          </xsl:otherwise>
        </xsl:choose>

      </xsl:for-each>
      <FONT face="Tahoma"><A href="javascript:history.go(-1)">Back</A></FONT>

      <!--xsl:value-of select="position()"/><br/-->
    </xsl:if>
  <xsl:if test="$cpage=2 and position()=2">
```

```

<!--P align="left"><FONT face="Tahoma"><U><STRONG><xsl:value-of
select="stitle"/></STRONG></U></FONT></P-->

  <xsl:for-each select="line">
    <!--xsl:value-of select="position()"/><br-->

    <xsl:if test="position()=1">
      <u><strong><FONT face="Tahoma"><xsl:value-of
select="."/></FONT></strong></u>
      </xsl:if>

      <xsl:choose>
        <xsl:when test="position()=last()">
          <P><A href="imageobject.swf"><FONT color="darkblue"
face="Tahoma"><xsl:value-of select="."/></FONT></A></P>
          </xsl:when>
          <xsl:otherwise>
            <xsl:if test="position()=1">
              <FONT face="Tahoma"><xsl:value-of select="."/><p/></FONT>
              </xsl:if>
            </xsl:otherwise>
          </xsl:choose>

        </xsl:for-each>
        <FONT face="Tahoma"><A href="javascript:history.go(1)">Back</A></FONT>

        <!--xsl:value-of select="position()"/><br-->
        </xsl:if>

      </xsl:for-each>
    </xsl:if>
  </xsl:for-each>
</br/>
</body>
</html>
</xsl:template>
</xsl:stylesheet>

```

Listing 5 Main ASP

```
<% Response.Buffer=True %>
<% Dim xml
  Dim xsl
  Dim template
  Dim processor
  Dim curq

  Dim xslProc

  answ=Request.form("answ")
  curq=Request.form("curq")
  'To keep track of curent question
  curq=1+curq

  Set xml = Server.CreateObject("MSXML2.DOMDocument.4.0")
  xml.async = false
  xml.load (Server.MapPath("quiz.xml"))

  Set xsl = Server.CreateObject("MSXML2.freethreadedDOMDocument.4.0")
  xsl.async = false
  xsl.load (Server.MapPath("quiz.xsl"))

  set xslt= Server.Createobject("Msxml2.XSLTemplate.4.0")
  Set xslt.stylesheet=xsl

  Set xslProc = xslt.createProcessor()
  xslProc.input = xml
  xslProc.addParameter "curq", curq

  set x =xml.getElementsByTagName("CorrectAns")
  'Check to see if it is a new request
  If answ="" then
  xslProc.addParameter "FeedBack",3
  else
  ' Item index start at 0
  If answ=x.item((curq-2)).text then

  xslProc.addParameter "FeedBack",3
  else
  xslProc.addParameter "FeedBack",0
  xslProc.addParameter "curq", curq-1
  end if
  end if

  xslProc.Transform
  Response.Write xslproc.output
  Response.write(curq)
  Response.write(answ)
```

Set xml = Nothing
Set xsl = Nothing
%>

Listing 6 Exercise module content

```
<?xml version="1.0" standalone="no"?>
<?xml-stylesheet type="text/xsl" href="Quiz.xsl"?>
<Quiz_Question>
  <New_question ID="1">
    <Question>
      What are the primary colors in an "additive" color system?(Easy)
    </Question>
    <AnswerA>
      Red, Green, Blue
    </AnswerA>
    <AnswerB>
      Red, Yellow, Blue
    </AnswerB>
    <AnswerC>
      Cyan, Magenta, Yellow
    </AnswerC>
    <AnswerD>
      Cyan, Red, Blue
    </AnswerD>
    <CorrectAns>
      1
    </CorrectAns>
    <Hint PC="color1.asp" PDA="color1.asp" Phone="color1.asp"/>
  </New_question>
  <New_question ID="2">
    <Question>
      What is the colour when mixing green and red in additive color system?
    </Question>
    <AnswerA>
      Blue
    </AnswerA>
    <AnswerB>
      Yellow
    </AnswerB>
    <AnswerC>
      White
    </AnswerC>
    <AnswerD>
      Black
    </AnswerD>
    <CorrectAns>
      2
    </CorrectAns>
    <Hint PC="color1.asp" PDA="color1.asp" Phone="color1.asp"/>
  </New_question>
  <New_question ID="3">
    <Question>
      What is the resulting color if Blue is added with Green ?
```

```
</Question>
  <AnswerA>
    Red
  </AnswerA>
  <AnswerB>
    Yellow
  </AnswerB>
  <AnswerC>
    Cyan
  </AnswerC>
  <AnswerD>
    Magenta
  </AnswerD>
  <CorrectAns>
    3
  </CorrectAns>
  <Hint PC="color1.asp" PDA="color1.asp" Phone="color1.asp"/>
</New_question>
<New_question ID="4">
  <Question>
```

What is the Resulting color if Red is added to Green and to Blue?

