LEARNING DESIGN IMPLEMENTATION IN CONTEXT-AWARE AND ADAPTIVE MOBILE LEARNING

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DOCTORAL THESIS

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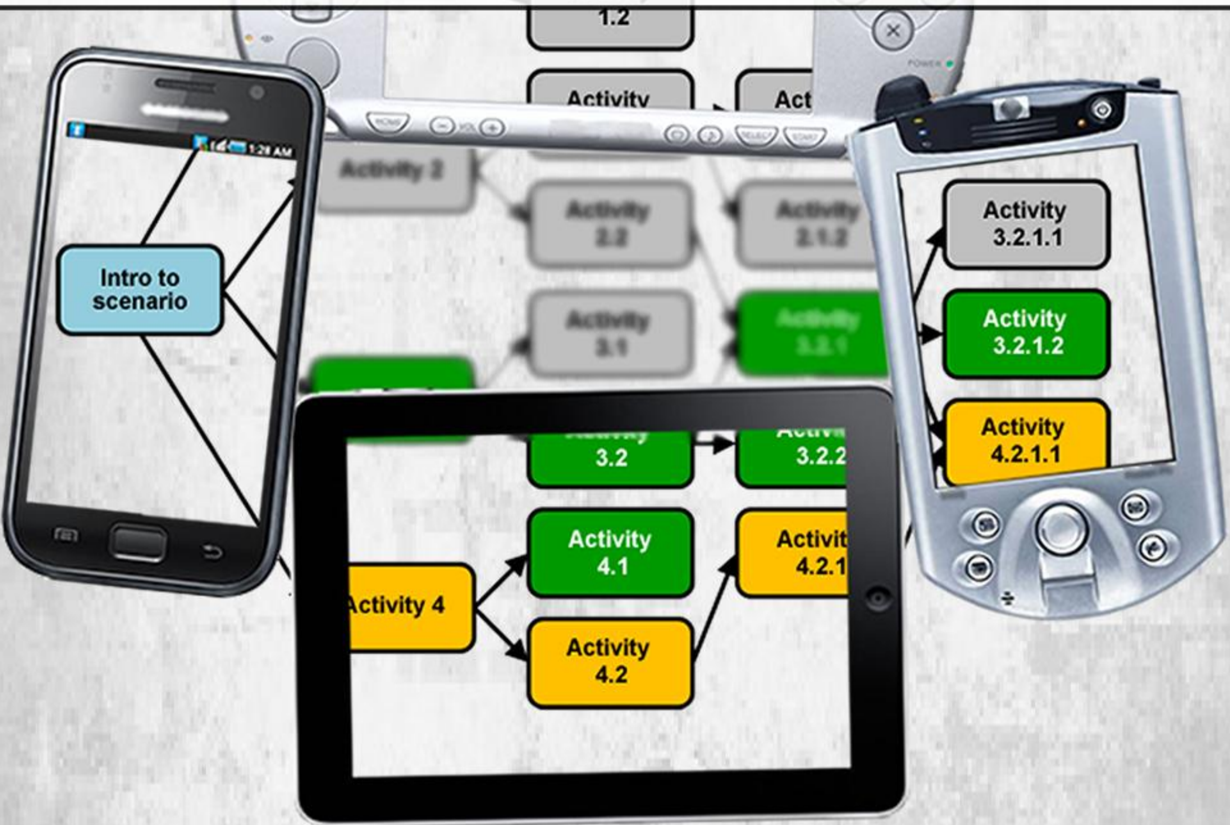

SERGIO EDUARDO GOMEZ ARDILA

Universitat de Girona

2013

Doctoral Thesis

Learning Design Implementation in Context-Aware and Adaptive Mobile Learning

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Girona, Catalonia, Spain

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El Dr. Ramon Fabregat Gesa, Titular de Universitat del Departament d'Arquitectura i Tecnologies de Computadors de la Universitat de Girona,

CERTIFICA

Que aquest treball, titulat "Learning Design Implementation in Context-Aware and Adaptive Mobile Learning", que presenta Sergio Eduardo Gómez Ardila per a l'obtenció del títol de doctor, ha estat realitzat sota la meva direcció i que compleix els requeriments necessaris. A més, certifico que aquesta tesi està optant a la Menció Europea.

Ramon Fabregat Gesa

Girona, 11 de març de 2013

List of Publications Resulting from This Thesis

Journal Papers

Gómez, S., Zervas, P., Sampson, D., & Fabregat, R. Context-Aware Adaptive and Personalized Mobile Learning Delivery Supported by UoLmP. *IEEE Transactions on Learning Technologies*. *Submitted on February 2013*. ***ISI Impact Factor 0.823 (2011).***

Gómez, S., & Fabregat, R. (2012). Context-Aware and Adaptive Units of Learning in mLearning. *International Journal of Handheld Computing Research (IJHCR)*, Vol. 3, No. 2, Pag. 1-25, 2012 (DOI: 10.4018/jhcr.2012040101), IGI Global (ISSN 1947-9158).

Book Chapters

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International Conference Papers

Gómez, S., Zervas, P., Sampson, D., & Fabregat, R. (2013). Supporting Context-Aware Adaptive and Personalized Mobile Learning Delivery: Evaluation Results from the Use of UoLm Player. 13th IEEE International Conference on Advanced Learning Technologies (ICALT 2013), Beijing, China, July 15-18. ***Acceptance rate 18,46%.***

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Zervas, P., **Gómez, S.,** Fabregat, R., & Sampson, D. (2011). Tools for Context-Aware Learning Design and Mobile Delivery. Proccedings of the 11th IEEE International Conference on Advanced Learning Technologies (ICALT 2011), Athens, Georgia, USA, 6-8, July. ***Acceptance rate 24,59%.***

Zervas, P., **Gómez, S.,** Fabregat, R., & Sampson, D. (2011). Designing Tools for Context-Aware Adaptive Mobile Learning. Proccedings of the European, Mediterranean & Middle Eastern Conference on Information Systems 2011 (EMCIS2011), Athens, Greece, May 30-31.

Gómez, S., & Fabregat, R. (2010). Context-Aware Content Adaptation in mLearning. Proccedings of 9th World Conference on Mobile and Contextual Learning MLEARN2010, Valletta, Malta. October 19-22.

Gómez, S., Mejía, C., Huerva, D., & Fabregat, R. (2009). Context-Aware Adaptation Process to Build Units of Learning Based on IMS-LD Standard. Proccedings of International Conference on Education and New Learning Technologies (EDULEARN 2009) Conference, Barcelona (Spain).

Gómez, **S.,** Huerva, D., Mejía, C., Baldiris, S., & Fabregat, R. (2009). Designing Context-Aware Adaptive Units of Learning Based on IMS-LD Standard. Proccedings of EAEEIE 2009 Conference, Valencia (Spain).

Mejía, C., Baldiris, S., **Gómez, S.,** & Fabregat, R. (2009). Personalization of E-Learning Platforms based on an adaptation process supported on IMS-LIP and IMS-LD. In I. Gibson, R. Weber, K. McFerrin, R. Carlsen, & D. A. Willis (Eds.), Society for Information Technology & Teacher Education International Conference 2009 (pp. 2882-2887). Charleston, SC, USA: AACE.

Mentions and awards

Gómez, **S.** (2011). Special Mention for the innovative and practical mobile solution: "Integrating second language learning skills in real-life tasks: using tools for a context-aware and adaptive Mobile Learning". Mobile Learning Challenge 2011, Co-sponsored by the International Association for Mobile Learning (IAmLearn) and Epic.

Invited Talks

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Gómez, S., & Fabregat, R. (2010). Learning design implementation in context-aware adaptive mobile learning. BCDS International Workshop. Salou, Spain.

Gómez, S., Mejía C., & Fabregat, R. (2009). Construction of Adaptive Learning Units based on the context of access. In First International Conference of "Ambientes Virtuales de Aprendizaje Adaptativos y Accesibles - Competencias para Todos (CAVA3 2009)", Montería, Colombia.

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Scientific collaborations

Collaborative work initiative for the development of the mobile delivery system: "Units of Learning Mobile Player" (UoLmP). Participating entities: Communications and Distributed Systems (BCDS) from the Universitat de Girona (Spain), and the Research Unit on Advanced Digital Systems and Services for Education and Learning (ASK) from University of Piraeus (Greece). 2012.

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Acronyms

ADL	Advanced Distributed Learning
API	Application Programming Interface
CC/PP	Composite Capabilities/Preference Profiles
EOI	Escola Oficial d'Idiomes (Official Language School)
GPS	Global Positioning System
IEEE	Institute of Electrical and Electronics Engineers
IMS	Instructional Management Systems
IMS-CP	IMS Content Packaging
IMS-GLC	IMS Global Consortium
IMS-LD	IMS Learning Design
IMS-SS	IMS Simple Sequencing
LCD	Liquid-Crystal Display
m-learning	Mobile learning
MMS	Multimedia Messaging Service
OMA	Open Mobile Alliance
OMA-STI	OMA Standard Transcoding Interface
PC	Personal Computer
PDA	Personal Digital Assistant
QR-Codes	Quick Response Code
RFID	Radio-frequency identification
RQ	Research Question
SCO	Sharable Content Objects
SCORM	Sharable Content Object Reference Model
SOAP	Simple Object Access Protocol
SMS	Short Message Service
TeL	Technology-enhanced Learning
UAProf	User Agent Profile

UML	Unified Modeling Language
UNESCO	United Nations Educational, Scientific and Cultural Organization
UoL	Unit of Learning
UoLmP	Units of Learning mobile Player
URL	Uniform Resource Locator
W3C	World Wide Web Consortium
WURFL	Wireless Universal Resource File
XHTML	Extensible HyperText Markup Language
XML	Extensible Markup Language

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ABSTRACT

Since the mid nineties, a continue increase in the market of handheld technologies and consequently in the widespread ownership of mobile devices has drawn the attention of researchers in *Technology-enhanced Learning (TeL)*. They have been interested in investigating how these technologies can be exploited for educational purposes aiming to enhance learning experiences. As a result, this has lead to a research trend which is commonly referred to as *Mobile Learning (m-learning)* in which, researchers' efforts have aimed to deliver suitable learning experiences to learners considering their personal mobility needs, the ubiquitous use of mobile technologies and the availability of information anytime-anywhere. Nevertheless, m-learning is still in its infancy and great efforts need to be done so as to investigate the potentials of a educational paradigm shift from the traditional one-size-fits-all teaching approaches to an adaptive and personalized learning that can be delivered via mobile devices.

Thereby, an open challenge has been identified from this implication:

How can be learning design implemented so as to benefit from the m-learning characteristics and achieve adaptation and personalization of the individual learning process in different contexts?

An important factor for achieving personalized and adaptive m-learning has been the pedagogically meaningful and technically feasible processing of *learners' contextual information*. Therefore in this work, design and delivery of traditional pedagogical-oriented educational scenarios are suggested to be re-thought so as to benefit from the affordances of learners' context and, thus present a solution that addresses the presented problem.

In order to achieve this, innovative use of learners' context has been examined to define a context model that supports both, design and delivery approaches of the learning design. As well as to demonstrate its implication in general traditional constructivist pedagogical principles, in terms of ways of using mobile tools, physical spaces, time allocation, means of communication, distribution of roles, distribution of resources and so on.

Moreover, it was inspected its technological relevance to the development of two context-aware adaptation mechanisms, namely *polymorphic presentation* (for *content adaptation*) and *content filtering* (for *educational scenarios delivery adaptation*), so as to provide learners with adapted educational activities and materials. Adaptations achieved by these mechanisms support *learning flow navigation and sequence*, *problem solving* and *interactive communication between learners* while they are following the learning paths of a designed educational scenario.

Being aware of contextual information also led to the construction of an m-learning delivery system, namely Units of Learning mobile Player (UoLmP), that can dynamically adapt to the changing context, during the learning process, towards to a more effective and enhanced delivery of educational scenarios.

Experimentation with the developed mechanisms, as well as with delivering a designed context-aware educational scenario through UoLmP, to students in a real language learning center, support the application of the proposed solutions and revealed promising results. Described results confirmed the effectiveness of the adaptation mechanisms and UoLmP. Finally, the results gave positive clues about the engagement of students' in constructivist context-aware educational scenarios, as well as the enhancement of students' attitude heading the use of a context-aware and adaptive delivery system for m-learning.

RESUMEN

Desde mediados de los noventa, un continuo incremento en el mercado de las tecnologías móviles y consecuentemente en su extensiva posesión, ha atraído la atención de investigadores en el *Aprendizaje Mejorado por Tecnologías* (*TeL* por sus siglas en inglés), quienes se han interesado en investigar cómo estas tecnologías podrían ser explotadas para mejorar las experiencias en el aprendizaje. Esto dio lugar a una línea de investigación que se conoce comúnmente como *Aprendizaje Móvil* (*m-learning* en inglés). En esta línea, los esfuerzos se han dirigido a ofrecer experiencias de aprendizaje a los estudiantes, teniendo en cuenta sus necesidades de movilidad, el uso ubicuo de las tecnologías móviles y la disponibilidad de información en cualquier momento y en cualquier lugar. Sin embargo, m-learning se encuentra todavía en su infancia y se deben hacer grandes esfuerzos para investigar el cambio de paradigma educativo, desde la forma de enseñanza tradicional de "un modelo único para todos" a un aprendizaje adaptativo y personalizado que se pueda entregar a través de dispositivos móviles.

De esta manera, el siguiente desafío ha sido identificado por esta implicación:

¿Cómo se puede implementar el diseño instruccional con el fin de beneficiarse de las características del m-learning y lograr la adaptación y personalización del proceso de aprendizaje personal en diferentes contextos?

Un importante factor para lograr un m-learning personalizado y adaptable ha sido el procesamiento de la *información contextual de los estudiantes*. Por lo tanto, en este trabajo se sugiere que sean re-pensados el diseño y la entrega de escenarios educativos basados en una pedagogía tradicional, con el fin de beneficiarse de las potencialidades del contexto de los estudiantes y así presentar una solución que aborde el desafío presentado.

Para lograr esto, ha sido examinado el uso innovador del contexto de los estudiantes para definir un modelo de contexto que apoye tanto, el enfoque de diseño y el de ejecución del diseño instruccional. Así también, para demostrar la implicación que puede tener en principios pedagógicos constructivistas tradicionales, con respecto a la forma de usar herramientas móviles, el uso de espacios físicos, la asignación de tiempo, los medios de comunicación, la apoyo de recursos, etc.

Por otra parte, se inspeccionó su relevancia tecnológica para el desarrollo de dos mecanismos de adaptación sensibles al contexto, a saber, la *presentación polimórfica* (para *la adaptación de contenidos*) y el *filtrado de contenidos* (para *la adaptación en la entrega de escenarios educativos*). Las adaptaciones logradas con estos mecanismos apoyan la *navegación y el seguimiento del flujo de aprendizaje*, *la resolución de problemas* y la *comunicación interactiva* entre estudiantes, mientras siguen los caminos de aprendizaje de un escenario educativo.

La explotación de la información contextual también condujo este trabajo a la construcción de un sistema para el m-learning, llamado "Reproductor móvil de Unidades de Aprendizaje (UoLmP por sus siglas en inglés)". Este sistema puede adaptarse dinámicamente al contexto durante el proceso de aprendizaje y ofrecer una entrega ajustada de los escenarios educativos.

La experimentación con los mecanismos desarrollados y con la entrega de un escenario educativo sensible al contexto a través de UoLmP a los alumnos de un centro de idiomas, ayudó a aplicar las soluciones propuestas y reveló resultados prometedores. Los resultados descritos confirmaron la eficacia de los mecanismos de adaptación y de UoLmP. Finalmente, los resultados dieron pistas positivas sobre el acoplamiento de los estudiantes en escenarios educativos constructivistas sensibles al contexto, como también sobre el mejoramiento en la actitud de los estudiantes hacia el uso de un sistema sensible al contexto para m-learning.

RESUM

Des de mitjans dels noranta, un continu increment en el mercat de les tecnologies mòbils i conseqüentment en el seu extensiva possessió, ha atret l'atenció d'investigadors en l'*Aprenentatge Millorat per Tecnologies* (*TeL* per les sigles en anglès), que s'han interessat en investigar com aquestes tecnologies podrien ser explotades per millorar les experiències en l'aprenentatge. Això va donar lloc a una línia d'investigació que es coneix comunament com *Aprenentatge Mòbil* (*m-learning* en anglès). En aquesta línia, els esforços s'han dirigit a oferir experiències d'aprenentatge als estudiants, tenint en compte les seves necessitats de mobilitat, l'ús ubic de les tecnologies mòbils i la disponibilitat d'informació en qualsevol moment i en qualsevol lloc. No obstant això, m-learning es troba encara en la seva infància i s'han de fer grans esforços per investigar el canvi de paradigma educatiu, des de la forma d'ensenyament tradicional d '"un model únic per a tots" a un aprenentatge adaptatiu i personalitzat que es pugui lliurar a través de dispositius mòbils.

D'aquesta manera, el següent desafiament ha estat identificat per aquesta implicació:

Com es pot implementar el disseny instruccional per tal de beneficiar-se de les característiques del m-learning i aconseguir l'adaptació i personalització del procés d'aprenentatge personal en diferents contextos?

Un important factor per aconseguir un m-learning personalitzat i adaptable ha estat el processament de la *informació contextual dels estudiants*. Per tant, en aquest treball es suggereix que siguin re-pensats el disseny i el lliurament d'escenaris educatius basats en una pedagogia tradicional, per tal de beneficiar-se de les potencialitats del context dels estudiants i així presentar una solució que abordi el desafiament presentat.

Per aconseguir això, ha estat examinat l'ús innovador del context dels estudiants per definir un model de context que doni suport tant, l'enfocament de disseny i el d'execució del disseny instruccional. Així també, per demostrar la implicació que pot tenir en principis pedagògics constructivistes tradicionals, pel que fa a la forma d'usar eines mòbils, l'ús d'espais físics, l'assignació de temps, els mitjans de comunicació, la suport de recursos, etc.

D'altra banda, es va inspeccionar la seva rellevància tecnològica per al desenvolupament de dos mecanismes d'adaptació sensibles al context, és a dir, la *presentació polimòrfica* (per a *l'adaptació de continguts*) i el *filtrat de continguts* (per a l'*adaptació en el lliurament d'escenaris educatius*). Les adaptacions aconseguides amb aquests mecanismes donen suport a la *navegació i el seguiment del flux d'aprenentatge*, la *resolució de problemes* i la *comunicació interactiva* entre estudiants, mentre segueixen els camins d'aprenentatge d'un escenari educatiu.

L'explotació de la informació contextual també va conduir aquest treball a la construcció d'un sistema per al m-learning, anomenat "Reproductor mòbil d'Unitats d'Aprenentatge (UoLmP per les seves sigles en anglès)". Aquest sistema pot adaptar dinàmicament al context durant el procés d'aprenentatge i oferir un lliurament ajustada dels escenaris educatius.

L'experimentació amb els mecanismes desenvolupats i amb el lliurament d'un escenari educatiu sensible al context a través de UoLmP als alumnes d'un centre d'idiomes, va ajudar a aplicar les solucions proposades i va revelar resultats prometedors. Els resultats descrits confirmar l'eficàcia dels mecanismes d'adaptació i de UoLmP. Finalment, els resultats van donar pistes positives sobre l'acoblament dels estudiants en escenaris educatius constructivistes sensibles al context, com també sobre la millora en l'actitud dels estudiants cap a l'ús d'un sistema sensible al context per a m-learning.

CHAPTER 1

INTRODUCTION AND OUTLINE OF THE THESIS

This chapter provides an overview on the main facets of the research in this thesis. First, the author describes the research problem and expresses the motivation to work on it and the related aspects presented along the chapters of this thesis. Then, general questions for the research are introduced and discussed in brief. After that, the defined objectives and research proposal is described and the research methodology is explained so as to give details of the general scopes in the work. This chapter concludes describing the contributions of this research and the description of the structure of this thesis at last.

1.1 Motivation and Problem Definition

Over the past years there has been a huge increase in the market of handheld technologies and consequently in the widespread ownership of mobile devices. The production of new and different mobile devices is tending to provide users with a variety of technological capabilities and diverse possibilities to access the information offering a ubiquitous immersion with interconnected communities. This have generated a growth in the provision of new services by mobile communications industry, that include internet access without place and device constraints, interpersonal and group communication (via wireless, mobile communications and virtual private networks) without location and time restrictions, sharing of digital content in any format (text, image, audio and video), location-aware information delivery and personalized assistance based on users' preferences and needs (Herrington, J., et al., 2009; Sharples & Roschelle, 2010). Therefore, mobile devices have became the type of objects with greatest index of usability, joining several functionalities, tools and services that can be accessed anywhere, anytime, and satisfying the nomadicity needs that people have while they are moving and normally carrying everyday tasks to any place.