```
</Question>
  <AnswerA>
    Black
  </AnswerA>
  <AnswerB>
    Cyan
  </AnswerB>
  <AnswerC>
    Magenta
  </AnswerC>
  <AnswerD>
    White
  </AnswerD>
  <CorrectAns>
    4
  </CorrectAns>
<Hint PC="color1.asp" PDA="color1.asp" Phone="color1.asp"/>
</New_question>
</Quiz_Question>
```

Listing 7 XSL for transforming the exercise

```
<?xml version="1.0"?>
<xsl:stylesheet xmlns:xsl = "http://www.w3.org/1999/XSL/Transform" version =
"1.0" >
<!--9/7/03-->
<!--Define parameters, value coming from ASP-->
<xsl:param name="curq"/>
<xsl:param name="FeedBack"/>

<!--Usermodel store the user preference-->
<xsl:variable name="profile" select="document('usermodel.xml')"/>

<xsl:template match="/">

<html>
<head><title> M-Quiz</title></head>
<body bgColor="#00ffff" link="#0080ff">
<p align="left"><font size="8"><strong>Welcome Mobile Learning
System</strong></font></p>

<!--check if reaches max=3 questions-->
<xsl:if test="$curq< 4">

<xsl:if test="$FeedBack= 3">
User Model =<xsl:value-of select="$profile" />
Curq=<xsl:value-of select="$curq"/>

<form method="post" action="Quiz_msxml4.asp">

<input>
<xsl:attribute name="type">hidden</xsl:attribute>
<xsl:attribute name="name">curq</xsl:attribute>
<xsl:attribute name="value"><xsl:value-of select="$curq"/></xsl:attribute>
</input>

<xsl:for-each select="Quiz_Question/New_question">

<xsl:if test="@ID= $curq">

Question <xsl:value-of select="@ID"/><br/>

<xsl:value-of select="Question"/>
<br></br>

answer:<br/>
<input type="radio" name="answ" value="1"><xsl:value-of
select="AnswerA"/></input><br/>
<input type="radio" name="answ" value="2"><xsl:value-of
select="AnswerB"/></input><br/>
```

```
<input type="radio" name="answ" value="3"><xsl:value-of
select="AnswerC"/></input><br/>
<input type="radio" name="answ" value="4"><xsl:value-of
select="AnswerD"/></input><br/>
```

```
<input type="reset" value="reset"></input>
<input type="submit" value="mark" ></input>
</xsl:if>
```