This growth has drawn the attention of researchers in ***Technology-enhanced Learning*** (TeL) which are interested in studying how mobile devices can be exploited for educational purposes aiming to enhance or re-think traditional classroom-based and/or desktop-based web-facilitated educational experiences. As a result, this has lead to a research trend which is commonly referred to as ***Mobile Learning*** (m-learning) in which researchers and educational stakeholders have been concentrating their efforts so as to consider the affordances of wireless and handheld technologies in education.

Briefly going through m-learning history, in its early days (mid 1990s) research and educational initiatives focused on taking the most of "*mobile and wireless technologies within the classroom"*, i.e. in this phase there was an interest on what devices, in particular PDA, laptops and mobile/cell phones, can be used for in an educational context for instruction and training. Then, in early 2000s, a second phase of m-learning focused on "*learning outside the classroom*". Researchers' interest relied on highlight the benefits that mobile technologies may bring to meaning-making for a person in situations outside institutionally framed educational contexts. This second phase includes field trips, museum visits, and personal learning organizers, among others. Finally, by mid 2000s, research initiatives start focusing on the "*mobility of the learner*" involving the design or the appropriation of learning spaces and on informal learning and lifelong learning. In this third phase, affordances of emerging technology, surrounding resources and availability of information to the learner's situation and context can be distinguished.

Since the beginnings of third phase of m-learning, a new research trend has been emerging which focus rely on *delivering personalized and adapted mobile learning experiences to learners* with regards to: i) the mobile device from which they are interacting with (i.e. aspects of 1st phase of m-learning); ii) their individual needs and preferences in learning situations different from a traditional classroom (aspects of 2nd phase of m-learning); and iii) the surrounding resources (people, ambient technologies, physical objects, etc.) that may affect the interaction between learners with anytime-anywhere available information (aspects of 3rd phase of m-learning) (Hwang, 2006; Sampson et al., 2012).

While m-learning is a growing research area, aspects of adaptivity and personalization are becoming more and more important and they are playing an important role towards providing learners with adaptive and personalized learning experiences delivered via mobile devices (Nagella & Govindarajulu, 2008; Economides, 2009; Kinshuk, Graf & Yang, 2009;). Thus, in order to achieve adaptive and personalized m-learning, suitable educational scenarios should be re-thought and re-designed (Beetham & Sharpe, 2007) considering different learning situations in which are participating: different personal learners' aspects (such as their individual preferences and needs among others) and aspects related to the heterogeneity of resources and information presented in different contexts (Ravenscroft & Sharples, 2011). Moreover, adaptivity and personalization issues should be incorporated in the development of m-learning systems (Graf & Kinshuk, 2008) so as to provide learners with a learning environment that is not only accessible anytime and anywhere, but also accommodating to their context.

An important success factor for achieving personalized and adaptive m-learning has been the pedagogically meaningful and technically feasible processing of ***learners' contextual information***. While the formal definition of context is still an open issue (Luckin, 2010), generally in TeL and for the background aspects of this research work, the perspective of contextual information involved every piece of information that characterizes a learners' given situation.

Innovate use of context from different disciplines can be examined for potential relevance to, the development of new educational scenarios and m-learning systems in TeL, as well as to demonstrate its implications in general traditional or newcomer pedagogical principles in terms of ways of using mobile tools, physical spaces, time allocation, means of communication, distribution of roles, resources and so on. Therefore, there is an existing need on examining technology and context relevance to "design and delivery for learning", the process whereby teachers, instructors, and designers in general arrive at a plan of design and delivery for different learning situations (Sharples, 2002; Müller, Krogstie & Schmidt, 2011; Schmidt & Braun, 2006).

Being aware of and exploiting contextual information (for example, learners' different prior knowledge, interests, learning styles, learning goals, as well as current location and movements in the environment) can lead to context-aware educational scenarios and m-learning systems that can dynamically adapt to the changing context during a learning process towards to a more effective, convenient and enhanced learning experiences.

However, in present TeL research there are neither learning design templates nor learning scenarios construction guidelines that let describing in the learning design process what mobile technologies and contextual information can be useful to provide what learners may need in different learning settings. Moreover, there exists a research challenge to define optimal ways on how educational materials can be suitable delivered in context and presented to different roles (learners, apprentices, teachers, instructors, etc.) which are the main actors of learning and instruction processes. An overarching challenge in the design of context-aware educational scenarios and mobile systems for learning is to determine when explicitly to model context and when to provide generic "awareness" activities, resources, tools or services that learners, individually and together, can undertake and employ respectively (Sharples, 2011)

Consistently, over the past years different types of context-aware mobile adaptation have been proposed (Jeng et al., 2010; Martin et al., 2011; Tan et al., 2009; Al-Mekhlafi, Hu & Zheng 2009). However, existing mechanisms for context-aware mobile content adaptation follows hard-wired implementations of their adaptation engines based on defined unique instances of learners' mobile contextual information. Consequently this impedes the process of (a) extending the adaptation engines with new instances of learners' mobile contextual information and (b) inter-exchanging these engines and their resultant types of mobile content adaptation with other adaptive learning systems and applications. Moreover, existing approaches consider that context-aware mobile adaptation is implemented only in real-time during the mobile delivery process, which in most cases, significantly delays the process of presenting adapted educational resources to the learners' mobile devices.

In general terms, in this research work author's motivation focused on studying the benefits that contextual information, existing on different learning situations and interactions, can provide to the ***learning design*** process, in terms of modeling it, defining it during design-time and retrieving and processing it during run-time, so as to achieve a personalized and adaptive m-learning design and delivery. Thus, in order to achieve this, context-aware adaptation approaches for the learning design process as well as tools for processing learners' contextual information and delivering adaptive educational scenarios via mobile devices are needed.

1.2 Research Questions

Through widespread ownership of portable devices and the increasing growth of mobile technologies and communications industry, people have been able to access information from any place at any time. Bearing this in mind, the computer science acquired a different perspective, marked by a ubiquitous manner of accessing and interacting with systems. This perspective, introduced by Weiser's vision (Weiser, 1991), was defined as a seamlessly integration between systems in the environment to aid and support people in their everyday activities. Following this trend, nowadays new technology has been produced so as to provide people with necessary tools and services facilitating their daily activities by means of a relaxing interaction with systems within different contexts.

TeL, as other related areas, has been influenced by this perception (Sakamura and Koshizuka, 2005). During the past years, a research challenge has been emerging with regards to involve ubiquitous use of mobile devices within teaching/learning strategies. Educational research initiatives has been focused on this ubiquitous characteristic combined with educational systems development, so as to offer important benefits to learning design and delivery processes, which could be summarized as follows (Abarca et. al, 2006; Ogata and Yano, 2004):

- Supporting pedagogical models that are based on authentic learning by exploiting real-life context.
- Providing flexible, adaptive and personalized learning experiences by exploiting learners' contextual information.

Consequently, different educational activities have been proposed by trainers/instructors/teachers to enhance teaching and learning experiences and to introduce learners with a ubiquitous m-learning initiative including: listening and watching different content provided as informative or self-assessment content to be used in specific places, communicating with peers anywhere and sharing content with them so as to produce collaborative projects, discussing with classmates about different topics presented in different downloadable media on a course web site, sending out bulk instant or short messages to inform learners about different events (new files available on subjects' web pages, evaluation dates, forum discussions opened, etc.), uploading videos with explanations about how to use tools in real world to ensure learners can recall instruction on different process when and where they need it, making field trips to engage learners in active experience, and providing learners with supportive mobile systems that guides them through visits, among other activities. Therefore, on the plethora of teaching/learning strategies and use cases that TeL users can be typically engaged in, the author of this research work is particularly interested in considering educational scenarios which may benefit from the use of mobile and wireless technologies and learners' contextual information, so as to re-think and implement them in a formal procedural learning plan that can be suitable delivered to learners' mobile devices. From this stems the first research and development question of this thesis is:

RQ1: *How can adaptive educational scenarios, which may benefit from learner's contextual information and m-learning dimensions, be designed and delivered?*

Among those different emerging activities and new incoming educational scenarios in which learners can be immersed by using their own handheld devices anytime and anywhere, one of author's focus rely on aiming to involve new trends of traditional *constructivist pedagogical approaches* for m-learning, so as to design constructive-oriented educational scenarios that benefits from m-learning characteristics.

With the growing impact of web based distance learning and open educational resources, constructivist pedagogical approaches are increasingly being studied by different researchers so as to define or apply suited pedagogical theories for contextual and m-learning (Ravenscroft & Sharples, 2011). According to this, the aforementioned research question implied the author of this thesis to bear in mind that for m-learning settings it is important to help individual learners to create mental images of the content they are viewing/watching/listening/reading so as they can follow self-directed the sequence of learning activities that are underway in a procedural learning structure and therefore they can construct knowledge and achieve the objectives defined by the instructor (O'Connell and Smith, 2007). Moreover, this led to an important issue that needed author's attention, that is, considering the affordances that activation of context may bring to the learning design process, i.e. identification and analysis of suited constructivist pedagogical theories for contextual and m-learning is needed to be applied in this research work.

On the other hand, a second author's focus rely on intending deliver those educational scenarios adaptively to learners' handheld device at hand considering how the information of learner's context may support and enhance learners m-learning experiences. Accordingly, this leads to a research challenge within this research work, that is, defining optimal ways on how educational activities and materials can be suitable delivered and presented to different learners (main actors of the learning process) considering diverse information from learner's contexts such as the characteristics of the learning place and its physical conditions, the spare time used to learn, the contributions of the surrounding people and the individual learning interests, preferences and needs in a particular moment, including the capabilities of the learners' mobile device at hand.

In addition to this, during the past two decades there have been a growing development of learning multimedia resources (e.g. presentations, web pages, animations, videos, etc.) and learning tools (e.g. collaborative tools, search engines, web translators, social network services, etc.) for e-learning purposes, and those digital educational resources have been mainly designed assuming access and delivery through desktop computers, this fact is increasing the barriers of learners in accessing them through their mobile devices (Su et. al., 2011; Zhao et al., 2008).

In m-learning environments, providing personalized educational sequenced activities (i.e. procedural learning plans represented in the learning design process) and educational digital materials (resources, tools, services, etc.) while taking into account limitations of the mobile devices such as limited screen sizes, limited memory available for page rendering and limited types of content supported (W3C-MBP, 2008) may cause the loss of information for learning and the failure to achieve the learning objectives if adaptation processes are not well designed and implemented. This leads to our second research and development question:

> ***RQ2****: How can educational digital materials, used by an instructor in a procedural learning plan (i.e. learning design), be adapted and suitable delivered to the learner's mobile device at hand considering learner's contextual information?*

Within this research work, it was important to consider the study of adaptation mechanisms based on learners' context characteristics that can be integrated into the learning design process and that enable suitable delivery of educational digital materials appropriately adapted to learners' mobile devices.

1.3 Objectives

The research heart, the title and the main objective (MO) of this thesis is to achieve a:

MO: *"Learning design implementation in context-aware and adaptive mobile learning"*

Nevertheless, to aim this, this research work needs to be focused on two main approaches that involve implementation of the learning design process, namely: (i) the *design approach* and (ii) the *delivery approach:*

i) ***Design approach****:* in this approach a procedural learning plan (i.e. *learning design*), which from now on in this thesis may be also named as educational scenario, is produced. This approach is executed in design-time. In this approach an instructional designer (commonly an instructor/teacher) can describe and represent teaching/learning strategies following the foundations of a specific pedagogical model, by means of defining a set of learning activities/tasks as a procedural structure learning plan for learners. Moreover, different educational elements can be described in the learning design including: learning objectives, support/monitoring activities, educational tools and learning resources that learners can use so as to complete activities, and environments in which tools and resources can be used, among other elements that the designer may consider relevant. As part of the proposals in this research work, the author of this thesis is considering to support description of educational scenarios in the learning design approach by identifying and exploiting real-life learner's heterogeneous contextual information. Moreover, in this approach adaptation of educational materials (i.e. digital content such as web content, videos, audios, images), which are populating constructed educational scenarios, is proposed so as to deliver them to the learner's mobile device without restrictions of the capabilities of the delivery device.

ii) ***Delivery approach***: in this approach a created educational scenario is provided and deployed to learners. This approach is executed in run-time. Moreover, favorable means to deliver adaptive educational scenarios that are created by the designer, needs to be designed and developed in this approach. Some of the commonly used means include adaptive *learning flow navigation and sequencing*, adaptive *problem solving support and feedback (scaffolding)*, and adaptive *interactive learners' communication*. Since in this research work the author of this thesis focused on achieving m-learning experiences delivery through the learner's mobile device at hand, providing and deploying context-aware and adaptive educational scenarios is attempted to be supported by the implementation of the proposed adaptation processes.

Since the past years, TeL has been introduced to a variety of technology-oriented settings and blended learning scenarios, and in all these settings and scenarios the learner's situation or context has been considered as an essential asset in designing and delivering the learning process (Chen & Kotz, 2000). In m-learning situations, completion of activities may be influenced by personal characteristics of the learner such as competence profile (knowledge, skills, attitudes) and individual features (mood, preferences, needs, interests, etc), as well as be supported by the interaction with resources such as surrounding people (learning peers, family, tutors, experts, etc.), digital devices (mobile technologies, ambient intelligence technologies, etc.) and non-digital resources (books, documents, etc,), and besides be affected by characteristics of the status of a learning situation such as time, physical conditions of the place, cultural and social milieu, among other characteristics. All this information and resources have the potential to enable teachers to take advantage of each learning situation by means of designing the learning process, bearing in mind how this information can be exploited to enhance learning experiences. Moreover, it has been suggested that the construction of adaptive and personalized educational systems, may provide solutions to the problem of considering this entire context's heterogeneity to support the design and delivery processes (Brusilovky & Millán, 2007).

Bearing the aforementioned aspects in mind, the author of this thesis aims to address those issues by the following specific objectives:

- ***O1:*** *Defining a context model for identifying and describing the information that can be used to characterize the situation of a particular entity (i.e. anything relevant) participating in the interaction between an individual learner and a mobile system.*
- ***O2:*** *Implementing context-aware and mobile adaptation processes for both design and delivery approaches of the learning design.*
- ***O3:*** *Designing exemplary context-aware and adaptive mobile educational scenarios so as to explain and present how possible adaptations, that are realized based on learner's contextual information, can be incorporated.*
- ***O4:*** *Delivering pedagogical-enhanced and structured adaptive and context-aware educational scenarios via mobile devices.*

In chapter 4 a description of the proposals to achieve the development of aforementioned objectives will be presented.

1.4 Research Methodology

TeL is the encompassing research field to which the work done in this thesis belongs. Particularly, this works focuses on bringing into play mobile technologies to enable m-learning and empowering the benefits that learner's contextual information can provide to mobile educational scenarios. As presented in previous section, in order to accomplish the ***MO***, four linked research goals were proposed (***O1***, ***O2***, ***O3*** and ***O4***) which can be summarized in: ***O1***), defining a context model, ***O2***) implementing context-aware and mobile adaptation mechanisms for both design and delivery approaches of the learning design, ***O3***) designing exemplary context-aware mobile educational scenarios, and ***O4***) delivering context-aware mobile educational scenarios via mobile devices. Therefore, an *engineering research* was applied and the used methodology must be understood as such. According to (Richards, 1993), the methodology of an *engineering researc*h (which has been followed in the presented work) is composed of the following four phases:

1) ***Information phase***. The aim of this first step is to identify the existing characteristics of the problem domain and to clearly state the subject under research. This phase usually consist in the revision of the existing literature. Thus, the information gathered by the author of this dissertation, comes from the following sources:
    - The review of relevant related literature with m-learning, context-aware adaptive computing, learning design and pedagogical approaches for m-learning, which provided a theoretical background of the problem domain and the existing work in the field.
    - The identification of researchers and research groups working on similar problems that enriched the discussions of the matter in question. Besides, along with the source, visiting related research groups and the participation in workshops, in information and communication technology oriented research projects and the development of coordinated field experiences.
    - The number of documented practical case studies and experiments in the research field, which suggests the development of experiences that contributed to the literature with empiric knowledge and research on the problem domain.

2) ***Definition phase.*** The information gathered from the previous phase results in the definition of proposals and approaches of implementation in order to find and produce a solution that overcomes the limitations presented in the existing alternatives. In this thesis, such solution consists in the implementation of the learning design so as to achieve a context-aware and adaptive m-learning.

   The definition of the proposal emphasizes the implementation by focusing on two approaches that involve implementation of the learning design process, namely: the *design approach* and the *delivery approach*. Thus, to achieve this some proposals were defined and briefly include (Further details of these proposals will be presented in chapter 4):

   i) Produce a taxonomy of contextual elements,
   ii) Adapting educational materials through mechanisms for *content adaptation* and *context-aware educational scenarios adaptation* so as they can be delivered to the learners' mobile device at hand.
   iii) Identifying traditional pedagogical strategies which have relevancy on a constructive (individual and social) and situated perspective of how learning process can be taken and be described for contextual and m-learning,
   iv) Adopting the IMS Learning Design (IMS-LD) Specification (IMS-LD, 2003) which has been proposed as a possible notation language for describing learning designs, as well as accompanying educational content-based adaptations and following a machine readable format,
   v) Developing a mobile delivery system that parses defined pedagogical-enhanced learning paths designed by the teacher (based on a notation language) and processing different instances for contextual elements (which normally are changing variables with different values) accordingly to a designer's plan and learner's situation.

3) ***Implementation phase.*** The implementation of the proposal assesses its practical feasibility and allows the deployment of case studies oriented towards the validation of the proposed model.

   The solution proposed in this thesis has been implemented considering two context-aware and mobile adaptation mechanisms, namely *content filtering* and *polymorphic presentation*, for both *design* and *delivery* approaches of the learning design, which includes the application of the taxonomy of contextual elements and the IMS-LD Specification as the core element; as well as a mobile system for capturing/processing learner's contextual information and delivering context-aware adaptive educational scenarios.

4) ***Validation phase.*** The last step of the applied methodology is the definition and deployment of experiments that evaluate the validity of the proposal, in order to show and document how the proposed solution overcomes the limitations identified in the information phase.

   In this thesis, the validation consisted in the deployment and later study of a case of study that used the proposed implementation solutions. Experiences with a constructed context-aware adaptive educational scenario, jointly with the approach for delivering through the developed mobile delivery system was analyzed with an evaluation that combines qualitative and quantitative analysis of the results.

1.5 New achievements of the thesis

This section gathers in a nutshell (a common term used to characterize mobile content) a description of the new achievements and outcomes of the research work explained along the chapters in this dissertation.

In general terms, as it was previously mentioned the motivation of the author of this thesis, relies on studying the benefits that contextual information, existing on different learning situations and interactions can provide to the learning design process, in terms of modeling it, defining it during design-time and retrieving and processing it during run-time, so as to achieve a personalized and adaptive m-learning design and delivery.

Thereafter, here are listed the new achievements of this research work which address the defined objectives:

- *Addressing* ***O1***: In this research work, heterogeneity of learner's contextual information was narrowed to a set of contextual elements that jointly together made part of a taxonomy for designing and delivery context-aware and adaptive m-learning educational scenarios. Thus, these elements can be used by authors (e.g. instructors, teachers, tutors, etc.) as part of the learning design process. Moreover, these elements characterize the information of a context model which, represented within the structure of a learning design, can be processed by an adaptation engine. The results of the adaptations achieved by such an adaptation engine are the delivery of learning activities and educational materials while a learner is following the flow of a procedural learning plan or learning design. The context model was firstly published in (Gómez et al., 2009b) and further refined and published in a journal (Gómez & Fabregat., 2012).
- *Addressing* ***O2***: Bearing in mind that existing mechanisms for context-aware mobile content adaptation follows hard-wired implementations of their adaptation engines based on pre-defined instances of learners' mobile contextual information, in this research work is presented a possible solution to these issues with the formal description of the adaptation engines by using a notation language that is independent of the particular implementation of the mobile content adaptation mechanism in hand. This solution involves the implementation of an adaptation approach based on the adoption of the IMS-LD Specification (IMS-LD, 2003). A specification that has been adopted by learning design researchers as a possible notation language for describing learning designs and which has not been exploited so far for considering the particularities of context-aware mobile content adaptation processes. This specification follows a machine readable format and it let addresses educational content-based adaptations in the form of rules.

  Summarizing the solutions for this issue, in this research work it is presented:

  i) an adaptation approach for designing context-aware adaptive educational scenarios which utilizes IMS-LD as the enabling specification for describing an adaptation engine (in the form of adaptation rules). This outcome was published firstly in (Gómez et al., 2009a) and then refined and published in a journal (Gómez & Fabregat, 2012);

ii) a subsequent process which utilizes a mobile educational content adaptation mechanism for packaging and delivering context-aware education scenarios based on a content transcoding process which can be integrated to Learning Design authoring tools or Learning Design packages repositories. This outcome was published in (Gómez & Fabregat, 2010); and

iii) a set of design requirements for tools that enable authoring and delivering of context-aware Learning Designs with mobile content adaptation features, that was published firstly in a peer-reviewed international conference (Zervas et al., 2011) and then refined and published in a book chapter (Zervas et al., 2012).

- *Addressing* ***O3***: Even though describing a new TeL educational scenario may not be seen as a new research achievement in this thesis, this exercise let demonstrate how pedagogical theories, teaching/learning strategies, educational content, immersion of new technologies, among other educational elements, can be combined and merged so as to support how knowledge, skills and attitudes can be acquired by learners, and this, nevertheless can be seen as an outcome of a complex task called learning design. Saying this, the author of this thesis in company with a teacher of the Official Language School ("EOI" in Spanish language) at Girona, Spain, produce two exemplary context-aware mobile educational scenarios so as to explain and present two new achievements: a) how traditional pedagogical models which have relevancy on a constructive (individual and social) and situated perspective can be considered so as to describe how learning process can be taken for contextual and m-learning, and b) how possible adaptations of learning materials (learning activities, resources, tools and services) that are realized based on learner's contextual information can be incorporated. One of these two educational scenarios was published in (Gómez et al., 2012) and the other in (Gómez et al., 2013a).
- *Addressing* ***O4***: Finally, aiming to address delivering pedagogical-enhanced and structured adaptive and context-aware educational scenarios via mobile devices, a mobile delivery system, namely Units of Learning mobile Player (UoLmP), is presented. This system supports adaptive delivery of educational activities, learning resources, mobile tools and communication services (considered within the structure of a Learning Design) to the learners' device at hand by processing captured contextual information. The system and its functionalities were firstly introduced and published in (Gómez et al., 2012). Then, it was firstly evaluated in a case study and published in (Gómez et al., 2013a). Finally, its architecture was further explained and the description of the evaluation was extended and submitted to a journal (Gómez et al., 2013b).

  Through this achievement the author of this thesis addresses the issue of needed tools that process learners' contextual information and deliver adaptive educational scenarios via mobile devices. Moreover, by achieving this he provides a solution for a m-learning research challenge, that is, taking into account other aspects not yet considered in context-aware m-learning systems development such as parsing defined learning paths designed by a learning design author (based on a notation language) and defining and capturing different instances for contextual elements (which normally are changing variables with different values) accordingly to a learning designer's plan and learner's situation.

As a relevant part of the followed research methodology, validation of the context-aware adaptation approach for designing and delivering adaptive educational scenarios and the mobile delivery system (i.e. UoLmP) is also described and presented in this document. Gathered experiences with the context-aware and mobile adaptation approach for packaging and delivering adaptive educational scenarios (more specifically the adaptation of the content that populates educational scenarios) was evaluated and published in a journal (Gómez & Fabregat, 2012). Additionally, a case study was held for the evaluation of delivering adaptive educational scenarios through UoLmP in the EOI (the Official Language School at Girona, Spain) with participating students enrolled in an intermediate English level course. Described results show the effectiveness of the adaptation approach in run-time and the usability and acceptance of UoLmP. Besides, the results show the support of the mobile system to enhance students' attitude heading the use of mobile technologies for learning. These results were introduced and published in (Gómez et al., 2013a), and further descriptions and discussions of the evaluation were submitted to a journal (Gómez et al., 2013b).

1.6 Structure of this document

Overall, this thesis presents a solution to the implementation of the learning design considering a context-aware and adaptive m-learning design and delivery, as well as it attempts to take stock of the details developments in the field of m-learning, to describe learning design issues for context-aware educational scenarios construction and to explain some adaptation developments for context-aware m-learning systems for context-aware educational scenarios delivery.

The structure of this document consists of eigth chapters and a set of appendices, described as follows:

1.6.1 Chapter 1: Introduction and Outline of the Thesis

This chapter starts off in the Introduction with an overview of the motivation of the author of this thesis and the problem definition from the key issues discussed throughout the thesis that involves implementation of learning design for context-aware and adaptive m-learning. Then, this overview is followed by the presentation of general formulated research questions and the defined objectives to achieve along the research work, accompanied with the proposal that support target achievements. Finally, the research methodology based on an engineering research is presented, as well as the achievements description obtained from the work done along the three years that this work lasted.

1.6.2 Chapter 2: Designing for M-learning

Chapter 2 begins with an overview of the work done in the *Information phase* (from the followed *engineering research* methodology). In particular, the description and explanations of the theoretical background related with the definitions, expansion and opportunities of m-learning. Moreover, it is presented the definition of context, and what it means for an m-learning system to be aware of context, as well as it is introduced the process of modeling the context so as to achieve a context-aware system. Besides, It is introduced the foundations of instructional/learning design and further description of related aspects (i.e. issues about its implementation) so as it can be implemented for m-learning scenarios.

1.6.3 Chapter 3: Context-aware Adaptivity in Heterogeneous M-Learning Environments

Afterwards, Chapter 3 goes into aspects of adaptivity by explaining first, main issues to take into account to achieve an adaptive m-learning design and delivery. Then, two scopes for adaptation are presented, namely *educational content adaptation* and *context-aware educational scenarios adaptation.* In each scope, some mechanisms and methods of adaptation are described.

1.6.4 Chapter 4: Proposal for Designing and Delivering Context-Aware Adaptive M-Learning

This chapter addresses the activities defined in the *definition phase* of the followed engineering research methodology. Moreover, this chapter presents details of the proposal made in this research work so as to achieve the defined objectives and to attempt answering formulated research questions.

1.6.5 Chapter 5: Designing Context-Aware and Adaptive Educational Scenarios for M-Learning (Design-Time)

This chapter along with Chapter 6 addresses the activities defined in the *implementation phase* of the followed engineering research methodology. Chapter 5 emphasizes on the implementation by focusing on one of the two approaches that involve implementation of the learning design process, namely: the *design approach*.

The implementation for the *design approach* is presented as follows: i) the context model is described, ii) an adaptation process to achieve authoring context-aware and adaptive educational scenarios is explained phase by phase, and iii) some testing made of the implementation is described.

1.6.6 Chapter 6: Delivering Context-Aware and Adaptive Mobile Educational Scenarios (Run-Time)

On the other hand, Chapter 6 emphasizes on the implementation by focusing on the *delivery approach* which involve implementation of the delivery of the learning design process.

The implementation for the *delivery approach* is presented in this chapter as follows: i) an introduction to the mobile delivery system, namely UoLmP is described, ii) an adaptation process, undertaken by UoLmP, to achieve delivering context-aware and adaptive educational scenarios is explained phase by phase, and iii) an usability study made for UoLmP and its results are described.

1.6.7 Chapter 7: Evaluation in a Language Learning Center

Chapter 7 addresses the activities defined in the *validation phase*. More precisely, in this chapter definition and deployment of a case of study to evaluate the validity of the developed solution is presented. The validation consisted in the deployment and later study of experiences with an authored context-aware adaptive educational scenario jointly with the approach for delivering through the mobile delivery system.

1.6.8 Chapter 8: Conclusions and Future Work

Finally, in this chapter general discussion and conclusions of the research work presented in this thesis is presented. Basically, some conclusions are drawn, general results are reviewed and some limitations are addressed. As a final point, future research work is proposed.

1.6.9 Appendices

A set of four appendices are presented so as to support further details and explanations made in the other parts of this thesis. The appendices are: i) Taxonomy of contextual elements for m-learning design, ii) Learning design of an adaptive context-aware educational scenario based on the *project based learning* pedagogical model, iii) Learning design of an adaptive context-aware educational scenario based on the *experiential learning* pedagogical model, and iv) Questionnaire for the evaluation of the experience with a context-aware and adaptive mobile educational scenario and UoLmP.

CHAPTER 2

DESIGNING FOR M-LEARNING

This chapter presents an overview of the relevant contributions regarding theoretical and technological concepts. In particular, the description and explanations of the theoretical background related with the definitions, expansion and opportunities of m-learning. It also presents relevant contributions about context definition in the education sector and what it means for an m-learning system to be aware of context, as well as it is introduced the process of modeling the context so as to achieve a context-aware system.

Consecutively it introduces theoretical concepts and foundations of the instructional/learning design process, which is pillar of this thesis, as well as further description of related aspects (i.e. issues about its implementation) so as it can be implemented for m-learning scenarios.

Finally, this chapter presents the most important contributions regarding the key challenges of designing the learning process in mobile contexts, as well as the relevancy that traditional pedagogical approaches are bringing to achieve the design of context-aware m-learning.

2.1 Mobile learning (m-learning)

Different traditional learning activities can be categorized as m-learning including: the development of individual and group work as homework, reading books in different places, doing field trips, visiting museums, and other activities that have been conducted over the years and have been provided the opportunity for learners to acquire knowledge outside of a classroom. All these types of activities, where learning occurs outside a formal classroom, can be framed in the concept of m-learning, however, there still exists a lack of clarity about what best be understood by the m-learning term with regards to the benefits that mobile and wireless technologies can bring to education.

Additionally, there are some other aspects of m-learning that get the attention of the author of this thesis with regards to how it can be designed and implemented considering aspects of the learner’s context. These aspects are relevant so as to help explaining the foundations and ground ideas of this dissertation. The aim of this section is to point out the fundamental concepts about m-learning at the basis of the research work presented in this thesis and to introduce the main key related subjects in literature, which are involved in such work.

2.1.1 Definitional Basis

As Pachler, Bachmair & Cook stated: "the basic principles informing work on m-learning are by no means new 'learning' in general, as well as its mediation by and through technology, is much written about field and it can hardly be claimed that the concept of 'mobility' has not been a concern of researchers, scholars and education practitioners for a long time" (Pachler, Bachmair & Cook, 2010).

M-learning is new in particular related to the i) capability of the mobile and wireless technology (i.e. the convergence of services and functions into a single device), ii) the emerging nomadicity needs that people are having while they are moving and normally carrying everyday tasks to any place, as well as iii) the ubiquity and abundance of information that can be accessed from any place (Kukulska-Hulme & Traxler, 2005).

According to this, definitions of m-learning in the literature are manifold but they tend to revolve around the *mobility of the technology*, the *mobility of the learner* and the increasing *mobility of information*.

One of the earliest definitions of m-learning was published by the year 2000 by Clark Quinn. He said that m-learning is "*the intersection of mobile computing and e-learning: accessible resources wherever you are, strong search capabilities, rich interaction, powerful support for effective learning, and performance-based assessment … e-learning independent of location, time and space.*" (Quinn, 2000)

With this first definition, researches could identify most of the elements that characterizes m-learning, and besides give their contributions to define m-learning as it was becoming a phenomena with new trends and practices in education, bearing in mind, the "mobility" aspect of participating elements.

According to (Shotsberger & Vetter, 2000), "*m-learning is a paradigm shift in teaching approaches based on the use of wireless internet connections and mobile devices such as laptops, mobile phones, smart phones, personal digital assistants (PDA), among others. The paradigm shift occurs due to the important features presented by these devices such as portability, immediacy, individuality, and accessibility*". (Kinshuk et al. 2003) propose a definition for m-learning as: "*the ability of using handheld devices to access learning resources*". Another definition for this term was given in (Dye, K'Odingo & Solstad, 2006) which defines it as "*learning that can take place anytime, anywhere with the help of a mobile computer device. The device must be capable of presenting learning content and providing wireless two-way communication between teacher(s) and student(s)*". In practical terms m-learning was defined in (Park, Baek & Gibson, 2008) as "*a form of learning delivered through mobile devices such as mobile phones, PDA, smart phones, tablet PC and similar devices combined with e-learning content*". Moreover, from a pedagogical perspective Mike Sharples (Sharples et al., 2008), one of the earliest pioneers of m-learning, conceive m-learning as "*a process of coming to know through conversations across multiple contexts amongst people and personal interactive technologies*".

These published definitions and some others have been emerging as m-learning is still evolving. According to Jhon Traxler (another pioneer of m-learning) in (Traxler, 2007), existing definitions of m-learning have been proposed in terms of devices and technologies, mobility of students, learning mobility and some others in terms of learning experiences of students using mobile devices. Further remaining discussions about definitions for m-learning were also taken by Traxler in (Traxler, 2009). Thus, the definition of m-learning is still an open issue.

However, there certainly exist some characteristics, beyond integrating mobile technologies in learning, which have grounded the definitions for m-learning so as to understand participating and interacting elements. In (Chen et al. 2002; Curtis et al. 2002; Sharples, Taylor & Vavoula, 2005; Ogata & Hui, 2008) a set of characteristics (grouped in this work) is presented and they can be seen as support to identify and understand the elements that are involved in m-learning:

- *Immediacy and Ubiquity*: Wherever learners are, they can find information immediately. Thus, learners can solve problems quickly.
- *Interactivity*: Learners can interact with experts, teachers, peers or people around in the form of synchronous or asynchronous communication. Moreover, they can interact with surrounding technologies and systems.
- *Situational*: Learning can be embedded in the daily life. The problems encountered and the knowledge required is all presented in their natural and authentic forms. This helps learners notice the features of problem situations that make particular actions relevant.
- *Contextual*: Context is constructed by learners through interaction.
- *Collaborative*: Mobile devices can help people learn together. The boundaries and restrictions are reduced in a collaborative learning environment, thus enhancing the overall learning process.
- *Accessibility*: Learners have access to multiple content types (web content, documents, videos, audios, images, etc.) from anywhere. That information is provided based on their requests. Therefore, the learning involved can be self-directed and self-regulated.
- *Simplicity and pleasurability*: M-learning can provide a paperless, movable and interactive learning environment. Simplicity is also the key to more effective learning, because unnecessary and complicated procedures are reduced, and more time is spent on the learning itself.
- *Ownership*: Raises deep ethical issues of privacy and ownership.

Despite the lack of clarity in the m-leraning concept and the common characteristics that researchers have remarked, in the context of this research work the author remarks that m-learning phenomenon involves three main elements: *assistance by mobile technology, involves facts and effects of learners' mobility and considers mobility of information* (see Figure 2-1). All of them immersed and participating in real *contexts* in which they can merge by interactions.

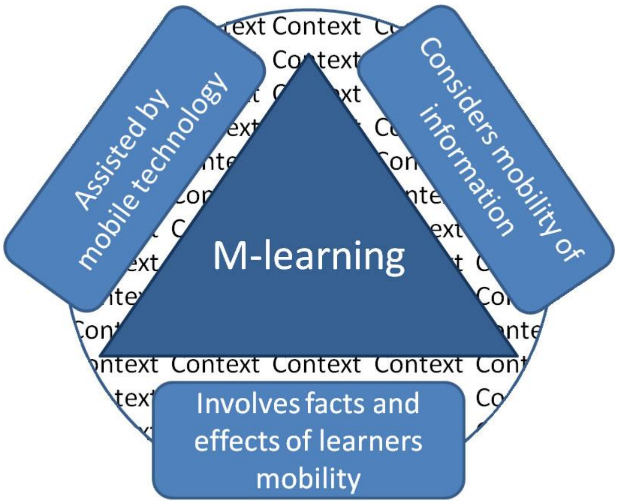


Figure 2—1 M-learning in context

Thereby, *m-learning* is not only about the size of a device or, for instance the mobile technology used for learning. Rather, *m-learning* takes into account the personal and ubiquitous *assistance*, the ownership and private use, and the diversity of *mobile technology*, which can be used for educational purposes. Besides, m-learning has been characterized by considering *learners' mobility*, i.e. m-learning compared to other types of learning activity, differences from the *fact* that learners are continually on the move, i.e. they are moving from topic to topic and learning across space and time, as well as from the *effects* of their mobility assuming that they are receiving the support of interactions with communities of people and available resources in context. Finally, m-learning considers the synchronous and asynchronous opportunities to interact with available *information*, i.e. in m-learning, interaction with information do not present barriers of time and space, although m-learning might be started by learners' initiative and interest in exploiting available information anytime, anywhere as they initiate their activities to achieve educational outcomes.

Shortly, in next sections the author immerse in an m-learning benefiting from information of the learner's context and this, as it will be explained, has profound implications for learning design, a topic that is discussed in next sections and chapters.

2.1.2 Expansion

The continuous increase in the range of mobile, wireless and interconnected technologies in learner's context allows education to be digitally linked to the learners' experiences across with and between multiple locations and learning situations.

In this section the author attempts to delineate the affordances that aforementioned elements in previous section have been providing to this link and the evolution of m-learning. As outlined by Sharples (2006) and further explained with detailed research projects examples by Pachler (2010), m-learning has been characterized by three phases: i) *focus on mobile devices*, ii) *learning outside the classroom* and iii) *mobility of the learner and information.*

Focus on mobile devices

The beginnings of widespread experimentation with mobile devices for learning happened from the mid 1990s. This phase is characterized by a focus on what devices, in particular PDA, tablets, laptops and feature phones, among others, can be used for in an educational context for instruction and learning. Some examples of the use of these mobile devices in formal education settings includes accessing rich-media m-learning objects placed in the phone's memory, students evaluating m-learning objects about different topics, pre-installed guides to scaffold m-learning, mobile office tools provision to staff and teachers so as to support management work and teaching respectively, among others.

In the development of this research work analysis of characteristics and capabilities of different mobile devices were taken into account so as to establish the basis for content adaptation considering the learners' device. This analysis is explained with more details in chapter 5. Nowadays, the diversity of mobile devices is quite wide due to the mobile and wireless technologies progress and also of the popularity they have in the market. Here, general properties of the different types/groups of existing mobile devices are described. Table 2-1 shows this description.

Table 2-1 Types of mobile devices

Mobile feature phones They feature a microphone, a speaker, LCD or plasma display, keypad, antenna, battery, etc. They count with incorporated features such as phone book, internet access, games, calendar, short message service (SMS), camera, email and bluetooth connection.	
Personal Digital Assistants (PDA) They are personal assistants and have built-in a calendar, notepad, phonebook, internet connection, email client, among other applications. It has a touch screen and a stylus for data input (no keyboard). Moreover, they have integrated an operating system (which makes the difference between existing brands; Palm, Pocket PC, etc.), processor, and storing memory. These devices can operate as fax, global positioning systems (GPS), among other functionalities. Generally, they are less preferred than mobile phones between users, as there are some new advances in the mobile industry. However, there are situations in which their large screens and flexible software options make them the preferred digital device for m-learning.	 
Smartphones They are high-end mobile phones joint with the properties of a personal digital assistant (PDA). They let installing software applications, increasing data processing and connectivity. Some of them come with touch screens and a higher level of access security. Common brands of this type of devices are Samsung Galaxy, Blackberry, iPhone, HTC and Nokia N900. Some of the features that they include are: SMS, Multimedia Messaging Service (MMS), app installation, internet access, GPS, bluetooth, email, wireless, rich-media content playback, etc.	
Tablets and Ultra mobile PC They are hardware/software hybrids between a laptop and a PDA. They are larger than a smartphone or PDA. They have integrated an operating system, processor, and storing memory. They lack of keyboard and mouse, although this hardware can be incorporated. The screen is touchable (like some PDA). Users can write and work directly on the screen. Moreover, some of them have inbuilt features like: GPS, accelerometer (a device that detects the physical movements of the tablet), wireless connectivity, storage drives similar to laptops, among others.	 

Portable digital media players Its main feature is the reproduction of digital media such as images, audios and videos. Some of these devices offer other features such as storage memory, color display and recording.	
Handheld gaming consoles They are devices mainly used for playing games. However, nowadays these devices offer in-built features such as wireless connectivity, internet access, playback of digital media (images, audio, video), among others, making them attractive for practical learning activities.	