```
</xsl:for-each>
```

```
</form>
</xsl:if>
</xsl:if>
```

```
Value of FeedBack =<xsl:value-of select="$FeedBack"/><br/>
```

```
<xsl:if test="$FeedBack= 0">
```

```
<p>You got it wrong!</p>
```

```
Please refer to:
```

```
<xsl:for-each select="Quiz_Question/New_question">
```

```
<xsl:if test="@ID= $curq">
```

```
ID= <xsl:value-of select="@ID"/><br/>
```

```
Curq=<xsl:value-of select="$curq"/><br/>
```

```
<a>
```

```
<xsl:attribute name="href"><xsl:value-of select="Hint"/></xsl:attribute>
```

```
<xsl:attribute name="target">_blank</xsl:attribute>
```

```
Hint
```

```
</a>
```

```
</xsl:if>
```

```
</xsl:for-each>
```

```
</xsl:if>
```

```
</body>
```

```
</html>
```

```
</xsl:template>
```

```
</xsl:stylesheet>
```

Appendix B

Multiplatform E-learning Systems Questionnaires (MELQ)

Part 1: Demographic

Please answer the following questions about yourself-

1. Enter your age group here

- 1 2 3 4 5 6 7 8 9
- 10-15 16-20 21-25 26-30 31-35 36-40 41-45 46-50 >51

2. Indicate your **highest** level of education achieved

- 1 Lower High school 2 Upper High school 3 Polytechnic 4 Under-graduate 5 Post graduate

3. Gender: 1 Female 2 Male

4. Please enter the activity code: (from the evaluation steps form)

Part 2: e-learning Experience

1. The browser that you are using for this activity is

- 1 Internet Explorer 2 Pocket PC IE 3 Opera

2. How long have you worked on this e-learning system with this particular browser.
(example : Blackboard and IE)

- 1 less than 1 hour
2 1 hour to less than 1 day
3 1 day to less than 1 week
4 1 week to less than 1 month
5 1 month to less than 6 months
6 6 months to less than 1 year
7 1 year to less than 2 years
8 2 years to less than 3 years
9 3 years or more

3. On the average, how much time do you spend per week on this browser type (as in question 1)?

- 1 less than 1 hour
2 1 to less than 4 hours
3 4 to less than 10 hours
4 over 10 hours

Part 3: Interaction Experience

1. List other browser (include mobile browser) you have worked with?

2. Of the following lists, checks those items that you have personally used and are familiar with:

1 <input type="checkbox"/> XBox	2 <input type="checkbox"/> PC games
3 <input type="checkbox"/> Multimedia Messages	4 <input type="checkbox"/> touch screen
5 <input type="checkbox"/> lap top computer	6 <input type="checkbox"/> graphics tablet
7 <input type="checkbox"/> personal tutor	8 <input type="checkbox"/> 3-D virtual game
9 <input type="checkbox"/> PDA	10 <input type="checkbox"/> Mobile Phone web Browsing
11 <input type="checkbox"/> Camera Phone	12 <input type="checkbox"/> e-learning system
13 <input type="checkbox"/> tablet PC	14 <input type="checkbox"/> wireless PC
15 <input type="checkbox"/> web page design	16 <input type="checkbox"/> multimedia software
17 <input type="checkbox"/> mobile Phone games	18 <input type="checkbox"/> SMS Text
19 <input type="checkbox"/> internet chat	20 <input type="checkbox"/> video conferencing

Part 4: Overall Learning Satisfaction

Please select the numbers which most appropriately reflect your impressions of using this e-learning site together with the specific device and browser. Not Applicable = NA.

1. Overall learning experience to the e-learning site.

	terrible	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/> 6 <input type="checkbox"/> 7 <input type="checkbox"/> 8 <input type="checkbox"/> 9	wonderful	<input type="checkbox"/> NA
2.	frustrating	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/> 6 <input type="checkbox"/> 7 <input type="checkbox"/> 8 <input type="checkbox"/> 9	satisfying	<input type="checkbox"/> NA
3.	dull	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/> 6 <input type="checkbox"/> 7 <input type="checkbox"/> 8 <input type="checkbox"/> 9	stimulating	<input type="checkbox"/> NA
4.	difficult	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/> 6 <input type="checkbox"/> 7 <input type="checkbox"/> 8 <input type="checkbox"/> 9	easy	<input type="checkbox"/> NA
5.	meaningless	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/> 6 <input type="checkbox"/> 7 <input type="checkbox"/> 8 <input type="checkbox"/> 9	meaningful	<input type="checkbox"/> NA
6.	rigid	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/> 6 <input type="checkbox"/> 7 <input type="checkbox"/> 8 <input type="checkbox"/> 9	user friendly	<input type="checkbox"/> NA

Part 5-1: Content Dimension - Organisation

Select the number which most appropriately reflects your impressions of using the e-learning system together with the specific device and browser. Not Applicable = NA.

1. Accessing the e-learning module was

difficult

easy

1 2 3 4 5 6 7 8 9

NA

2. Navigate through the e-learning module was

difficult

easy

1 2 3 4 5 6 7 8 9

NA

3. The e-learning module is meaningfully structured

disagree

agree

1 2 3 4 5 6 7 8 9

NA

Part 5-2: Content Dimension - Granule

Select the number which most appropriately reflects your impressions of using the e-learning system together with the specific device and browser. Not Applicable = NA.

1. The e-learning content was concise and easy to understand

never

always

1 2 3 4 5 6 7 8 9

NA

2. Tasks (exercises, reading content, simulation) can be completed

with
difficulty

easily

1 2 3 4 5 6 7 8 9

NA

3. The e-learning content is at the level of

expert

beginner

1 2 3 4 5 6 7 8 9

NA

Part 5-3: Content Dimension - Multimedia object

Select the number which most appropriately reflects your impressions of using the e-learning system together with the specific device and browser. Not Applicable = NA.

1. Quality of still images within the module

inadequate

1 2 3 4 5 6 7 8 9

adequate

NA

2. Images within the module are

fuzzy

1 2 3 4 5 6 7 8 9

clear

NA

3. Image brightness within the module

dim

1 2 3 4 5 6 7 8 9

bright

NA

4. Quality of animation or video within the module

inadequate

1 2 3 4 5 6 7 8 9

adequate

NA

5. Content of animation or video within the module

useless

1 2 3 4 5 6 7 8 9

meaningful

NA

6. Multimedia display size is

inadequate

1 2 3 4 5 6 7 8 9

adequate

NA

7. Sound output

inaudible

1 2 3 4 5 6 7 8 9

audible

NA

8. Sound output quality

inadequate

1 2 3 4 5 6 7 8 9

adequate

NA

9. Colors used are

unnatural

1 2 3 4 5 6 7 8 9

natural

NA

10. Amount of colors available

inadequate

1 2 3 4 5 6 7 8 9

adequate

NA

11. Amount of multimedia interactivity available within the module

inadequate

adequate

1 2 3 4 5 6 7 8 9

NA

Part 5-4: Content Dimension - Pedagogy

Select the number which most appropriately reflects your impressions of using the e-learning system together with the specific device and browser. Not Applicable = NA.

1. Instructions given for completing module

confusing

clear

1 2 3 4 5 6 7 8 9

NA

2. The e-learning module was

useless

helpful

1 2 3 4 5 6 7 8 9

NA

3. The e-learning module content was

meaningless

meaningful

1 2 3 4 5 6 7 8 9

NA

4. Revisit learning e-learning module content is

meaningless

helpful

1 2 3 4 5 6 7 8 9

NA

Part 6-1: User Dimension-Environment

Select the number which most appropriately reflects your current environment. Not Applicable = NA.

1. The surrounding is

noisy

1 2 3 4 5 6 7 8 9

quiet

NA

2. Activities surround me are

interruptive

1 2 3 4 5 6 7 8 9

non interruptive

NA

3. Current surrounding affect my attention

very much

1 2 3 4 5 6 7 8 9

very little

NA

4. My environment is

distracting

1 2 3 4 5 6 7 8 9

relaxing

NA

5. My learning experience in this environment is

indifference

1 2 3 4 5 6 7 8 9

satisfying

NA

Part 6-2: User Dimension – Environment - Available of Help

Select the number which most appropriately reflects your impressions of using the e-learning system together with the specific device and browser. Not Applicable = NA.

1. Amount of personal help available

dissatisfying

1 2 3 4 5 6 7 8 9

satisfying

NA

2. Available of help make me feel

less confident

1 2 3 4 5 6 7 8 9

confident

NA

3. Available of help allow me to operate the system with

difficulty

1 2 3 4 5 6 7 8 9

ease

NA

4. Available of help allow me to understand the content much

confusion

1 2 3 4 5 6 7 8 9

easier

NA

5. Available of help make my learning experience

indifference

1 2 3 4 5 6 7 8 9

satisfying

NA

Part 6-3: User Dimension - Motivation

Select the number which most appropriately reflects your situation of using the e-learning system together with the specific device and browser. Not Applicable = NA.

1. Time given to perform tasks

inadequate

1 2 3 4 5 6 7 8 9

adequate

NA

2. I completed the task

urgently

1 2 3 4 5 6 7 8 9

at my own pace

NA

3. I have strong need to complete the tasks

disagree

1 2 3 4 5 6 7 8 9

agree

NA

Part 6-4: User Dimension - Preference

Select the number which most appropriately reflects your situation of using the e-learning system together with the specific device and browser. Not Applicable = NA.

1. The web page background meets my preference

dissatisfied

1 2 3 4 5 6 7 8 9

satisfied

NA

2. The fonts used meet my preference

dissatisfied

1 2 3 4 5 6 7 8 9

satisfied

NA

3. The content difficulty meets my preference

very little

1 2 3 4 5 6 7 8 9

very much

NA

4. The teaching strategy suits my preference

little

1 2 3 4 5 6 7 8 9

much

NA

Part 7-1: Capability Dimension – Presentation Capability

Select the number which most appropriately reflects your impressions of using the e-learning system together with the specific device and browser. Not Applicable = NA.

1. Characters on the device screen

hard to read

1 2 3 4 5 6 7 8 9

easy to read

NA