Since first phase of m-learning expansion, practices of m-learning in education has been focused only on using tools in traditional learning settings rather than on delivering learning experiences considering situations where learner's real-life contexts and settings different from formal learning can be exploited. At the latter years of this phase, these handheld and portable devices started combining tools and services that can be accessed anytime and anywhere, and because of this advantage researchers had tried to integrate them into learners' daily activities.

Learning outside the classroom

A characteristic of m-learning in early 2000s, was the focus on learning outside the classroom. Researchers' interest relied on highlight the benefits that mobile technologies may bring to meaning-making for a person in situations outside institutionally framed educational contexts. This second phase includes field trips, museum visits, and personal learning organizers among others educational activities that involve the learner participating in the knowledge construction process outside the classroom.

Learning activities on this phase focused on shifting from traditional learning with handheld devices towards supporting the learners by the use of tools and services (built-in functionalities in mobile devices such as SMS, media players, calendar, etc.) and by the deployment of location aware systems that that can be used in different learning settings.

M-learning not only was focusing on providing tools to learners but to provide information and guidance support depending on the users' location. During those years this converged functionality starts to be integrated within the mobile communications industry by building a new spectrum of mobile devices and smartphones which has led to their extensive use for learning outside the classroom.

Moreover, learning outside the classroom phase starts a new way of thinking beyond the box with regards that education starts to be profiting by supportive learning activities that can be undertaken in different places. Researchers started focusing on providing well-structured directions of how learning, benefiting from the mobility characteristic of technologies and learners, can be designed and delivered. Supporting the use of technology in learners' own pace and letting them to organize their self-directed learning by using their mobile devices, started to be a promising characteristic for m-learning. From those past years learners started to be provided and encouraged to use their mobile devices in a competent way which was leading meaning-making, knowledge construction and learning skills and attitudes development to go beyond the formal settings in situations outside institutionally framed educational contexts.

Since then, the focus on mobility of the technology, learner and information for m-learning design and delivery was coming to the fore. Thereafter, in next years this focus started an emerging interest on learning being aware of the learner's context. Thus, this focus was representing a research challenge regarding on how to define optimal ways to deliver suited educational materials and to personalize them to different roles (e.g. learners, apprentices, teachers, instructors, etc.), main actors of learning and instruction processes, according to their situations. This challenge, yet open, also became of the interest of the work presented in this thesis.

Mobility of the learner and information

Finally, by mid 2000s, research initiatives start focusing on the "mobility of the learner" merged with the "mobility of information" and involving the design or the appropriation of learning spaces and on context-aware informal learning and lifelong learning. In this last phase, affordances of emerging technology, surrounding resources and available information in context, to the learner's situation can be distinguished. Some examples of the incorporated technologies in this phase includes devices with embedded identification, detection, sensing and location technologies, such as RFID readers, accelerometer, digital compass, gyroscope, GPS, microphone, camera, infrared, bluetooth, QR-Code readers, among others (Bravo, Hervás & Chavira, 2005; Chu & Liu, 2007; Naismith & Smith, 2006; Rouillard & Laroussi, 2008; Lane et al. 2010).

This phase is characterized by research efforts on attempting to augment learners meaning-making by enabling them to participate in media-rich environments rather than view the learner as consumer of content. Learners are enabled to construct content and place it in context using mobile devices where other learners can access to it (FitzGerald, 2012). Moreover, this phase is also characterized by immersion of technological tools in real-life that can be used to augment user activity in context (i.e. augmented learning) (Price & Rogers, 2004). According to this phase, knowledge can be constructed around the specifics of a place and learning trails can be developed to foster meaning-making across and between multiple contexts. Therefore, learners are enabled to engage in knowledge construction through interactive practice with entities (e.g. people, objects, systems, etc.) in context (Dourish, 2004). Thus, learning based on interactions in context started focusing on what intervention is appropriate and can provide relevant tools and services to aid learning in real-life situations (Brown et al., 2010). In this case, context-aware systems, therefore, may enable the delivery of appropriate learning content regarding contextual information and facilitates delivering suitable learning activities, tools and services through the mobile devices relevant to the learner's lived context.

Since the beginnings of third phase of m-learning, a new research trend has been emerging which focus rely on delivering personalized and adapted learning experiences to learners regarding: the mobile device from which they are interacting with (i.e. *focusing on mobile devices*), their individual mobility needs and preferences in learning situations different from a traditional classroom (i.e. *learning outside the classroom*), and the surrounding resources (people, ambient technologies, physical objects, etc.) that may affect the interaction between learners with anytime-anywhere available information (i.e. *mobility of the learner and information*).

While m-learning is a growing research area, aspects of adaptivity and personalization are becoming more and more important and they are playing an important role towards providing learners with adaptive and personalized learning experiences delivered via mobile devices. Thereafter, there is a research challenge and need to build and achieve context-aware adaptation approaches for the learning design process as well as mobile systems for processing learners' contextual information and delivering adaptive educational scenarios via personal interactive technologies. These aspects are presented and discussed along the next chapters of this thesis.

2.1.3 Opportunities

According to Kukulska-Hulme & Traxler (2007) new technical and situated learning opportunities can change what is considered effective in pedagogic design. There is much interest in the possibility that mobile and wireless technologies can support greater choice in how learners engage with learning activities, and that this might enable more flexible approaches to learning design.

Along the expansion phases aforementioned, m-learning has been characterized by trials in which different educational scenarios have been benefiting from the affordances of mobile technologies in a variety of learning contexts. Thanks to those research studies, researchers have been proposing different key opportunities in m-learning for the present and forecoming years (Mobile Learning infoKit, 2011; Pandit, Lebraud & Seetharaman, 2012), which summarize design arguments stated by UNESCO in the debate about how to design enhanced learning experiences for m-learning (UNESCO, 2012). Here, it is presented three identified opportunities in common on those related works, which encompass the interests in this research work on how learning design can be implemented for context-aware and adaptive m-learning.

1) ***Opportunity1****: Encourage 'anywhere, anytime' learning*. Mobile devices allow students to gather, access, and process information outside the classroom. They can encourage learning in a real-world context, and help bridge school, afterschool, home and outdoor environments.
2) ***Opportunity2****: Engage learners in context*. Mobile devices have a very special role in achieving a closer relationship between a physical location, the information it offers and the learning that is enabled by the availability of the device and surrounding resources (people, objects, ambient systems, etc.).
3) ***Opportunity3****: Enable an informal, situated, personalized learning experience*. Not all learners are alike; instruction should be adaptable to individual and diverse learners. There are significant opportunities for genuinely supporting differentiated, autonomous, and individualized learning through mobile devices.

2.1.4 Context-awareness in m-learning

An important success factor for m-learning has been the pedagogically meaningful and technically feasible process of learners' contextual information. Technological characteristics of the devices and other aspects regarding the learner's situation such as her/his location, temporal aspects for learning, the physical conditions of the learning place, among others characteristics, have been considered as components of what can be included in the "context" so as to develop context-aware systems. However, the formal definition of context and what constituents are parts of it is still an open issue.

Context has diverse interdisciplinary interpretations. Yet, there are many points of overlap between each discipline in particular where digital technology is a feature of research (Luckin, 2010). One of the most well-received definitions by research communities in the computer science discipline, was made by (Dey & Abowd, 2000) who states that context is "*any information that can be used to characterize the situation of an* *entity*” understanding the term “*entity*” as anything relevant participating in the interaction between an user and a system, such as a person, a place, or an object including the user and the system. Accordingly, in TeL research communities the “context” involves the information that characterizes a learners’ given situation.

Saying this, TeL researchers have stated that context is relevant to learning systems and it can be complex and local to a learner. A promising conceptualization of context to learning can be the one exposed by (Luckin & Clark, 2012) which declares that:

> *“Context is dynamic and associated with connections between people, things, locations and events in a narrative that is driven by people’s intentionality and motivations. Technology can help to make these connections in an operational sense. People can help to make these connections have meaning for a learner. A learner is not exposed to multiple contexts, but rather has a single context that is their lived experience of the world”*

Context can be considered in learning to understand the relations among learners, people, artifacts, locations and events, and more specifically, to comprehend how learners interact with other people, artifacts and location that surrounds them in order to construct knowledge. Context concept to learning is all about learners’ interactions and how technology, surrounding resources and information may support those interactions in order to enhance learning process.

Additionally, within the scope of this dissertation the term "context-aware" is used and it denotes the intrinsic properties of a model/design/system that is “aware” and considers the characteristics of the context as part of an input retrieved by a delivery end. Context-awareness involves gathering information from the environment to provide a measure of what is currently going on around the user and the device. In mobile and ubiquitous computing, this term is commonly used to indicate the actors, technologies, and any other element participating in the interaction between a user and a system so as to deliver valuable information in different situations. For example, the work in (Christopoulou, 2008) emphasizes the necessity of the context and its relevance to mobile applications development. Moreover, it argues that context for mobile applications can be used not only to provide users with tailored information regarding user’s location, but it is useful also to support the selection of appropriate techniques by a system to provide users with useful tools.

Briefly, the work presented in (Dey & Abowd, 2000) remarks that a system can be considered "context-aware" if it uses the context to provide relevant information and/or tools and/or services to users, where relevancy depends on the user's task. Thereafter, this feature can also be referred to the design of system architectures considering services-based communications, connections and human-computer interaction technologies, as well as the development of new applications in which interaction, not only be one-target but also considering the surrounding elements of that target in the environment.

Context-awareness can be seen to offer great potential with respect to new ways of meaning-making that extend beyond the classroom. Context-awareness will be a key area for m-learning in the oncoming years because it is moving beyond content delivering in place and it is getting involved with issues surrounding how information from context can be retrieved, stored, represented so as to support tools and services be delivered in optimal ways.

2.1.5 Modeling the context

Bearing in mind the existing heterogeneous features of what can be used to describe the learners' context and that can be used to differentiate their learning situation, some research efforts have been focused on the importance of modeling contextual information in order to define and design how contextual data can be stored in a readable format so as to be processed by a system (Baldauf, Dustdar & Rosenberg 2007).

In the field of TeL, there have been a number of attempts to model the context so as to describe the elements that could participate in learner's interaction with learning systems (Schmidt, 2005, Derntl & Hummel, 2005).

Related work have proposed different context modeling strategies. In (Strang & Linnhoff-Popien, 2004) for example, different context modeling techniques are presented as a survey on context modeling, to demonstrate some solutions and projects which build data structures allowing context information to be represented and exchanged in systems. According to Strang & Linnhoff-Popien (2004), there are models based on attribute-value tuples which represent the simplest data structure for modeling. Also, there are models based on labeling schemes which use a hierarchical data structure that consists of tags with attributes and content. Other modeling technique is based on graphical data structures such as the Unified Modeling Language (UML), and there are also object-oriented models that focus on the use of object-oriented techniques to optimize the encapsulation, reusability, and inheritance. Other models are based on logic which has a high degree of formality to represent data structures in expressions and rules. Moreover, there are models based on ontologies that let represent a description of the concepts and the relationships between concepts. According to Christopoulou (2008) this latter approach of modeling has been one of the most used tools that highlight the benefits of using ontologies as a tool to model information due to the high level of expression and opportunities of applying reasoning techniques based on them. For example, in (Berri, Benlamri & Atif, 2006) and (Siadaty et al., 2008) ontologies are used to represent information of the context in order to build mobile applications and to define which information can be captured in m-learning environments respectively.

The context has a meaning when is considered and used to provide what the learners need in different situations (i.e. relevant information or enabled tools and services to assist and support the learning process).

According to this, contextual information can be integrated to propose new scenarios of learning, thus, the author of this thesis focused on the learning design process as the basis to model the learner's contextual information and proposed to integrate and represent context-related data in that process in a notation language that support context representation in a readable format so as it can be processed by the developed mobile system in this research work. In chapter 5 heterogeneity of learner's contextual information was narrowed to a set of contextual elements that jointly together made part of a context model for designing and delivery context-aware and adaptive m-learning educational scenarios.

2.2 Learning design

"Learning or Instructional design is the process of translating general principles of learning and instruction into plans for educational materials delivery" (McNeil, 2007). In other words, learning design refers to the process of creating and delivering well-structured and procedural educational scenarios to learners, which in most of the cases,

is based on a pedagogical model. However, sometimes it is very common to be confused on the use of term “learning design” because in some cases it refers to the specification adopted by the IMS Global Learning Consortium as the framework to create (authoring), package and deliver learning courses. For the purpose of this dissertation, the educational scenarios creation and delivering process will be called “learning design” (in lowercase), and the specification will be referred as Learning Design (with capital letters) or IMS-LD.

During the last decade, the concept of ‘designing for learning’ in connection with TeL has been the focus of several research communities. Nevertheless, despite its relatively recent appearance in connection with computer-oriented learning, this concept is far from being a new idea. In traditional face-to-face settings, many instructors may consciously and reflectively engage in the process of learning design in this general sense as part of everyday lesson planning, whilst other teachers or lecturers may never have given it much thought, but nonetheless make subconscious learning design decisions every time they prepare a teaching session.

Learning design is mainly characterized by three central ideas (Britain, 2004), namely:

1) People learn better when actively involved in doing something (i.e. are engaged in a learning activity).
2) Learning activities may be sequenced or otherwise structured carefully and deliberately in a learning workflow to promote more effective learning.
3) It would be useful to be able to record “learning designs” for sharing and re-use in the future.

2.2.1 Engagement in learning activities

Learning is an active process of knowledge construction and meaning-making that humans perform quite naturally, however, not all learners are equally capable and competent of effective learning on their own. Indeed, learning process is accompanied by the immersion of learners through different activities, which can be understood as the engaged-in means for the purpose of acquiring certain skills, concepts, or knowledge and besides these activities can whether be guided by an instructor or not.

Commonly, most learners if not all, benefit from some level of guidance and support. Successful instruction involves a variety of strategies and techniques for engaging and motivating learners over and above merely presenting them with well-designed learning materials (Gagne et al., 2005). There are a number of pedagogical techniques that focus on providing activities for learners to perform either in groups or as individuals that help to create deeper and more effective learning.

During the last years a challenge within TeL has been to focus on quite a narrow set of learning activities that can be easily managed within a computer-oriented learning system: “read this content”, “watch this video with instructions”, “do this multi-choice quiz”, etc. Part of the aim of learning design is to help broaden the set of activities that are used to support learning in a TeL context.

2.2.2 Structure of learning activities in a workflow

Activity-based learning needs a well organized sequence of activities (aka. a learning flow) to produce learning. A second feature of successful instruction is not just the creation of thoughtful and engaging activities for students to undertake, but also giving thought to the sequential order and timing of the various activities and the presentation of the resources and tools needed to support them.

This orchestration may form a simple sequential flow, and in most cases it will, but there may sometimes be call for a learning design that involves branching of workflow into parallel activities undertaken by sub-groups before coming back together (Sharpe & Oliver, 2007). Or a design may be constructed that allows different routes to be taken based on achievement at a testing stage within a sequence. Thus a second key aspect of tools to support the concept of learning design will be the notion of workflow.

From the instructor's perspective there are two main advantages associated with consciously thinking about the process of designing learning activities (Luis de-la-Fuente-Valentín, 2011). The first is that it provides a framework for instructors/teachers to reflect in a deeper and more creative way about how they design and structure activities for different learners or groups of learners and the second is that designs that prove to be effective may then be communicated and shared between teachers or archived for re-use on future occasions.

2.2.3 Sharing and re-using learning designs

The last idea related to the learning design is to find optimal ways of sharing and re-using created and structured learning flows (Oliver et al., 2007). Thus, instructional design techniques have been used so as to deliver and provide learners with a created learning design (Masterman & Vogel, 2007). Commonly optimal means to share educational scenarios, structured in a learning workflow and represented in a learning design, include face-to-face, computer-oriented and blended (a mixture between face-to-face and technology-oriented learning).

Although, the face-to-face scenario allows the teacher to improvise a new activity in case it is suggested by the circumstances, computer-oriented scenarios lack this flexibility, and thus require a more thoughtful plan of activities.

The formalization of this plan of activities, so that the workflow can be replicated in a compliant platform, is called a *learning script*. However there is a problem in that it is not so easy to describe a given *learning script* in a consistent and transferable way that will allow easy re-use (Koper, 2005). This is mainly caused by the complexity of representing and delivering the educational elements that may be used in a learning workflow, including: learning environments, learning activities, educational contents, supportive tools and services, participating roles, immersion of new technologies, among other educational elements that can be combined. Therefore, this *learning script* needs to be described at a sufficient level of abstraction that it can be generalized beyond the single teaching and learning context for which it is created, but not at such an abstract level that the pedagogical value and richness is lost.

Consequently, this issue has been tackled by TeL researchers whom efforts focused to produce a formal and interoperable way in which the learning scripts can be represented as well as defining a computer readable format so as they can be delivered. Thus, some specifications, which can be seen as learning design frameworks, have been created facilitating the process of learning design and delivery. Next sections are devoted to explore the details of two of the most used specifications for computer-based and blended learning, namely IMS Learning Design (IMS-LD, 2003) and SCORM (SCORM, 2004), with special emphasis on the affordances and constraints of the case of IMS Learning Design which was used in this research work.

2.3 Learning design specifications

The learning design process and delivery of an educational experience is the result of a complex process that involves several tasks. First, the authors of the learning design choose a pedagogical method, elaborate the proper content and make decisions about supportive resources and tools. Then, all these materials are then allocated in a repository so that it can be accessed by learners. Finally, teachers and learners get involved in the course and they start interacting among themselves and with the course contents, resources and tools. This is a costly process, whose elaboration effort is worth to be reused several times and therefore, that's a mainly reason why the need of a framework that promotes reusability of educational scenarios.

There are some international organizations responsible for the definition of standards and specifications for computer-mediated learning such as the IMS Global Learning Consortium (IMS-GLC), IEEE (IEEE), ADL (ADL), among others, which have created guidelines to consider: construction of educational content, storing students' data about their personal characteristics, defining competencies, generating assessment structures and development of instructional designs, that, in short, are relevant educational elements involved in the teaching and learning processes.

The work published in (Anido, 2006) presents a widely description and analysis of some freeware standards and specifications that have been developed for using in e-learning environments.

According to (Masie, 2003) the importance of the construction, deployment and use of standards and specifications rely on ensuring the following:

- *Interoperability*, to allow sharing of content from multiple sources so as to be used in different systems.
- *Reusability*, to group, ungroup and reuse content in different environments from that one to which it was initially designed for.
- *Manageability*, to allow a system to obtain and complete a scan of the information gathered from the interaction between a user and the system.
- *Accessibility*, to allow a user to access appropriate content at the right time and from the own device.
- *Durability,* to allow content to be accessible and interoperable over time.
- *Scalability*, to allow new technologies to be configured so as to read new releases of a specification according to new additions in content or refining.

The main aim of this section is to describe two existing available and widely-used specifications by research communities to model the learning design, namely SCORM and IMS Learning Design; and possibly to argue that IMS Learning Design presents a possible realization of the concept of learning design for context-aware and adaptive m-learning.

2.3.1 SCORM

Shareable Content Object Reference Model (SCORM) (SCORM, 2004) is a framework of the Advanced Distributed Learning Initiative (ADL), which comes out of the Office of the United States Secretary of Defense. More than being a unique and exclusive specification to model the learning design process, SCORM is a reference model (i.e. descriptions of how existing technical specifications may be used together to achieve some aim) based on a collection of standards and specifications which aim is to describe how learning content and the systems that manage that content can interoperate in a standard way.

The reference model of SCORM includes a content aggregation model, a runtime environment model and a sequencing and navigation model which allow designers to describe and represent in a readable format some components of the learning design process. The framework describes the creation, deployment and the behavior of shareable content objects (SCO), which are individual, electronic units of learning that may be combined to create a course of study. Moreover the framework defines communications between client side content and a host system called the run-time environment, which is commonly supported by a learning management system.

SCORM has been developed to accomplish four high level requirements that refer to SCO directly and they aim that SCO should be durable, interoperable, accessible and reusable.

- Durable: SCO are electronic resources that do not need to be updated or modified as learning technology systems develop over time.
- Interoperable: SCO can be launched successfully in different learning management systems.
- Accessible: SCO can be found when needed. The SCO have linked a description or meta-data which facilitates discovery within and across content repositories.
- Reusable: SCO are developed once and can be used in many courses.

Technical description

The first version released of SCORM was on 2000 and it has progressed through a number of releases since that version, with each release adding further maturity and functionality. There are currently three main releases: SCORM 1.1, SCORM 1.2 and SCORM 2004.

Every release of SCORM has been adding new functionalities to previous versions; the last version of SCORM (SCORM, 2004) enables educational designers and stakeholders to:

- Provide web-based training for individual learners. The approach is self-paced and self-directed. The SCORM was originally designed to support personalized instruction within the US Department of Defense, and implies a pedagogical model closest to industrial and military training.
- Create individual, electronic learning designs that may be reused in different courses.
- Package instructional material and meta-data for import/export between different learning management systems.
- Track and store records of the progress of a learner moving through a unit of learning.
- Adds support for sequencing and navigation. This enables to control the conditions under which a SCO is selected and delivered, or skipped during presentation to a learner. Although, last version of SCORM allows the creation of conditional flows, sequencing is intended to be used by a single learner so it does not allow the creation of collaborative activity flows.

SCORM models

The SCORM works by describing the interface between a learning management system and the content it uses. That is, the SCORM describes how learning content is created and packaged for import into a learning management system, how content is selected by the learning management system for presentation to a learner, and how the progress of a learner can be tracked by the learning management system.

These three features map to the three SCORM models (described in books) as follows:

- The *Content Aggregation Model* describes the process of creating, describing and packaging SCO into a course structure. To achieve this, the model profiles the IMS Content Packaging (IMS-CP, 2004) specification (explained in section 2.4). This means that most SCORM compliant learning management systems also support non-SCORM versions of IMS Content Packaging.
- The *Sequencing and Navigation model* describes the controls for managing when a SCO is selected or skipped during presentation to a learner. For this purpose, the model profiles the IMS Simple Sequencing specification (IMS-SS, 2003).
- The *Run Time Environment* book outlines the process of launching a SCO from within a learning management system and then tracking the learner's activity with the SCO. To achieve this, the book profiles two IEEE standards about learner tracking information and SCO to learning management system communication.

Creating SCO begins with files called assets. Assets are digital media, such as text, images, sound, assessment objects or any other data that can be rendered by a web browser. Assets are assembled into SCO (see Figure 2-2). Describing assets and SCO is achieved by adding meta-data. For that, the use of the IEEE Learning Object Meta-Data standard is prescribed (IEEE-LOM, 2002).

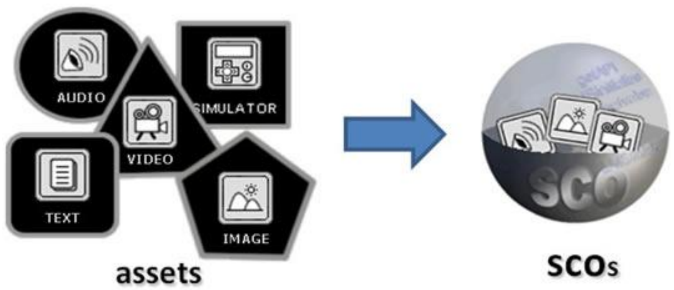


Figure 2—2 Representation of assets and SCO

Packaging SCO into a course structure is managed by a file called a package manifest. To enable learners to navigate between SCO, a table of contents written into the package manifest is typically exposed in the learning management system user interface.

Sequencing rules and controls may also be added to the manifest at this stage if the target learning management system is SCORM 2004 conformant. This sequencing information describes paths through the collection of SCO included in the manifest and declares the relative order in which the SCO are to be presented to a learner. This sequencing information model describes the intended sequencing behavior that a user will experience as they work with the SCO at run time.

Run-time behavior is managed by the SCORM runtime environment. A key feature of this environment is the ability of a SCO to communicate with a learning management system. This feature is provided by a small piece of software provided by the learning management system and named an API Adapter. API Adapters are provided by the learning management system. When a learner requests a SCO, the SCO searches the learning management system to find the API Adapter. Once found, the SCO initiates communication with the learning management system via the API Adapter. The communication between the SCO and the learning management system is used to track and store records of learner activity.

Limitations of SCORM

SCORM presents a set of limitations and weak points to bear in mind with regards to the learning design concept:

- SCORM is exclusively oriented to instructional content design and delivery which sets a boundary to content-oriented learning. This impedes designers to think in the teaching/learning processes as a set of components involving the basis of a pedagogical model and a learner-centered learning and activity-based instruction.
- The lack of pedagogical meta-model. SCORM have not taken pedagogy support as one of their core issues in specification (Huang et al., 2006).
- SCORM is oriented to an individual learning process in which support activities, guided tasks, and aided training are excluded. Monitored instruction is not within SCORM objectives.
- Although, last version of SCORM allows the creation of conditional flows, sequencing is intended to be used by a single learner so it does not allow the creation of collaborative activity flows.
- Creation of SCORM objects, namely SCO, is not intuitive.
- The lack of a well bounded definition of the size and granularity learning objects should have (Gonzalez-Barbone & Anido-Rifon, 2008).

2.3.2 IMS Learning Design

A common experience by authors (instructors, teachers, designers, tutors, etc.) with learning design includes defining a set of learning activities as a procedural structure identifying different objectives that learners have to achieve so as to acquire the knowledge of a specific subject matter. Sometimes in this process authors combine other kind of activities so as they can monitor and follow the learners' learning process. Moreover, some authors go deep inside in this process and define which learning tools learners can use as support to complete the learning activities, as well as the environments in which these tools and some other services can be applied. In the context of TeL, learning design process have been benefiting by the existence of a variety of technological possibilities to access, visualize and gather information, as well as new environments definition for learning across different settings from the traditional ones. During the past years this technologies emerging have been getting the attention of TeL researchers so as to define and analyze new practices of learning design in which affordances of new technologies for education can be identified.

In order to support the representation of all those innovative and diverse of author's pedagogical strategies in a common *learning script* and the study of new practices of learning design benefiting from technologies immersion, the IMS Global Learning Consortium (IMS GLC) release the IMS Learning Design (IMS-LD, 2003) specification, which is a framework that defines how authoring (design) and deployment (delivery) of learning courses can be performed, as well as it promotes the exchange and interoperability of learning designs and learning-oriented digital materials (resources, tools, services, etc.).

Although IMS-LD itself is not the focus of this thesis but rather a given framework that facilitates implementation of the learning design process, a basic understanding of the specification will help to understand the challenges for the design of context-aware and adaptive educational scenarios and an associated delivery implementation. In this section, we summarize the technological description of the specification and a compilation of the supporting software currently available in the market and in the literature. The section finishes with an overview of the related literature which gives details of its affordances for contextual and m-learning.

Technical description

The first version released of the Learning Design specification was on 2003 and it was developed on the basis of Educational Modeling Language (Hermans et al., 2000), originally designed in the Open University of Netherlands (Koper & Manderveld, 2004) and following a set of requirements proposed by Koper (Koper, 2005) who states that every learning practice has an underlying learning design, just as every building has an underlying architecture. Koper's main aim was that the learning design can be applied over and over again in similar and new situations of instructional and learning practices. Moreover, Koper remarked that the learning design needs of using a formal notation for such a learning practice, because of the lack of a formal, commonly understood notation in education.

Koper set out the following requirements for a formal learning design notation derived from theory, examples and patterns (Koper, 2005):

i) "The notation must be comprehensive. It must describe the teaching and learning activities of a course in detail and include references to the learning objects and services needed to perform the activities. This means describing:
   - How the activities of both the learners and the staff roles are integrated.
   - How learning resources (objects and services) are integrated.
   - How both single and multiple user models of learning are supported.

ii) The notation must support mixed mode (blended learning) as well as pure online learning.

iii) The notation must be sufficiently flexible to describe learning designs based on all kinds of theories; it must avoid biasing designs towards any specific pedagogical approach.

iv) The notation must be able to describe conditions within a learning design that can be used to tailor the learning design to suit specific person or specific circumstances.

v) The notation must make it possible to identify, isolate, de-contextualize and exchange useful part of learning design (e.g. a pattern) so as to stimulate their reuse in other contexts.

vi) The notation must be standardized and in line with other standard notations.

vii) The notation must provide a formal language for learning designs that can be processed automatically.

viii) The specification must enable a learning design to be abstracted in such a way that repeated execution, in different settings and with different persons, is possible."

The IMS-LD has been considered a *de facto* standard in the field of educational modeling languages (Laforcade, 2010) and with it a generic and flexible notation language for the description of educational scenarios is provided. Through IMS-LD standard the learning design can be modeled, implemented and expressed in XML structures. IMS-LD states that "regardless of the pedagogy involved, in practice every learning design came down to: a *Method* prescribing various *Activities* for learner and staff *Roles* in a certain order, and each *Activity* refers to a collection of specific *Objects* and *Services* needed to perform those *Activities*" (IMS-LD, 2003).

The relation of these elements participating in an IMS-LD is depicted in Figure 2-3. The standard describes this relation as the structure of a theater play (i.e. the IMS-LD vocabulary is taken from a theatrical metaphor). Thus, the learning flow of an educational scenario is then like a theatrical *play*, in which one or more *acts* are delivered and played in a linear sequence. Each *act* involves different participants (actors) who can assume a *role* and who performs a *learning activity*, a *support activity* or an *activity structure* (a collection of learning or support activities). Moreover, each *act* can be related to *environments*, which can be seemed as the set of components that describe and support the performance of the activities, therefore, an *environment* is a collection of *resources* (*learning objects*) and *tools (items) or services* that support the participants in their tasks. The result of this structure is a package called "Unit of Learning" (UoL), defined as "*the smallest unit providing learning events for learners, satisfying one or more inter-related learning objectives*" (IMS-LD, 2003), with specific adaptive properties which are explained in next chapters.

The theatrical metaphor is valid to introduce the specification to beginners, but there are more supported functionalities that are not part of the metaphor. First, a learning flow is not restricted to include synchronization points: the use of the different structure types allow course designers to create flows where the participants asynchronously reach their objectives (de-la-Fuente-Valentín, Pardo & Kloos, 2007). The theatrical metaphor does not allow either introducing adaptive content material: course and participants state can be mapped into concrete values through the use of properties. A proper evaluation of these properties, done with conditions permits the modification of the learning activities and materials depending on learner's information.

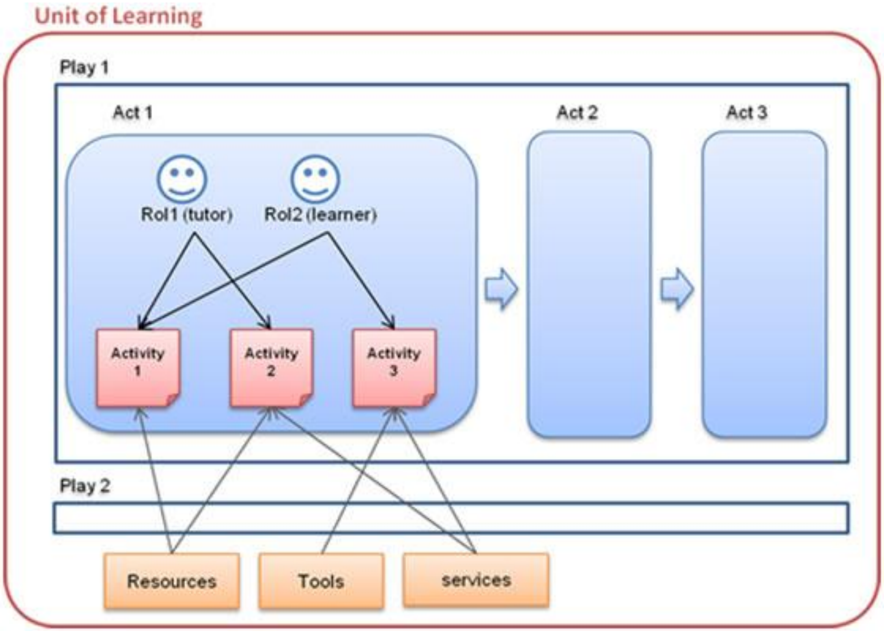


Figure 2—3 Unit of Learning elements and their relationship

The learning design is the key element in a UoL and is basically what it is tried to be modeled; the other elements are necessary and complementary parts. IMS-LD specification defines the guidelines to build an UoL covering the complete course life-cycle: first, proposes a data model that supports the formalization of learning flows (IMS-LD, 2003); then, offers the XML binding of the data model and defines the exact shape that a course package (UoL) must have (IMS-LD XML Binding, 2003); finally, details how runtime environment should interpret the different elements of the course (IMS-LD BPG, 2003).

Another important characteristic in UoL building is the relation and integration with other specifications like: IMS Content Packaging (IMS-CP, 2004) for distribution of UoL, the IMS/LOM Metadata (IMS-MD, 2001) for characterization of the resources, IMS Learner Information Package (IMS-LIP, 2001) for characterization of the students, among others. This property adds interoperability and durability to the different proposed models in order to obtain adaptive UoL.

IMS Learning Design levels

In order to build a UoL, IMS-LD describes and implements learning activities based on different pedagogical methodologies, including group work and collaborative learning. In addition, it lets to coordinate multiple learners and roles within a model unique-student or multi-student. It let manage the use of learning contents with collaboration services and also it support models delivery including blended learning.

With the purpose of make possible the implementation of the specification in a learning management system, IMS-LD can be built in three different levels: level A, level B and level C, providing different schemes of XML for each level that can be integrated considering the purpose wanted for a certain learning system (In Figure 2-4, elements of the 3 levels are depicted from the concept model extracted from IMS-LD, 2003):

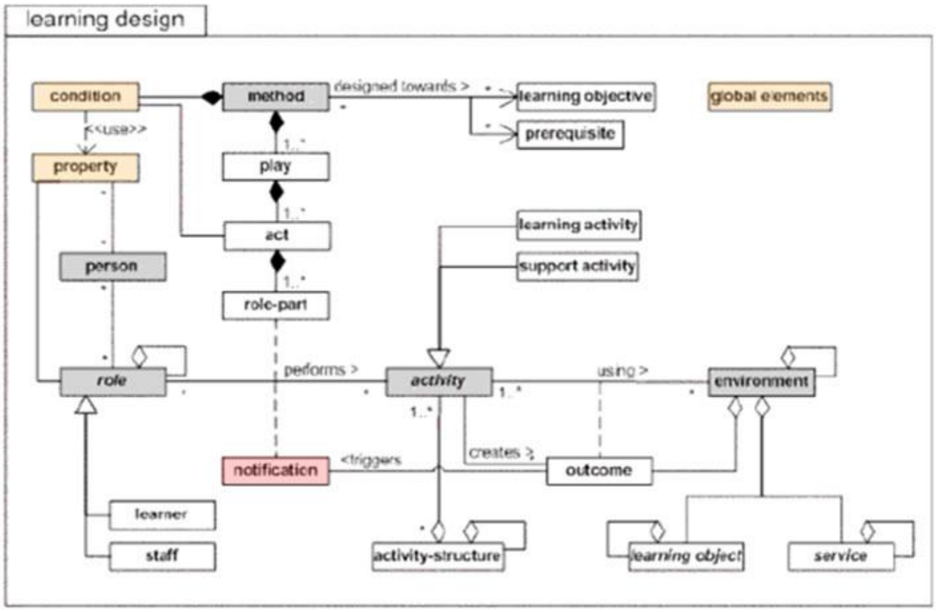


Figure 2—4 Conceptual model of overall Learning Design levels structure (Level B: condition, property and global elements; Level C: notification). Extracted from (IMS-LD, 2003)

- Level A: offers the necessary vocabulary to express a general learning process, including learning paths. It considers the definition of different user roles in the process (e.g. teacher and student), several learning and support activities that these roles perform and diverse environments in order to establish which learning resources and services can be used in those activities.
- Level B, adds the possibility of defining conditions to evaluate different expressions based on properties of an individual user or different roles in order to enable the personalization.
- Level C, allow notifications mechanism to be defined (i.e. messages as answers to events execution).

With IMS-LD level A it is possible to model multi-role and multi-user learning designs. However, the possibilities for designing runtime personalization are still rather limited. Level B adds four new concepts (properties, conditions, global elements and monitor) to the Learning Design core that enable runtime personalization. Here, a briefly detail extraction from (Vogten, 2008) for three of these four concepts are presented, namely properties, conditions and global elements. Only these three since they are used in this research work to achieve context-aware adaptations. Further, in chapters 4, 5 and 6 the author of this dissertation explains how level B conditions, properties and global elements are considered and used in order to define different variables and conditional statements that can generate adaptive processes to affect presentation of learning activities, resources, tools and services delivery according to the characteristics of the learner's context.

Properties

Properties are similar to variables as defined in common programming languages. They have a unique identifier and are of a certain data type. Each property is capable of holding a single value corresponding to its type. Furthermore, each has to be declared explicitly before it can be used. Valid values can be limited by adding restrictions to each property declaration. The run-time environment (i.e. delivery/player system) is responsible for enforcing these restrictions, which can be used, for example, to limit user input. Each property can optionally be seeded with an initial value. Properties can be grouped together, which allows them to be addressed by a single reference. Unlike most programming languages, properties are persistent beyond the lifetime of a learning design runtime session. The run-time environment is expected to ensure this persistence. Properties also have an instantiation scope, determining how many occurrences of a property should be created during run-time. The following scopes are defined in (IMS-LD, 2003): local, local personal, local role, global personal and finally global. These scopes determine when a new property should be instantiated. For example, a local personal property will be instantiated for each learning design user. The scopes are closely related to the repeated deployment of a learning design during run-time; this deployment instance is called a run (IMSLD-BPG, 2003). A run provides a context for assigning users to the roles of a learning design. Table 2-2 depicts the relationship between the values of the property scope attribute and their instance occurrences.

Table 2-2 Relationship between property scope and the possible instantiations

Property scope	Occurrence
Local	One for each run
Local personal	One for each user in a run
Local role	One for each role instance in a run
Global personal	One for each user
Global	One instance only

Conditions

The second construct for manipulating property values, besides the global elements, are conditions. These conditions consist of an antecedent and a consequence. For example, in the condition “if X then Y”, the “if X” part is the antecedent and “then Y” is the consequence. These conditions can be compared with those found in programming languages. What sets them apart from most programming languages, however, is the fact that the conditions are not imperative, meaning that the order of the evaluation is not determined by the order in which they are entered in the learning design. Instead, they resemble the production rules of a production system. Their antecedents must be continuously monitored by a run-time delivery player/system to determine when to evaluate the consequences. A consequence might be an instruction to show or hide an IMS-LD element such as activities, items, environments or parts of the global content. It might also be the manipulation of property values: the change of a property value could cause antecedents of one or more other conditions to evaluate to true. This results in the execution of their consequences, and so on. The run-time delivery player/system must pay special attention to avoid ending up in an infinite loop. It resembles a production system but with a twist–it processes the ripple effect caused by events and consequences, rather than attempting to find a solution via forward or backward reasoning.

Both the antecedent and the consequence make use of expressions built around an operator and zero or more operands. An operator can act also as an operand for another operator. IMS-LD contains a number of Boolean operators such as and, or, is, not, greater than and less than. These Boolean operators are typically the root for antecedent expressions. For the consequence, additional operators such as sum, subtract, multiply, divide and no-value are available.

Global elements

Besides conditions, property values can be also manipulated by other level B elements, called global elements. Global elements are XML constructs that extend the W3C-XHTML specification (W3C-XHTML, 2002). Four global elements are defined: set property, get property, set property group and get property group. These elements should be rendered by the run-time delivery player/system as either entry fields providing the possibility to change the property value, or text fields showing the properties' value. The run-time delivery player/system should ensure that restrictions defined for these properties are respected when a user enters data for them. The set property element has an attribute that limits the number of times a property may be set by a user.

Resource elements have type attributes that determines the kind of resource referenced. IMS-LD supports two resource types: “webcontent” and “imsldcontent”. Whenever a resource contains global elements, the type of resource should be set to ‘imsldcontent’. This triggers the runtime to parse this resource for global elements and render the content accordingly.

Learning Design delivery tools

The availability of supporting software in the market is a measure of a specification health. In the case of IMS-LD, software can be produced for two main areas. On the one hand, for authoring and creating UoL, even without knowing the details of the specification. An authoring software should provide an expressive and usable user interface that facilitates courses creation. On the other hand, for delivering UoL, it is required a compliant platform that imports a course package and reacts to the different elements as expected by course authors. In this research work, we are focused on both areas to achieve context-aware adaptations for designing and delivering mobile educational scenarios. However, the author of this thesis focused his efforts on developing a mobile delivery system (or player) as first scope, so as to demonstrate how context-aware adaptations are carried out in run-time, where learner's lived context is the current source for retrieving contextual information.