2. Image of characters (characters in the image)

fuzzy

1 2 3 4 5 6 7 8 9

sharp

NA

3. Character shapes (fonts)

barely legible

1 2 3 4 5 6 7 8 9

very legible

NA

4. Highlighting on the screen

unhelpful

1 2 3 4 5 6 7 8 9

helpful

NA

5. Use of bolding

unhelpful

1 2 3 4 5 6 7 8 9

helpful

NA

6. Screen orientation were helpful

never

1 2 3 4 5 6 7 8 9

always

NA

7. Screen display size is

inadequate

1 2 3 4 5 6 7 8 9

adequate

NA

Part 7-2: Capability Dimension – Ergonomic Capability

Select the number which most appropriately reflects your impressions of using the e-learning system together with the specific device and browser. Not Applicable = NA.

1. Learn to use the browser is

difficult

1 2 3 4 5 6 7 8 9

easy

NA

2. The browser is user friendly

never

1 2 3 4 5 6 7 8 9

always

NA

3. Time to learn using the browser is

slow

1 2 3 4 5 6 7 8 9

fast

NA

4. Learning to operate the device

difficult

1 2 3 4 5 6 7 8 9

easy

NA

5. The device is user friendly

never

1 2 3 4 5 6 7 8 9

always

NA

6. Time to learn using the device is

slow

1 2 3 4 5 6 7 8 9

fast

NA

Part 8-1: Communication Dimension – Perceived Response

Select the number which most appropriately reflects your impressions of using the e-learning system together with the specific device and browser. Not Applicable = NA.

1. Page Download time

too slow

1 2 3 4 5 6 7 8 9

fast enough

NA

2. Response time for most operations

too slow

1 2 3 4 5 6 7 8 9

fast enough

NA

3. Rate information is displayed (rendered)

too slow

1 2 3 4 5 6 7 8 9

fast enough

NA

Part 8-2: Communication Dimension – Perceived Quality

Select the number which most appropriately reflects your impressions of using the e-learning system together with the specific device and browser. Not Applicable = NA.

1. The system is (seem) reliable

never

1 2 3 4 5 6 7 8 9

always

NA

2. Operations are

undependable

1 2 3 4 5 6 7 8 9

dependable

NA

3. System failures (hang) occur

frequently

1 2 3 4 5 6 7 8 9

seldom

NA

Part 8-3: Communication Dimension – Delivery Mode

Select the number which most appropriately reflects your impressions of using the e-learning system together with the specific device and browser. Not Applicable = NA.

1. Current mode of content delivery is

dissatisfying

1 2 3 4 5 6 7 8 9

satisfying

NA

2. The mode of delivery is

not acceptable

1 2 3 4 5 6 7 8 9

acceptable

NA

3. Current mode of delivery is easy to operate

never

1 2 3 4 5 6 7 8 9

always

NA

Part 9-1: Coordination Dimension - Navigation

Select the number which most appropriately reflects your impressions of using the e-learning system together with the specific device and browser. Not Applicable = NA.

1. Navigation within the e-learning site is

difficult

easy

1 2 3 4 5 6 7 8 9

NA

2. Next screen in a sequence

unpredictable

predictable

1 2 3 4 5 6 7 8 9

NA

3. Going back to the previous screen

impossible

easy

1 2 3 4 5 6 7 8 9

NA

4. Progression of work related tasks

confusing

**clearly
marked**

1 2 3 4 5 6 7 8 9

NA

5. Using icon (small picture) for navigation

difficult

easy

1 2 3 4 5 6 7 8 9

NA

6. Using anchored text (underlined hyper link) for navigation

difficult

easy

1 2 3 4 5 6 7 8 9

NA

Part 9-2: Coordination Dimension - Interaction

Select the number which most appropriately reflects your impressions of using the e-learning system together with the specific device and browser. Not Applicable = NA.

1. Tasks can be performed in a straight-forward manner

never

always

1 2 3 4 5 6 7 8 9

NA

2. Number of steps per task

too many

just right

1 2 3 4 5 6 7 8 9

NA

3. Steps to complete a task follow a logical sequence

never

always

1 2 3 4 5 6 7 8 9

NA

4. Feedback on the completion of the steps

unclear

clear

1 2 3 4 5 6 7 8 9

NA

Part 9-3: Coordination Dimension - Presentation

Select the number which most appropriately reflects your impressions of using the e-learning system together with the specific device and browser. Not Applicable = NA.

1. Amount of information displayed on screen

inadequate

adequate

1 2 3 4 5 6 7 8 9

NA

2. layout of information on screen

unsatisfied

satisfy

1 2 3 4 5 6 7 8 9

NA

3. Overall content presented on screen

unsatisfied

satisfy

1 2 3 4 5 6 7 8 9

NA

Appendix C

Ethic Approval Forms



Massey University

22 December 2004

Tiong-Goh
P O Box 600
WELLINGTON

OFFICE OF THE ASSISTANT
TO THE VICE-CHANCELLOR
(ETHICS & EQUITY)
Private Bag 11 222
Palmerston North
New Zealand
T 04 8 350 5573
F 04 8 350 6622
humanethics@massey.ac.nz
www.massey.ac.nz

Dear Tiong

Re: An adaptation framework for web based e-learning system

Thank you for the Low Risk Notification that was received on 22 December 2004.

Your project has been recorded on the Low Risk Database which is reported in the Massey University Human Ethics Committee Annual Report.