A first overview of available software for delivering Learning Designs is given in (Burgos, 2008). Then, in (de-la-Fuente-Valentín, 2011) is presented a complementary overview for the work presented in (Burgos, 2008). This section summarizes and complements that compilation with the improvements found for m-learning run-time delivery players/systems in the literature since then.

Despite that currently few solutions have been proposed for delivering, all of them still remain as attempts to offer a satisfactory solution and none have been considered as an optimal adoption of the specification (Neumann et al. 2010). For that reason the number of available systems has increased year by year.

IMS Learning Design players are still in their infancy. Players that have been developed fall into one of two main categories: client-side players and server-side players. With server-side players, the IMS-LD modules are stored on a server and are accessed real-time via the connecting device, such as a laptop or desktop computer. Starting with server-side players, there are a number of them that have been developed during the first decade of 2000 year.

- CopperCore – Compliance with levels A, B, and C of the IMS Learning Design Specification – CopperCore runtime environment is the reference implementation of the IMS LD specification (Martens et al., 2004)
- Reload – tool used to draw up units of learning (UoL). Reload may also be used as a player (Reload, 2004).
- SLeD and SLeD2 – front end player for a CopperCore Run-Time (CCRT) Environment Mobile connectivity has brought the need for the development of client-side players (SLeD, 2007).
- Clix Prolix – represents an embedded (into a Learning Management System) IMS-LD player. It supports IMS-LD level B (properties and conditions) that allows creating personalized units of learning that adapt based on pre-knowledge, preferences, and accessibility requirements (like visual disabilities). Beside, properties and conditions enable the learning supporter to control the learning process/workflow within a UoL (Clix; Prolix).
- Astro Ld Player – developed to address the limitations of the SLeD Player. It provides a rich set of interface elements, and a well structured architecture and code. Astro's design philosophy is to try and break from the traditional "tree view" outline which previous LD players have been based. Instead, Astro also seeks to provide an additional method of navigation, known as the "filmstrip" (Astro player, 2010).
- GRAIL – the first implementation completely build into a Learning Management System (Escobedo-del-Cid et al., 2007). GRAIL complies with the three levels of the specification and takes advantage of other modules of the Learning Management System to provide the player with some functionalities.

Connectivity via mobile devices generally is low in bandwidth, and the interfaces for these devices tend to be textual in nature, which requires a different set of specifications for display. Sampson, Gotze & Zervas (2007) introduce the SMILE PDA Learning Design Player, which is an open source software implementation that allows the execution of IMS-LD activities via mobile devices. When designing the SMILE system for these devices, the categories of limited internet connectivity, lightweight design, and display limitations were all taken into consideration. The SMILE PDA was designed as a client-side run-time delivery player. In a follow-up paper, Sampson and Zervas (2008) presented initial evaluation results from evaluation workshops on a group of students using the SMILE PDA Learning Design Player.

Another player/delivery system proposed to be implemented for mobile devices is the one presented in (Zualkernan, Nikkhah & Al-Sabah, 2009). The system, developed for Android devices, takes a sub-set of IMS-LD elements specification as input and automatically generates native code for multiple mobile devices where each device corresponds to a role.

In Table 2-3, a summary of identified Learning Design delivery tools and their characteristics regarding the device(s) to which it is targeted, whether it is Stand alone or Web-based, whether it is compliant with IMS-LD level A, level B or level C is presented

Table 2-3 Learning Design delivry tools

	Learning Design delivery tool	Target device	Stand-alone / Web based	Deliver general learning process (IMS-LD level A)	Adaptativity and Personalization (IMS-LD level B / level C)
Server-side	CopperCore runtime environment (Martens et al., 2004)	(Laptop, Desktop computer)	Stand-alone	√	level B and C
	Reload Learning Design player (Reload, 2004)	(Laptop, Desktop computer)	Stand-alone	√	level B and C
	SLeD (SLeD, 2007).	(Laptop, Desktop computer)	Web-based	√	level B
	CLIX Prolix (Clix; Prolix)	(Laptop, Desktop computer)	Web-based	√	level B
	Astro LD player (Astro player, 2010)	(Laptop, Desktop computer)	Web-based	√	level B
	GRAIL (Escobedo-del-Cid et al., 2007)	(Laptop, Desktop computer)	Web-based	√	level B and C
Client-side	SMILE PDA Learning Design Player (Sampson, Gotze & Zervas, 2007)	PDA	Stand-alone	√	-
	(Zualkernan, Nikkhah & Al-Sabah, 2009)	Smartphone	Stand-alone	√	-

In this work, we aim to address delivering context-aware adaptive and personalized m-learning by describing a system for delivering pedagogical-enhanced and structured adaptive and context-aware educational scenarios via mobile devices. The proposed system is implemented, taking as basis the architecture oriented to the client-side approach proposed by Sampson, Gotze & Zervas (2007). Our delivery system, namely UoLmP, let delivering adaptively educational activities, learning resources, mobile tools and communication services considering retrieval and processing of contextual information, and other characteristics not yet considered in context-aware m-learning systems such as processing conditional statements, compliance with IMS-LD Level B, so as to achieve context-aware adaptations. This is further explained in chapters 4, 5 and 6.

2.4 Learning design packaging

Besides defining a grammar and syntaxes for describing the learning design process, SCORM and IMS-LD also specifies how a learning design should be packaged, so as to facilitate its delivery to the end user.

IMS Content Packaging is a specification that gathers participant elements in the learning design and populating resources. Moreover it enables the delivery of learning design packages from one program to another, facilitating easier delivery, reuse and sharing of materials (Wilson & Currier, 2002).

Both IMS-LD and SCORM use the IMS Content Package specification (IMS-CP, 2003) as means for packaging the learning design and the associated resource together. This packaging process is discussed in more detail in chapter 5, in which a content adaptation mechanism makes use of it so as to adapt media content, that are populating a current educational scenario, considering mobile device capabilities. A learning design package can be thought of as a zip file containing all media files as well as the learning design itself. The IMS-LD and SCORM item models were informed by and based on IMS-CP. It binds resources to the learning design; each item is associated with a resource element which either links to one of the files in the content package or to an external resource via an absolute URL.

In the case of IMS-LD, a Learning Design package also called a UoL, contains a complete unit of education or training such as a course, module, lesson, etc., with a set of referenced media source files. IMS-LD recommends the use of IMS-CP for this purpose. Thus, a content package consists of a manifest and associated resources; the manifest contains: one or more references to organizations which describe how the resources are structured within the manifest file. An IMS-CP is often zipped into a single file for ease of use, although this is not obligatory.

Figure 2-5 is a graphical representation of the structure of a Learning Design package. The Figure shows a Learning Design containing a manifest that has related metadata, a learning design structure that represents a *learning script* and resources. These resources may refer to one of the physical files included within the Learning Design package.

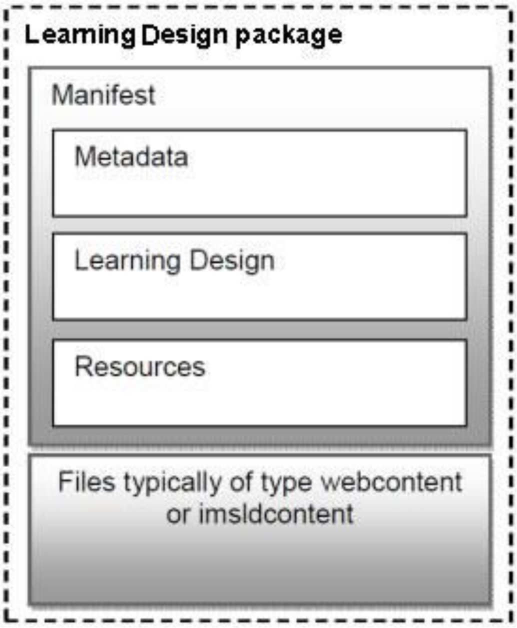


Figure 2—5 Structure of a Learning Design package

IMS Content Packages enable Learning Design or SCORM authors and end users to export content from one authoring system, content management system or digital repository, and import it into another while retaining information describing the media in the IMS-CP (see Figure 2-6), and how it is structured, such as a table of contents or the

HTML page to show first. Currently there is a number of learning design authoring systems, learning management systems and digital repositories that now supports IMS Content Packaging (IMS-CP EduTech Wiki).

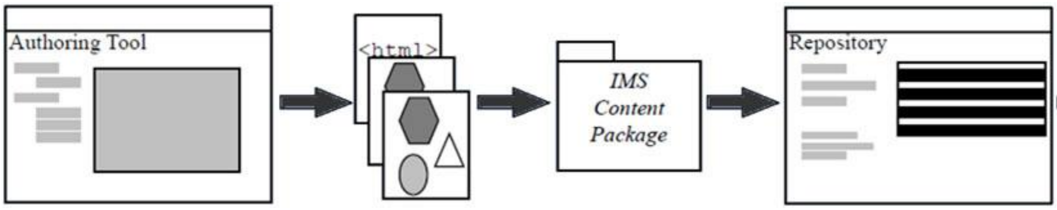


Figure 2—6 Interoperability of IMS-CP - Content sharing between systems. Extracted from (Wilson, S., & Currier, 2002)

2.5 Learning design for context-aware m-learning

Although, main focus of learning design in TeL rely on aforementioned ideas and frameworks, TeL researchers have been making efforts to represent new ideas/possibilities in those specifications for increasing the quality and variety of teaching and learning, by considering the affordances that new mobile and wireless technologies may bring to these processes (Sampson & Zervas, 2008; Zualkernan, Nikkhah & Al-Sabah, 2009). Mainly these new ideas have been represented as follows (Sharples, Taylor & Vavoula, 2010):

- *People are continually on the move, for instances we move in and out of engagement with mobile technology, we also move from topic to topic as well as we are moving between different places and learning at the same time.*
- *Learning can occur in different places out from formal and traditional settings as people initiate their activities to achieve educational outcomes.*
- *Learning is supported on practices which are enabled by interactions with communities of people, technologies and available surrounding resources.*
- *People can be engaged by taking into account of the personal and ubiquitous use of mobile technology.*
- *Almost every piece of supporting information can be found in the cloud and be accessed anywhere, anytime.*

In order to move from academic theorizing about m-learning to operational and successful use of its characteristics and aforementioned ideas for designing it, some key challenges about m-learning are mentioned at this point so as to explain how learning can be designed for mobile contexts.

Since in its early days, m-learning has been characterized by trials in which different educational scenarios have been benefiting from the affordances of mobile technologies in a variety of learning contexts. Thanks to those research studies, researchers have also been identifying different key challenges in m-learning which summarize arguments in the debate about designing for m-learning (Taylor & Sharples, 2006; Shuler, 2009). Here, three identified challenges in common on those related works, which also encompass the interests in this research work, are presented.

- ***Challenge 1**: Limiting mobile technologies attributes.* Poorly designed mobile technologies and systems adversely affect usability and can distract learners from learning goals. Physical aspects of mobile technologies that may prevent an optimal learning experience include: restricted text entry, small screen size, and limited battery life. Software design aspects of mobile systems that may reduce satisfaction of learner's experience include: lack of human-computer interaction issues, lack of user control over mobile functionalities, uncertainty in context-recognition caused by several different sources, such as detection accuracy, information fusion, or inferring logic (Dey & Häkkilä, 2008).

- ***Challenge 2****: No mobile theory of learning.* Currently, no widely accepted learning theory for mobile technologies has been established, hampering the effective assessment, pedagogy, and design of new applications for learning (Kukulska-Hulme et al., 2011; Traxler, 2013).
- ***Challenge 3****: Heterogeneity of context.* Existing different features participating in the interaction between users and systems across spaces such as different technologies and interfaces for interaction, conditions of a place, surrounding people, learning preferences, skills, educational content, rich-media learning resources, among others, may affect negatively the interest and motivation in learning among students if learning design and delivery is not adapted (Christopoulou, 2008).

Thereby, several research efforts have been undertaken (presented in next sub-section) so as to build a framework/model to achieve conceptualization and design of m-learning, which educational stakeholders may find useful, in order to comprehend how m-learning key opportunities and challenges may join together to enable m-learning design and delivery.

2.5.1 Frameworks/Models for m-learning

Through this framework/model construction process, researchers have been following and evaluating important criteria with regards to assuming m-learning opportunities and aiming these m-learning challenges achievement as stated in (Sharples, Taylor & Vavuola, 2005). According to Sharples, Taylor & Vavuola, a first step in constructing a framework/model for m-learning is to distinguish that m-learning takes account of the personal, ubiquitous use and diversity of mobile technology (aiming Challenge 1). Second, that it embraces the considerable learning that occurs outside traditional learning settings, accepting that learning can occur outside as people initiate their activities to achieve educational outcomes (aiming *Challenge 2 and Challenge 3*). Third, that m-learning compared to other types of learning activity, differences from the assumption that learners are continually on the move, i.e. we move from topic to topic and learn across space and time (aiming *Challenge 3*). Lastly, m-learning is based on contemporary accounts of practices that enable successful learning; It matches a constructivist (individual and social) and situated approach, in which learning as an active process of building knowledge and skills through practice within a supportive group or community (aiming *Challenge 2*).

Following those criteria, some of the most well-received and acknowledged proposals of a framework/model for m-learning are:

i) **A Theory of Learning for the Mobile Age** (Sharples, Taylor & Vavoula, 2010).

Sharples, Taylor & Vavoula (2010) propose a framework (see Figure 2-7) for analyzing m-learning, which encompasses two layers, namely semiotic and technological, based on activity theory (Engeström, 1996) and internalization and socialization processes in knowledge construction (Vygotsky, 1978).

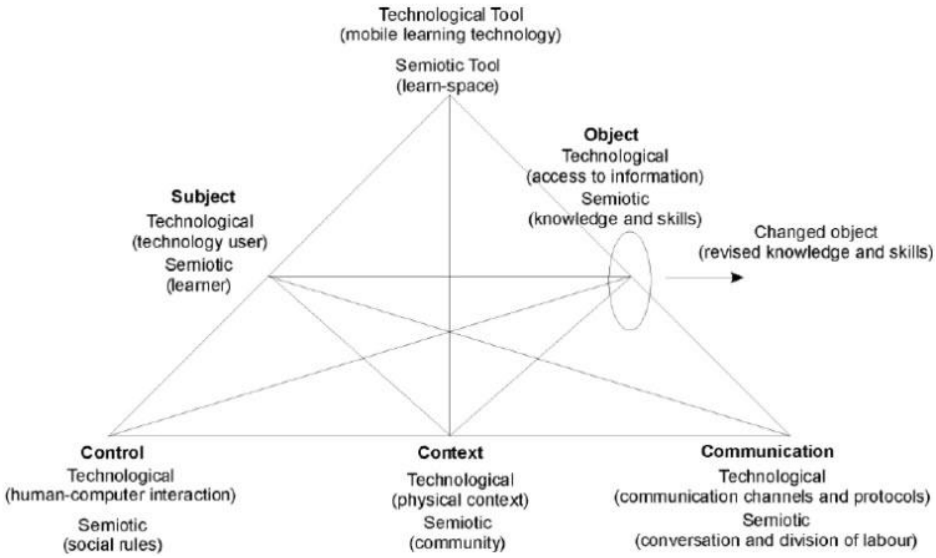


Figure 2—7 Framework for analyzing m-learning. Extracted from (Sharples, Taylor & Vavoula, 2010)

The semiotic layer describes learning as a semiotic system in which the learner's object-oriented actions (i.e. actions to promote an objective) are mediated by cultural tools and signs. On the other hand, the technological layer shows learning as an engagement with technology, in which tools such as computers and mobile phones function as interactive agents in the process of coming to know. These layers can be separated, to provide either a semiotic framework to promote discussion with educational theorists to analyze the activity and discourse of m-learning, or a technological framework for software developers and engineers to propose requirements for the design and evaluation of new m-learning systems (Sharples, Taylor & Vavoula, 2010).

ii) **Pedagogical Framework for M-learning** (Park, 2011).

An alternative focus is Park's (2011) pedagogical framework for m-learning (see Figure 2-8), which provides a way of understanding how 'transactional distance' and the 'social' nature of an activity can be mapped against one another. The former is defined as the 'cognitive space' between individuals whereas the latter is to what extent an activity involves interaction with others in order to be completed successfully. Park's framework allows academics and institutions to plan for the type of learning and teaching experiences that may work well in their particular context.

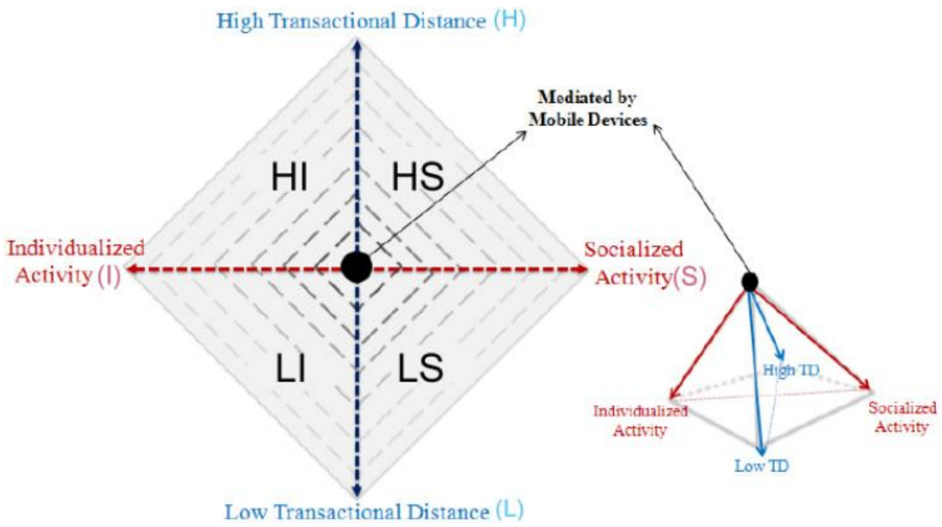


Figure 2—8 Pedagogical framework for m-learning (Extracted from Park, 2011)

Park gives each element a code: with H standing for high transactional distance, L for low transactional distance, S for high social interaction and I for low social interaction. An HS approach, for example, allows for high transactional distance and high social interaction with peers. This can be appropriate at any level of education, but may be more appropriate with learners who already have expertise in a given area. An LI approach, on the other hand, would be closer to a traditional experience for learners, with highly-structured and with (mostly) individual interaction with a single instructor. (Mobile Learning infoKit, 2011)

iii) **A Model for Framing M-learning** (Koole, 2009).

A more holistic framework for m-learning is presented in Koole's model (see Figure 2-8). This consists of a three-circle Venn diagram comprising the Learner aspect (L), the Social aspect (S) and the Device aspect (D). Koole provides criteria for each individual and overlapping section. M-learning is therefore a combination of the interactions between learners, their devices, and surrounding resources (people, objects, ambient technologies, etc.).

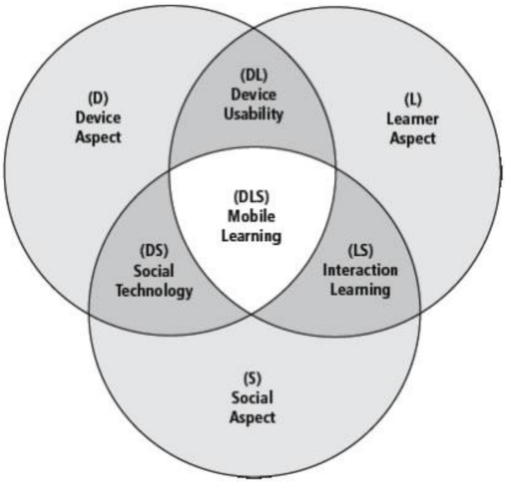


Figure 2—9 Model for framing m-learning (Extracted from Koole, 2009)

> M-learning provides enhanced collaboration among learners, access to information, and a deeper contextualization of learning. Hypothetically, effective m-learning can empower learners by enabling them to better assess and select relevant information, redefine their goals, and reconsider their understanding of concepts within a shifting and growing frame of reference (the information context). (Koole, 2009)

2.5.2 Pedagogical considerations

Besides aforementioned frameworks/models are examples of the foundations for m-learning design, all those proposals have been linking m-learning opportunities (presented in section 2.1.3) as well as they have been involving the *context* as an intrinsic part of the m-learning elements interaction. Moreover, those frameworks/models suggest that meaning-making process in m-learning cannot simply be transferred or trained, but rather it has to be built in each individual and in context.