Please notify me if situations subsequently occur which cause you to reconsider your initial ethical analysis that it is safe to proceed without approval by a campus human ethics committee.

Please ensure that the following statement is used on Information Sheets:

"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor Sylvia Rumball, Assistant to the Vice-Chancellor (Ethics & Equity), telephone 06 350 5249, email humanethicspn@massey.ac.nz".

Please note that if a sponsoring organisation, funding authority, or a journal in which you wish to publish requires evidence of committee approval (with an approval number), you will have to provide a full application to a Campus Human Ethics committee. You should also note that such an approval can only be provided prior to the commencement of the research.

Yours sincerely

Professor Sylvia V Rumball, Chair
Assistant to the Vice-Chancellor (Ethics & Equity)

cc Prof Kinshuk & Prof Klaus-Dieter Schewe
Department of Information Systems
PN311

Massey University Human Ethics Committee
Accredited by the Health Research Council



An adaptation Framework for Web Based e-learning System

INFORMATION SHEET

Introduction

I am a phd student with the department of information system, Massey university. I am currently conducting a research into an adaptation framework for web based e-learning system. The main aim of the research is to evaluate the factors influencing e-learning experience from a multiplatform scenarios perspective. I would like your opinion when using different devices such as PC, PDA and mobile phone while accessing e-learning system.

Participant Recruitment

The participants will be recruited from advertisement from notice board and flyer. Participants will be recruited for the seven scenarios to be evaluated. Participant's who completed the evaluation shall be compensated with a voucher for their time. There will be no discomforts or risks to participant as a result of participation.

Project Procedures

Data will be analysis using statistical method to determine the relationship between several environmental parameters and learning experience. The data will be kept in a secured cabinet with lock. The data will be disposed off after 2 years of project completion. A summary of project finding will be included in the final thesis and will be kept in Massey University library. No individual identity shall be included in the report.

Participant involvement

Participant will be given a scenario and then access e-learning web sites to complete several tasks. Upon completed a task, participant need to response to a set of questionnaires. An informal discussion will follow after the completion of the assigned tasks. Approximate time to complete the evaluation is about 2 hours.

Participant's Rights

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- *decline to answer any particular question;*
- *withdraw from the study anytime;*
- *ask any questions about the study at any time during participation;*
- *provide information on the understanding that your name will not be used unless you give permission to the researcher;*
- *be given access to a summary of the project findings when it is concluded.*
- *I also understand that I have the right to ask for the audio/video tape to be turned off at any time during the interview.*

Project Contacts

Tiong Goh

Researcher

Phone: 04-4636860

E-mail : tiong.goh@vuw.ac.nz

Associate Professor Kinshuk

Supervisor

E-mail : kinshuk@ieee.org

1. Committee Approval Statement

This project has been evaluated by peer review and judged to be low risk. Consequently it has not been reviewed by one of the University's Human Ethics Committees. The research(s) named above are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor Sylvia V Rumball, Chair, Massey University Campus Human Ethics Committee: Palmerston North, telephone 06 350 5249, email humanethicspn@massey.ac.nz.

2. Compensation for Injury

If physical injury results from your participation in this study, you should visit a treatment provider to make a claim to ACC as soon as possible. ACC cover and entitlements are not automatic and your claim will be assessed by ACC in accordance with the Injury Prevention, Rehabilitation and Compensation Act 2001. If your claim is accepted, ACC must inform you of your entitlements, and must help you access those entitlements. Entitlements may include, but not be limited to, treatment costs, travel costs for rehabilitation, loss of earnings, and/or lump sum for permanent impairment. Compensation for mental trauma may also be included, but only if this is incurred as a result of physical injury.

If your ACC claim is not accepted you should immediately contact the researcher. The researcher will initiate processes to ensure you receive compensation equivalent to that to which you would have been entitled had ACC accepted your claim.

An adaptation Framework for Web Based e-learning System

PARTICIPANT CONSENT FORM

This consent form will be held for a period of five (5) years

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree/do not agree to the interview being audio taped.

I wish/do not wish to have my tapes returned to me.

I wish/do not wish to have data placed in an official archive.

I agree to not disclose anything discussed in the Focus Group.

I agree to participate in this study under the conditions set out in the Information Sheet.

Signature: _____

Date: _____

Full Name - printed _____

Appendix D

Listing of publications generated from current research

2006

Goh, T., & Kinshuk (2006). Structure equation modeling approach in multiplatform e-learning system evaluation. In proceedings of the 17th Australasian Conference on Information Systems, Adelaide 6-8 December 2006.

Goh, T., & Kinshuk, D. (2006). Getting Ready For Mobile Learning—Adaptation Perspective. *Journal of Educational Multimedia and Hypermedia*. 15 (2), pp. 175-198. Chesapeake, VA: AACE.

2005

Goh, T. T., & Kinshuk (2005). Web Content Adaptation Frameworks and Techniques. *Encyclopedia of Multimedia Technology and Networking* (2-volume set) Edited by: Margherita Pagani ISBN: 1-59140-561-0 h/c, eISBN: 1-59140-796-6, pages: 1,218 2005

Goh, T., & Kinshuk (2005). Context Aware E-Learning for Multiplatform Environment - Preliminary Analysis. *Proceedings of the 4th IASTED International Conference on Web-Based Education (WBE 2005)*, February 21-23, 2005, (pp.296-299). Anaheim, CA, USA: ACTA Press.

Goh, T., & Kinshuk (2005). An Adaptation Framework For Multiplatform e-Learning System. PISA (Perspectives of Intelligent Systems' Assistance) workshop 3-5 March 2005 Massey University Palmerston North.

2004

Goh T., & Kinshuk (2004, Invited session). An Adaptation Framework for Web based learning system. 8th International conference on Knowledge-Based Intelligent Information & Engineering System, New Zealand Wellington 2004.

Goh, T., & Kinshuk (2004). Getting Ready for Mobile Learning. *ED-Media World Conference on Educational Multimedia, Hypermedia and Telecommunication*, Lugano Switzerland 2004.

Kainulainen, V., Suhonen, J., Sutinen, E., Goh, T., & Kinshuk. (2004). Mobile Digital Portfolio Extension <<http://infosys.massey.ac.nz/~kinshuk/papers/wmte2004.pdf>>. *Proceedings of the Second IEEE International Workshop on Wireless and Mobile Technologies in Education*, March 23-25, (pp.98-102). CA, USA: IEEE Computer Society Press.

Schewe, K-D., Goh, T., and Kinshuk (2004). Content adaptivity in wireless web access, *Int. J. Mobile Communications*, Vol. 2, No. 3, pp.260-270.

2003

Kinshuk, & Goh, T. (2003, Keynote speech). Multiple Representation Approach with Mobile Adaptation In Developing Web Based Learning System. International Conference on open and on-line learning, ICOOL 2003, Mauritius.

Kinshuk, Suhonen, J., Sutinen, E., & Goh, T. (2003). Mobile Technologies in Support of Distance Learning. Asian Journal of Distance Education, Asian J D E 2003 Vol 1, no 1, pp 60-68.

Goh, T., and Kinshuk (2003). Developing an adaptive mobile learning system. International Conference on Computer in Education ICCE 2003, Hong Kong.

Kinshuk, and Goh, T. (2003). Mobile Adaptation with Multiple Representation Approach as Educational Pedagogy. in 6th Business Informatics International Congress, September 17 – 19, Dresden, Germany, 2003.

2002

Goh, T., and Kinshuk (2002). Mobile Web based ITS Adaptation. In Proceeding of the International conference on computer in education 2002. Auckland, New Zealand.

Appendix E

Sample Task Form

Evaluation 1

Objective (for participant)

The aim of the experiment is to experience e-learning system with different engaging environment.

Scenario

Consider you are now sitting in a classroom. You will be using PC, PDA and Mobile phone to explore two similar e-learning web sites. Web site A (Blackboard) is a traditional web site without adaptation capability while web site B has adaptation capability. In this experiment you are free to ask any questions during the process to aid your understanding.

Blackboard Home Page	Device
Module 2	PC
Module 1	PDA
Module 3	Mobile

Physics101E Home Page	Device
Module 2	PC
Module 1	PDA
Module 3	Mobile

Each participant must complete 6 tasks, 3 from the Blackboard page with 3 different environments and 3 tasks from the Physics101 page with 3 different environments.

Activity code: _____

1. Take the pre-test first
2. Read the scenario and objective.
3. Launch the IE browser from the PC.
4. Record the Date _____ and Time: _____ now.