During the early days of e-learning, one important issue that has been outlined for context-awareness in learning design is the affordances that activation of context may bring to the learning design process (Tessmer & Richey, 1997). Therefore, there is nowadays an existing need on examining mobile technology and context relevance to “design for mobile learning” (Sharples, 2011).

With the growing impact of web based distance learning, open educational resources and inclusion of mobile technologies, different traditional pedagogical approaches are increasingly being studied by different researchers so as to define or apply suited pedagogical theories for context-aware m-learning (Specht, 2008; Nouri et al., 2010; Ravenscroft & Sharples, 2011), which may leads to a formal description and representation of educational elements in the learning design process, including participation of contextual information.

During the last decade, there has been a major shift towards the *Constructivist learning* theories and their descendants with regards to designing for *situated and context-aware* m-learning (Beetham & Sharpe, 2007; Herrington, Herrington & Mantei, 2009; Kukulska-Hulme et al., 2011;). M-learning thus, based on the constructivists and situated’ perspectives, should be self-determined and situated in real-life situations (Schmidt & C. Winterhalter, 2004). Thereafter, knowledge construction in context-aware m-learning may best be facilitated by constructivist and situated learning scenarios.

Constructivist learning is an active process in which learners construct new ideas or concepts based on their current and past knowledge. According to *Constructivism*, learners interpret the information and the world according to their personal reality; they learn by observation, processing and interpretation, and then personalize the information into personal knowledge (Piaget, 1970). Moreover, in a social point of view, *Constructivism* asserts the relevance of an active subject and contextualizes it on a social environment (Vygotsky, 1978). That is, the interaction with other subjects and objects is an important part of the learner’s construction of knowledge.

On the other hand, ***Situated learning*** is a process that takes place in a social and participation framework (becoming part of communities of practice), which implies a highly interactive and productive role for the skills that are acquired through the learning process (Lave & Wenger, 1991; Oliver & Herrington, 2000).

Research studies have indicated that both *Constructivist* and *Situated* paradigms are benefiting of the affordances of mobile technologies and contextual information (Ally, 2005; Sharples, Taylor & Vavoula, 2010). Additionally, in several case study results presented in (Patten, Arnedillo Sanchez & Tangney, 2006; Herrington, 2009) indicate that mobile devices can be embedded in constructivist and situated based curriculum resources especially in tasks that involve students learning as they are mobile in different learning settings (i.e. in context). Mobile devices are providing a unique opportunity to have learners embedded in a realistic context at the same time as having access to supporting tools (Taylor, J & Sharples, 2006).

In present TeL research there are attempts to model the learning process for mobile contexts as explained above in the three frameworks; however, there exists a research challenge to define optimal ways on how mobile technologies and contextual information can be described in the learning design process and how educational materials can be suitable delivered and presented to different roles (learners, apprentices, teachers, instructors, etc.) which are the main actors of learning and instruction processes.

In this thesis educational scenarios construction based on *Constructivist* and *Situated* pedagogical models including learner's contextual information as an important design factor is presented and explained with details in chapter 5.

2.6 Summary and discussion

With the goal of providing an overview of the history, present and trends, this chapter summarizes the state of the art regarding m-learning and learning design. Firstly, this chapter mainly discusses the theoretical background about m-learning definition and the research background related with its expansion and opportunities that the learning design process can address. Accordingly, it is stated that the definition of **m-learning** is still an open issue, as well as it is described that related trials on m-learning along the past years have been proposed in terms of devices and technologies availability for learning, the benefits of learning outside the classroom and the affordances that learners mobility and context may bring to the learning process. Therefore, for the scope of this research work, it was declared that: current m-learning involves "**mobility**" of three main elements, namely *technology*, *information* and *people*, in real contexts in which these elements are immersed and interacting.

After that, this chapter presents the definition of **context**, and what it means for an m-learning system to be aware of context, as well as it introduces some approaches for modeling the context. Thereby, context can be considered in learning to understand the relations among learners, people, artifacts, locations and events, and more specifically, to comprehend how learners interact with other people, artifacts and location that surrounds them in order to construct knowledge.

Secondly, It is introduced the foundations of **Learning design** and further description of related issues about its implementation so as it can be benefitted from mobile and context-aware learning characteristics. Then, SCORM and IMS-LD specifications were presented as identified specifications that can be used to describe the learning process. Nevertheless, it were pointed some limitations of SCORM that IMS-LD can overcomes, with regards to allow pedagogical-enhanced educational scenarios be described, as well as, the flexibility and neutrality to design the learning process considering different approaches to be included such as the characteristics of a context-aware m-learning.

Through IMS-LD standard authors can represent pedagogical models with learning procedural planning in which different learning objectives and various teacher-defined activities are defined, so as to guide and monitor the students' learning processes. The authors can also define which learning contents are referenced in those activities and the environments that include the resources and tools to facilitate activity completion. Moreover, different adaptation approaches can also be defined within IMS-LD structure aiming to deliver personalized and adapted educational elements (activities, resources, tools, services) to learners (Burgos, Tattersall & Koper, 2007).

Additionally, at the end of this chapter it is discussed that in present TeL research there are attempts to model the learning process for mobile contexts as explained by three frameworks presented (Sharples, Taylor & Vavoula, 2010; Park, 2011, Koole, 2009). However, there exists a research challenge to define optimal ways on how mobile technologies and contextual information can be described in the learning design process and how educational materials can be suitable delivered and presented to different roles (learners, apprentices, teachers, instructors, etc.) which are the main actors of learning and instruction processes (a possible solution for this issue is further discussed in chapter 5).

Finally, we remarked that attempting to design a contextual and m-learning, researchers can clearly focus on considering traditional pedagogical models which have relevancy on a constructive (individual and social) and situated perspective of how learning process is taken and can be described. Traditional models seem to be benefiting from the characteristics of the m-learning: considering learners' mobility, engagement and ubiquitous use of mobile technology, exploiting available information, and support of interactions with communities of people and available resources. To this end the IMS-LD specification, which presents the structure of a learning modeling language and which brings some adaptation capabilities, seems to be appropriate for integrating the description of traditional pedagogical models with context-aware adaptation aspects for m-learning.

However, it is important to remark that there is a challenge in the learning design process so as to attempt considering constructivist-based or situated-based pedagogical strategies for context-aware m-learning. Since the learning design process stayed at an abstract level, considering a constructivist-based or situated-based pedagogical strategy requires struggling with certain components in the process (Strobel et al., 2009). For example, in many constructivist design models, not many fixed sequences exist and many learning activities can be iterative. Moreover, different available mobile tools and services can be used by the learner so as to complete activities. This flexibility means there is a great deal of learner's free choice regarding resource, tools, services and activity selections.

Even though, both constructivist and situated paradigms are characterized by nonlinear content interaction, complex and ill-structured problems, non-sequential pathways, and a variety of situation and context-sensitive support structures (like experiential learning, problem and project-based learning, scaffolding, modeling, and coaching) (Jonassen & Land, 1999; Mayes & Freitas, 2007), the constructivist-based and situated-based design can provide a design template for building non-sequential, open-ended learning activities within the formalized IMS-LD model (Strobel et al., 2009). IMS-LD claims to be pedagogically neutral (Nodenot, 2006), meaning it does not enforce a particular instructional strategy or model, and the decisions of design are left to the instructor or instructional designer. This is further discussed and overtaken with the solutions proposed in chapter 4 and presented in chapters 5, 6 and 7.

All these aspects sets the ground about the foundations considered in this research work so as to achieve learning design implementation in context-aware and adaptive m-learning. Next chapter discusses aspects of adaptativity for m-learning so as to achieve designing and delivering adaptations in this implementation.

CHAPTER 3

Context-aware Adaptivity in Heterogeneous M-learning Environments

This chapter provides an overview of the main issues and considerations with regards to achieving adaptivity in m-learning design and delivery. It presents relevant contributions regarding theoretical and technological concepts of adaptivity in two scopes, namely *educational content* and *context-aware educational scenarios*. Moreover, in each scope, some mechanisms and methods of adaptation are described, as well as an overview of identified existing solutions in each scope is presented.

3.1 Adaptive m-learning

In recent TeL research there is an existing interest to provide learning actors (students, apprentices, etc.) through systems with suitable and appropriated instructive materials that fit to their current needs and characteristics. This trend has been commonly known as *adaptive learning* (Brusilovsky, Specht & Weber, 1995). Research efforts in this tendency have addressed the definitions of adaptation with regards to: a) the system capabilities of delivering/outputting suited materials to its users, and b) to the user's means to customize the functionalities and properties of a system (Ahmad, Basir & Hassanein, 2004; Chen & Magoulas, 2005). These two approaches go from machine-centered (*adaptivity*) to user-centered (*personalization or adaptability*), nevertheless, both two-way of adaptations focused on the basis of enhancing the experience of system's users increasing their efficiency and satisfaction with regards to personal tasks and system's functionalities respectively, as well as narrowing the chances of getting lost within big amounts of information and reducing the probability to confuse in navigation through information (Oppermann & Rashev, 1997).

Both concepts *adaptivity* and *personalization* have been an important issue of research for learning systems during the last two decades. Research on this issue has shown that the application of *adaptivity* and *personalization* can provide a better learning environment in such systems.

Regarding the affordances that *adaptivity* and *personalization* issues have been bringing to the computer-mediated learning process, during the last decade research initiatives start focusing on the mobility aspects of the learner involving the appropriation of learning spaces in which ubiquitous technologies, surrounding resources and everywhere information merge together to facilitate learning. This new trend has been intended to be known as ***adaptive m-learning*** and its firsts progresses starts appearing since mid 2000s (i.e. 3rd phase of m-learning) (Economides, 2006; Goh, Kinshuk & Lin, 2003; Jeng et al., 2010; Liu & Hwang, 2009; Martin et al., 2011). This emerging trend focus on delivering personalized and/or adapted learning content and educational scenarios to learners regarding: the mobile device from which they are interacting with, their individual mobility needs and preferences in learning situations different from a traditional settings, and the surrounding resources (people, ambient technologies, physical objects, cultural milieu, etc.) that may affect the interaction between learners with anytime-anywhere available information (Kinshuk et al., 2011; Sampson et al., 2012;). In this new trend, affordances of emerging *mobile technology*, facts and effects of *learner's mobility* and availability of surrounding resources and *information* to the learner's situation and context can be distinguished.

Both *adaptivity* and *personalization* in m-learning systems refers to the process of enabling a learning system to fit the learners' current situation, needs, and characteristics, taking into account, for example, their current location, their access device, knowledge level, learning styles, interests, preferred language, and so on (Kinshuk, Graf & Yang, 2009; Wu et al., 2008). While *adaptivity* focuses on taking learners' situation, needs, and characteristics into consideration in generating appropriately designed educational scenarios and delivery suited learning content (activities, resources, tools and services, etc.), *personalization* is a more general term and highlights the customization of the system, including also issues which can be adapted and specified by learners themselves, such as interface, the preferred language, or other issues which make the environment more personal.

Aspects of *adaptivity* and *personalization* are becoming more and more important for m-learning research and they play an important role towards providing learners with adaptive and personalized learning experiences delivered via mobile devices (Motiwalla, 2007; Ogata, 2008). However, this research topic is still in its infancy, and great efforts need to be taken so as to achieve designing and delivering adaptive and personalized mobile educational scenarios and mobile systems. Thereafter, *adaptive m-learning* is obviously immature in terms of both its pedagogies and its technologies (Mohamed, 2009; Sharples, 2007). On the one hand, designing for m-learning should consider different learning situations, different personal learners' aspects (such as their individual preferences and needs among others) and aspects related to the heterogeneity of resources and information presented in different learning contexts. These considerations were previously discussed in chapter 2. On the other hand, delivering m-learning should incorporate adaptivity and personalization issues in the development of m-learning systems so as to provide learners with an environment that is not only accessible anytime and anywhere, but also accommodating to their individual preferences and needs, taking into consideration contextual information, such as environmental and location conditions.

3.2 Main issues in adaptive m-learning design and delivery

From the user's access device through the learning resources to the learning context there are many aspects to take into consideration for effective adaptation. From the early eighties, where computer-based training was used to fully control the flow of a learning process (Tennyson, 1981), to the concept of adaptive guidance, which provides rich information and a diagnosis to help the learner to take effective decisions about his own learning (Bell & Kozlowski, 2002), there is a wide collection of approaches that can be considered for adaptation in m-learning.

For instance, to incorporate external entities as a key factor in the adaptation process such as surrounding resources (Luckin, 2010), or to build a system strongly supported by artificial intelligent (AI) agents that adapt its interface (Mitrovic, Mena & Royo, 2008). All of them are based on the proposal of an adaptive and personalized learning to the context of each student in order to stimulate his learning process and to encourage his involvement in this process (Fredericksen, Pickett, Shea & Pelz, 2000).

Consistently, these approaches hold that the best adapted and personalized learning performance may comes from instructional design (Towle & Halm, 2005). Moreover, recent research states the meaningful and pedagogical affordances that contextual information may bring to this adaptation processes. This does imply that characteristics of a user/learner situation would help to deliver full suited learning materials to their situation and gives personalized control over a learning system. This would mean that in terms of adaptation and personalization, design and delivery of m-learning should consider that:

i) a system could know what is the actual situation of a learner

ii) a user/learner can be aware of her/his personal conditions and could know and control all the contributions that she/he can make to his own process; and

iii) a system can be able to carry out right decisions when all this information is gathered so as to adapt itself along a *learning script*.

Adaptation in m-learning can be understood as a *method to create suited learning experiences through educational scenarios, aiming to deliver a set of tailored elements through a mobile system across specific learning situations and based on pre-defined criteria*. These criteria could be characteristics of the learners' context including access device aspects, time aspects, personal aspects, location aspects, surrounding resources, among others characteristics (Brusilovky & Millán, 2007). Elements to modify/adapt could be based on learning activities flow, educational resources, tools, services, interface and so on.

Some authors have reported that a good practice of *adaptive m-learning* is based on applying the aforementioned criteria (Kinshuk, Graf & Yang, 2009; O'Connell, 2007) and properties of mobility (in terms of *technology*, *learners* and *information*) described in chapter 2. A good practice for adaptive m-learning design and delivery would consider the affordances of the characteristics of learner's location and surrounding resources, the capabilities to achieve immediate access to learning content and information, the possibilities of remain always connected and allow learning to occur in locations other than formal learning environments such as home, museums, public transport stations, outdoors, among others. However, to achieve successful design and delivery of adaptive m-learning, researchers should focus on giving solutions to some issues that still affect aforementioned aspects. Next sub-sections describes identified issues that should be taken into account for the implementation of best practices in the design and delivery process to achieve an adaptive m-learning.

3.2.1 Diversity of capabilities in mobile devices

The range and diversity of handheld devices on the market today present a challenge to provide contents on mobile device for users. Even though memory and computational capabilities of these devices will continue to improve, achieve adaptivity in terms of assuming the learner's access device encompass the convergence of different capabilities.

Latest new devices have rich capabilities: input via touch screens with built-in or onscreen keyboards and noise-cancelling microphones; output via vibrant screens and quality audio; sensors such as GPS, cameras, compasses, and orientation sensors; and connectivity via multiple networking methods including Wi-Fi, Bluetooth, data via phone service, and cables (Quinn, 2011a). Figure 3-1 depicts some of these main devices' capabilities.

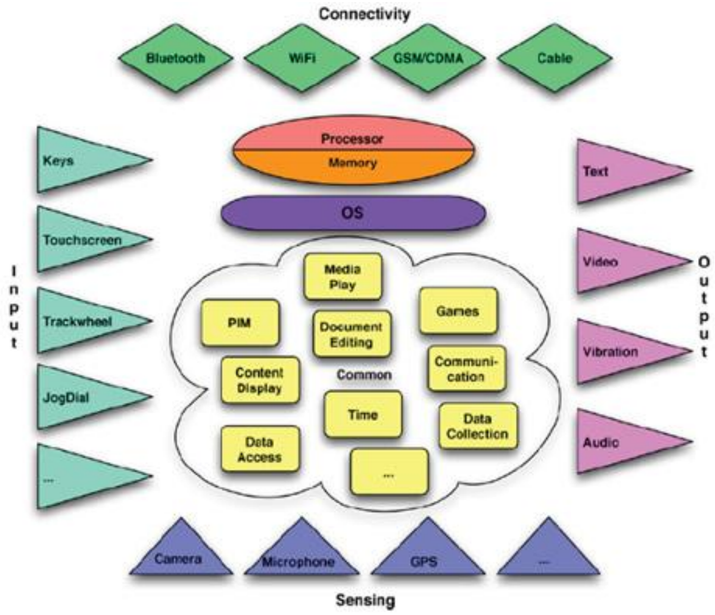


Figure 3—1 Converged device capabilities. Extracted from (Quinn, 2011)

Nevertheless, when looking at the available type of devices in market (as shown in section 2.1.2) there exist some preferences on devices targeted for mLearning development. Tendency in research work on adaptive m-learning is pointing to choose smartphones as target device (see Figure 3-2) because they are the most-converged device in terms of capabilities, are more portable than tablets, and also are the most adopted by people (Comscore, 2012). On the other hand, tablets are effectively quite new, and yet they've already established a respectable presence; and media players still prevails given the ease of developing Podcasts, and the number of people likely looking for ways to make commute time more valuable.

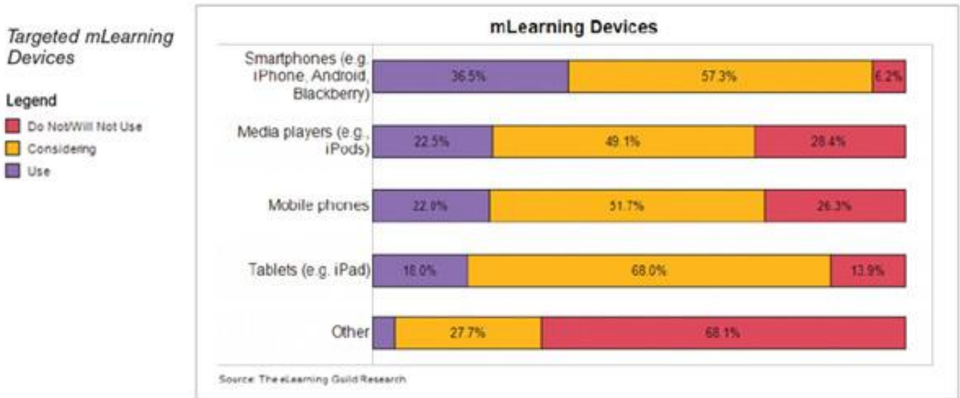


Figure 3—2 Targeted m-learning devices. Extracted from (Quinn, 2011)

Here, the convergence of devices' capabilities and the targeted devices provides a rich source of channels for supporting learning. These channels are pretty much a given; the only thing that provides an extra level of challenge is in developing interactivity and furthermore adaptivity. Although, these channels provide new opportunities to think about how learning might be supported, and thus is what is fueling the mobile revolution, it is likely to remain a bottleneck to achieve adaptivity and personalization in many mobile systems.

Yet, there are some limitations and restrictions (from users' perspectives) regardless devices capabilities (W3C-MBP, 2008):

- Limitations on the device capabilities

  The small screen size stills be a constraint for some users about using mobile devices. There are yet other limitations regarding users' device capabilities, for instance some feature mobile phones do not have a navigation interface to provide content browsing. Another example is the limitations that some devices have to support displaying different types of digital content. There are other limitations that were identified and analyzed in this work so as to achieve adaptive content delivery. These limitations are explained in chapter 5.

- Lack of commonly used input peripherals

  This drawback can become a problem because most users are accustomed to the use of desktop computer peripherals such as the keyboard, mouse, among others. The mayor number of users' mobile devices has a limited keyboard with small keys and usually they do not have a controller to aim like a mouse.

  The difficulty arises when entering data via the keyboard or selecting a specific navigation link for users that want to interact with content and applications. Due to the limitations of screen size and lack of input peripherals, content with forms, tables, many navigation links and multiple digital content can cause loss of information.

- Restrictions in bandwidth and cost of connections

  One important capability that presents limitations for some users is the restrictions presented in some networking methods to achieve high-speed connectivity. Mobile networks are often slow compared to the fixed data connections. This can lead to very long delivery times, especially for large files in bits and for content that requires complex navigation paths between pages.