5. Get into BlackBoard.vuw.ac.nz and go to the Course Document folder > Physics101 folder.
6. Select Module _____ ONLY.
7. Activate and read carefully the first sub link within this module.
8. Activate and read carefully the second sub link within this module.
9. If you are ready, activate the exercise within this module and answer the questions. Complete all the questions in the exercise to the best of your knowledge. You can go back to review the sub-module.
10. The password is 12345
11. Once completed, record the number of correct answer.
12. Record the Time: _____ now.
13. Complete the evaluation form in Excel and take notes on anything that might be useful for the researcher.

Activity code: _____

1. Read the scenario and objective.
2. Record the Date_____ and Time:_____ now.
3. Launch the IE browser from the PC.
4. Get into the web site
<http://student.sim.vuw.ac.nz/project/P1/Physics101E.html>.
5. Select Module _____ ONLY.
6. Activate and read carefully the first sub link within this module.
7. Activate and read carefully the second sub link within this module.
8. If you are ready, activate the exercise within this module and answer the questions. Complete all the questions in the exercise until you get all the answer correct. You can go back to review the sub-module.
9. The password is '12345' and user name is 'P1'
10. Record the Time:_____now.
11. Complete the evaluation form in Excel and take notes on anything that might be useful for the researcher.

Activity code: _____

1. Take the pre-test first
2. Read the scenario and objective.
3. Launch the Pocket IE browser from the PDA.
4. Record the Date _____ and Time: _____ now.
5. Select the " Physics101 folder" in Blackboard.
6. Select Module _____ ONLY.
7. Activate and read carefully the fist sub link within this module.
8. Activate and read carefully the second sub link within this module.
9. If you are ready, activate the exercise within this module and answer the questions. Complete all the questions in the exercise to the best of your knowledge. You can go back to review the sub-module.
10. The password is 12345
11. Once completed, write down the number of correct answer.
12. Record the Time: _____ now.
13. Complete the evaluation form in Excel and take notes on anything that might be useful for the researcher.

Activity code: _____

1. Read the scenario and objective.
2. Launch the Pocket IE browser.
3. Record the Date _____ and Time: _____ now.
4. Get into <http://student.sim.vuw.ac.nz/project/P1/Physics101E.html>.
5. Select Module _____ ONLY.
6. Activate and read carefully the first sub link within this module.
7. Activate and read carefully the second sub link within this module.
8. If you are ready, activate the exercise within this module and answer the questions. Complete all the questions in the exercise to the best of your knowledge. You can go back to review the sub-module.
9. The password is 12345 and user name is "P1".
10. Once completed, write down the number of correct answer.
11. Record the Time: _____ now.
12. Complete the evaluation form in Excel and take notes on anything that might be useful for the researcher.

Activity code: _____

1. Take the pre-test first
2. Read the scenario and objective.
3. Launch the Opera browser from the mobile phone
4. Record the Date _____ and Time: _____ now.
5. Select the " Physics101 folder" in Blackboard.
6. Select Module _____ ONLY.
7. Activate and read carefully the first sub link within this module.
8. Activate and read carefully the second sub link within this module.
9. If you are ready, activate the exercise within this module and answer the questions. Complete all the questions in the exercise to the best of your knowledge. You can go back to review the sub-module.
10. The password is 12345
11. Once completed, write down the number of correct answer.
12. Record the Time: _____ now.
13. Complete the evaluation form in Excel and take notes on anything that might be useful for the researcher.

Activity code: _____

1. Read the scenario and objective.
2. Launch the Opera browser from the mobile phone
3. Record the Date _____ and Time: _____ now.
4. Get into <http://student.sim.vuw.ac.nz/project/P1/Physics101E.html>.
5. Select Module _____ ONLY.
6. Activate and read carefully the first sub link within this module.
7. Activate and read carefully the second sub link within this module.
8. If you are ready, activate the exercise within this module and answer the questions. Complete all the questions in the exercise to the best of your knowledge. You can go back to review the sub-module.
9. The password is 12345
10. Once completed, write down the number of correct answer.
11. Record the Time: _____ now.
12. Complete the evaluation form in Excel and take notes on anything that might be useful for the researcher.