  Moreover, data transfer to mobile devices is generally a waste of money. The fact that the vast majority of mobile devices are limited to support only certain types of content can lead to users follow links that will present unusable information on their devices. Some web content can contain digital media resources that the user has not asked specifically to visualize, for example, advertising messages or very large images. In m-learning this kind of experiences affects and reduces the usability of a system and increases the delivery cost of materials.

  According to (Quinn, 2011), given that the ability to deliver content is arguably easy in mobile environments, it is somewhat surprising that learning content delivery is relatively low (although more is planned, see Adkins, 2011). However, it is a large area of endeavor, overall, which makes sense to study as an issue of adaptive m-learning design and delivery.

3.2.2 Diversity of digital content in learning resources

A classic m-learning example is content delivery. An easy experience for some learning designers is to put existing content online for mobile access, taking existing PDF, audio, and video files among other resources and making them downloadable. Regardless of whether the content is dynamic, such as audio or video, or static, such as graphics, photos, and text, having information available on demand can be valuable for learning. Frequently, this access is for convenience so that we can occupy time otherwise wasted, such as sitting during a commute, in an airport, or in line.

Nowadays, most of computer-based learning contents, designed for desktop computers and high-speed network connections, are not suitable for handheld devices, whose capabilities are usually limited (He et al., 2007; Chang, 2008; Yang, Chen, & Chen 2007) as mentioned in previous sub-section. Digital content have been commonly developed for presentation at desktops screens and exploit the capabilities of browsers on these computers. Thus, accessing a desktop-oriented content using a mobile device can translate into a bad or useless experience. Due to small size of the display screen and the limited amount of resources that may be visible by the user, general information and content argument can be lost.

During the last years and in the shortcoming time, studies have been predicted that m-learning is having an increasing demand so as learners being able to deploy/find/use content on their own handheld devices (Adkins, 2008). See Figure 3-3.

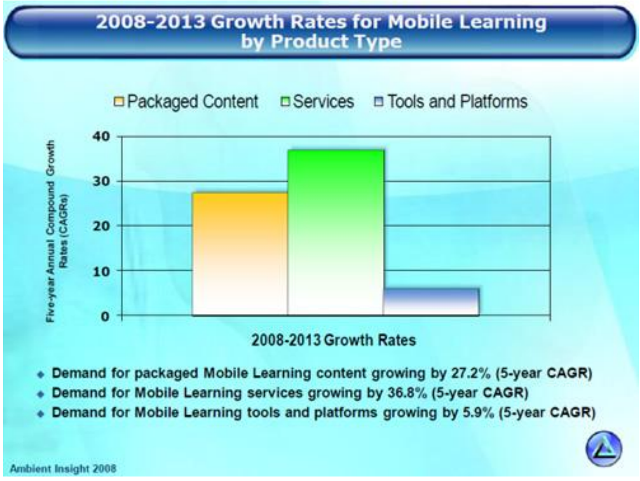


Figure 3—3 Growth rates for m-learning (2008-2013). Extracted from ambient insight 2008 (Adkins, 2008)

Nonetheless, because of the diverse devices capabilities related to limited screen size, content rendering, networking restrictions, etc., digital content is requiring of solutions for delivering them in optimal ways without be restricted of the delivery end.

In general, this processing need is known as **content adaptation**, which according to the W3C definition (W3C), *is the transformation and the manipulation of contents to meet desired targets (defined by the terminal capabilities and the application needs)*. Content adaptation is usually related to mobile devices that require special handling because of their limited capabilities (MOBIforge, 2009; Zhang, 2007). Moreover, related to this issue, research efforts have been focusing in context-aware access opportunities presented by mobile devices. This issue will be further described in section 3.3 concerning adaptation of educational content.

3.2.3 Diversity in learner's needs and context

Users who use mobile devices to access content typically have different interests and needs compared to when using desktop computers. Mostly, they need immediate access and straightforward information, which suits directly to their needs and without extra data of what they want to access (information related to their goals) i.e. they want content to be delivered "just-in-time, just-enough, and just-for-me" (Motiwalla, 2007; Thomas, 2007). Furthermore, these users often want that information suits to the environment in which they are (i.e. context-related information). For example, in an educational situation, a learner would like querying test schedules that are close to a date that teachers set or looking for content that support a task to be performed in a specific place. Other example, could be a learner who may need support when facing a problem in real life; in this case a digital content (e.g. video, audio, image, etc.) of a problem-solving procedure can be viewed and used as a just-in-time aid.

People on the move need information relevant to their location and immediate needs. The capabilities of mobile devices are restricted when compared to desktop alternatives, nevertheless a context-aware adaptive mobile system can match deliverable information to the current context including the available device at hand as well as other aspects regarding learner's location and the learner's needs and preferences (Lonsdale, Baber & Sharples, 2004).

Context-awareness may enable adaptive mobile systems to assist the users in an efficient and intelligent manner and enhance their experience by increasing productivity and satisfaction with the process and outcomes of a decision-making process (Henricksen, Indulska & Rankotonirainy, 2002).

Thus, context should be reasoned by systems, and adaptivity may be achieved by defining a context-aware adaptation engine which can handle and process one of more different aspects of contextual information as follows (Delir Haghighi et al., 2008):

- *Dynamic and static context*: context can be dynamic, like user's interaction data; or static, like user's name or e-mail.
- *Continuous data streams:* context can be continuous like sensor data streams.
- *Uncertain and imperfect context:* context information is liable to imperfection and can be erroneous, ambiguous or incomplete.
- *Temporal context*: context can be associated with temporal data, which enables representation of histories of context.
- *Situational context*: contextual information can be used to represent a situation such as a user activity.

The emphasis for adaptivity in mobile systems is shifting from complex modeling of the alternative decisions regarding heterogeneity of context, to representation of the context in which these decisions are situated. The complexity of heterogeneity in context increases the importance of identifying, modeling, learning and managing the right context for making efficient decisions (Burstein, Brézillon & Zaslavsky, 2011).

In the case of m-learning systems, adaptivity solutions have been focusing on being aware of the heterogeneity in learner's context. A context model for m-learning systems may include learners' location, supporting people, spare time, interests and needs among other characteristics (this will be discussed in chapter 5) and clearly it has a meaning when is considered and used to provide what the learners need in different situations (i.e.

relevant information or enabled tools and services to assist and support the learning process).

According to this, contextual information can be integrated to propose adaptive systems and new scenarios for learning. Aforementioned aspects of contextual information promote defining different solutions to the problem of the construction of adaptive m-learning systems, integrating variables that have so far been less considered regarding the learner's context. In next sections we present some adaptivity aspects, mechanisms and approaches used in different studies that serve to implement context-aware adaptive educational scenarios and mobile systems.

3.3 Educational content adaptation

In TeL, a great amount of digital educational resources (e.g. images, audios, videos, web contents, etc.), tools (e.g. image viewers, audio and video players, instant messengers, text-processing tools, etc.) and services (e.g. communicative services, collaborative tools, e-portfolios, social network services, etc.) have been developed to facilitate enhanced learning experiences. However, as mentioned before, most of these materials have been developed assuming desktop computers as the delivered end, increasing the barriers of learners in accessing them through their mobile devices. Furthermore, due to this massive production of contents (educational resources, tools and services), sometimes irrelevant to learners' preferences or contextual environment, have made learners feel frustrated and dissatisfied (Evangelos, Elissavet & Anastasios, 2008).

In m-learning environments, providing those kinds of materials while taking into account the limitations of mobile devices and context-related information is a challenge (Rho, Cho & Hwang, 2005). Therefore, TeL researchers who focused on designing and delivering m-learning experiences have been presenting with a twofold problem: how to ensure seamless access to content taking into consideration the end device (i.e. mobile devices) and how to exploit the possibilities of the devices in providing context-aware adaptive learning experiences (Lemlouma & Layaïda, 2004).

One of the main parts of any computer-oriented learning design is the population of educational resources with digital content and the association of assimilative, productive and communicative tools and services (Gang & Zongkai, 2005). In a *learning script* is described how people perform activities using learning content/materials (including resources, tools and services), and how these materials are coordinated into a learning flow. The resources in any *learning script* itself can be of type of digital media; for example, HTML files, GIF and JPEG images, videos, audios, Flash animations, PDF documents, PowerPoint slides, and Word documents among others. The tools can be for example: notepad, word processor, audio player and recorder, video player and recorder, camera, among others. The services on the other hand can be for example: instant messaging, translating, searching engines, web browsing, emailing, discussion forums, phone calling, voice messaging, video conferencing, blog hosting, among others. The only limitation is whether the recipient (delivery end) of such a *learning script* has an application or the mean capable of delivering the materials designers have included and/or packaged up.

For example, if a teacher defines in the learning design of a course that students review an audio file of a lecture and a video file explaining the main idea of a subject (both files designed assuming access and delivery through a desktop computer) in order to make a productive task and participate in a communicative task with their learner-peers, how can those activities be adapted and presented to a student if the student wants to complete them on her mobile device while she/he is out of the house and with no learner-peers near? A student can complete the three activities [an assimilative task (review), a productive task (writing) and the communicative task (pair discussion)] using a personal desktop computer from home without any problem (considering that she/he has internet connection and the files can be downloaded). Nevertheless, the challenge in m-learning scenarios is that the three tasks could be held in the student mobile device at anyplace and at anytime, without any problem as well, even if the audio and video files were not designed considering the capabilities of the device.

Hereafter, in m-learning design, providing educational content included and packaged within a *learning script* (i.e. procedural learning planning represented in the learning design process) while taking into account limitations of the mobile devices (W3C-MBP, 2008) may cause the loss of information for learning and the failure to achieve the learning objectives if adaptation processes are not well designed and implemented. Thus, context-aware content adaptation has been looked as a good resolution to tackle some of the issues in adaptive m-learning design and delivery. Accordingly, in this section we discuss content adaptation mechanisms which can be considered to achieve context-aware adaptive m-learning design and delivery.

A context-aware content adaptation mechanism to deliver adaptive contents to the students' mobile devices while they follow a learning flow (described in the learning design process) may help to overcome the restrictions associated with mobile devices (Sampson, Tze & Zervas, 2007) and provide support for teachers who monitor students' learning processes.

3.3.1 Content adaptation mechanisms for m-learning

Building a context-aware content adaptation processes over a learning system involves variables from the learner's situation that needs to be taken into account so as to design and deliver authentic learning experiences. According to Bomsdorf (2005), in mobile systems development, context-aware content adaptation commonly consists in four types, namely: *content filtering*, *application filtering*, *polymorphic presentation* and *content classification*. Next, these types are presented in details:

Content filtering

Depending on the learning situation, educational contents are selected and presented to the student. For example, a student sitting in a library could do some learning tasks using her/his smartphone accessing different content. However, if the technical network characteristics are not optimal, it would make no sense to provide big-size resources and complex tests related to an extensive subject, even if the content were small to be presented in a small screen.

Not in all learning spaces content is adaptable, as shown in the above example. Therefore, content filtering can be a mechanism for the selection of educational content, as well as for deciding to "show" or "hide" resources if conditions of a learning space are appropriate or inadequate for learning respectively.

Application filtering

Depending on the learning method, same content should be presented by different applications. For example, a subject with technical terms that might be presented through digital content within a learning management system could be presented through a training system or content management system as well.

Polymorphic presentation

Learning content might be presented with different levels of detail and format. For example, in a slides presentation all content can be displayed in text format, but if the screen of the delivered end is small-size only keywords should be presented. The keywords version supports the presentation of content on small screens, showing only an overview or summary of the whole content (Stary & Auinger, 2005).

A commonly used adaptation technique related to *polymorphic presentation* is content transcoding. A *transcoding process* consists of a set of steps to transform the technological properties of one or more multimedia resources (Chandra, Ellis & Vahdat, 2000).

Here, some examples of a transcoding process are described detailing diverse transformation processes (Mirri, 2007):

- *Conversion* between encoding formats for the same content. (e.g. convert WAV files to MP3 audio).
- *Degradation or decreasing* between different types of content, such as changing text to speech (text-to-speech) or vice versa (speech-to-text), changing animations to images, among others.
- In other instances, *Degradation or decreasing* instead is a *Changing* process that needs that additional data can be provided so as to modify the type of content. For example, changing images to text, identifying which images can be replaced with an alternative text description.
- *Scaling*, which may consist of resource compression or reduction of resources dimensions, rates or data quality.
- *Translating* from the original language to a different one, based on the user profile. This operation can be only performed for textual and audio speech contents.

Content classification

Based on content filtering and application filtering, content classification consists of providing a list of learning materials or tools, from which the student can select which learning objects she/he will work with. Specifically, this mechanism consists in a two-stage process: first a leaner submits the profile of her/his current situation to a system, so that it can determine the right material for that situation. Given that the result could be a large set of resources, initially should be presented only a part of that set. Summarizing, contents are presented based on the inputs provided by a user.

In chapter 4 a context-aware adaptation proposal targeting the implementation in the design and deliver approaches of learning design is presented and, as first scope, its architecture involves *content filtering* and *polymorphic presentation* mechanisms. Generally speaking, in m-learning design and delivery these mechanisms involve filtering a set of content (including learning activities, learning resources, tools and services) according to learner's learning situation and the transformation of properties of learning resources (which are populating an educational scenario), leading to transcoding processes (recoding) so as the format of files or resource properties can be adapted according to different parameters set by access device capabilities or by user requests.

3.3.2 Adaptation levels

According to where an adaptation process may run and be carried out, the World Wide Web consortium (W3C-MBP) has classified three levels of adaptation for mobile environments: on the client side, on the server side and by a proxy. Next, these levels are presented in details:

Client-side level

On the client-side level, the adaptation process is the responsibility of the client platform, as shown in Figure 3-4.

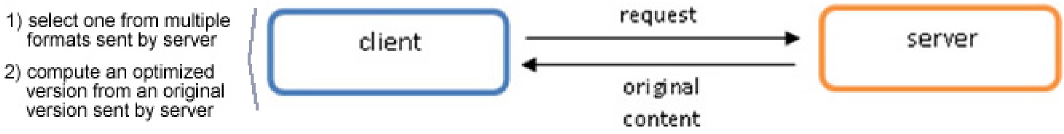


Figure 3—4 Adaptation level on the client side

Client-side solutions can be classified into two main categories with different behaviors:

1) Clients receive multiple content formats and adapt them by selecting the most appropriate fit to run.
2) Clients compute an optimized version of an original version. This category proposes a distributed solution for the management of client heterogeneity, assuming that all clients can decide locally and use the most appropriate adaptation process for them.

Server-side level

In the server-side level, the server which provides contents is in charge of running the adaptation (see Figure 3-5). The content adaptation can be performed in offline mode or online mode (at runtime).

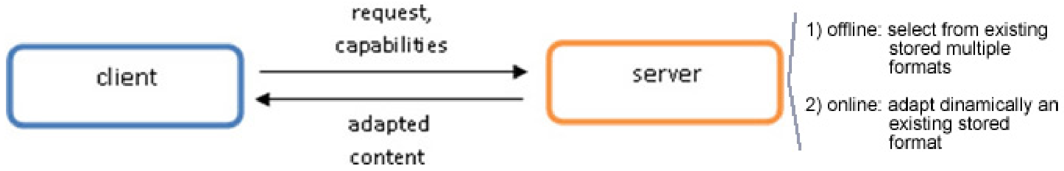


Figure 3—5 Adaptation level on the server side

1) In the first case (offline), a content transformation process takes place when there are existing contents on the server (i.e. uploaded and stored on the server). Generally, in this case there is a content designer and/or builder who modify the content in different formats. Accordingly, multiple formats of a same content are stored on the server, and then are dynamically selected to match the capabilities of the client device.

2) In the second case (online), a single content is stored in the server only in one format and the server performs dynamic adaptation processes before delivering the content to the client.

In both cases, the server previously must know which is the target device by receiving its capabilities (this information is sent by the client) to know who it should deliver the adapted content.

Proxy-based level

In a proxy-based level, the adaptation process is carried out by another node (proxy) between the server and the client (see Figure 3-6). The process involves capturing, performed by a proxy, of the responses to client requests generated by a server, so as to execute three actions:

- Decide whether to make performance improvements.
- Make adjustments (adaptations) to the content.
- Send the adapted content to clients.

Figure 3—6 Adaptation level based on a proxy

To implement this process, the proxy must know the target device, this means knowing the technological capabilities of the device (this information is sent by the client), and also have a full version of the available original contents (these data are sent by the server). Consequently, the use of bandwidth of the network connection can be intensive in the link between the server and the proxy.

3.3.3 Overview of educational content adaptation systems

Considering the previously presented mechanisms (namely, *content filtering*, *application filtering*, *polymorphic presentation* and *content classification*) and the three levels of content adaptation above described (namely, *client-side*, *server-side* and *proxy-based*), the author of this thesis underline some related work done by researchers who proposed different models of context-aware adaptation in relation to where adaptation can be set and run. Aditionally it is presented some advantages and disadvantages of the application of these levels (Laakko & Hiltunen, 2005; Mirri, 2007).

Client-side level

A main advantage of content adaptation on the client-side level is the knowledge about the capabilities of the client platforms. For example, in (Wei, Bhandarkar & Li, 2009) a dinamyc multiple choice makes a system in client-side capable of handling various kinds of videos without having to manually redefine a program model. A different solution consists in sending different multiple formats of content to clients, who have to select which is best content to display (Lei & Georganas, 2001).

Other different adaptivity solutions can be made on the client side, specifically in the browsing tool included in the device, for example, let the user to increase or decrease the size of the text font in the content, or set the permissions of dynamic content, or allow the browser or not displaying images, among others examples.

A common solution by using a browsing tool is to achieve adaptivity through the use of templates on the markup languages supported by these browsers so as to customize content presentation. A relevant example is adaptation by means of the use of cascading style sheets (CSS) (W3C-CSS, 1998) that authors can customize to apply presentation and design styles to HTML content (W3C-HTML, 1991) to XHTML content (W3C-XHTML, 2002), to scalable vector graphics (SVG) (W3C-SVG, 2003), and even to content in XML (W3C-XML, 2008).

However, this level has some limitations such as:

- Generally it is not possible to send different versions of a same content encoded in different formats. This limitation is relevant when communication is performed using client-server communication protocols.
- This level increases computational processing of the client platform.
- It is inadequate when clients access multimedia resources through low-end devices.

Server-side level

The server-side level may overcome the limitations presented by the client-side level. A web server that uses detection mechanisms of some types of access device and a repository to store their profiles can send adapted and optimized content according to the requests set by the client and the technological capabilities of the device.

Considering the application of transcoding mechanisms of the contents on the server side, there are several research projects that propose different adaptivity models taking into account the capabilities and features of the client device. For example in (Huerva et al., 2008) a multi-agent architecture on the server side can capture the characteristics of the user's access device and after evaluating these characteristics contents are deployed or not. In (Xinyou et al., 2008) a functional architecture on a server based on adaptive algorithms that analyze the information obtained from the context of the student is presented. Information considered let to present dynamically adapted content based on the access time, the location, the type of network and mobile device profile. The work in (Domenico & Giuseppe, 2006) defines also a multi-agent architecture on the server side to capture user behavior. At the time when the user accesses web content by means of using different mobile devices, a global profile is created to recommend adapted web pages according to the analysis of the profile or profiles of other users who have used the same access devices. In (Park, Baek & Gibson, 2008) a mobile and adaptive learning management system evaluate student preferences based on her/his learning style (capturing this information through a test which is then stored on a server) in order to adjust the learning resources to the user interfaces mobile devices.

Proxy-based level

In (Li et al., 2006) a content adaptation process based on transcoding mechanisms, using the proxy level, is presented. This process considers the network characteristics and processing demand in order to improve the potential capacity of the system. A content provider on a proxy server that receives information of the context of the user's client device is presented in (Lum & Lau, 2002). This server executes algorithms to compute the network characteristics and the optimal resource version that can be sent to the client device.

Most related work in the area of m-learning have focused on detecting specific technical characteristics of access devices, and other related features, such as the browser, connection technology, server status, among others, in order to perform an adaptation process using the server-side and proxy-based levels. However, a combination of these levels, including the client-side level can result in a better solution to propose context-aware adaptation for m-learning design and delivery. This idea is discussed in chapter 4.

3.4 Context-aware educational scenarios adaptation

Traditionally, research work on delivering computer-mediated suited learning experiences to learners have stated that adaptive educational scenarios design should:

- Be significant, so that should be appropriate for monitoring a pedagogical model that allows acquiring knowledge (Paquette et al., 2001)
- Consider different aspects of the users in order to adapt the contents to their needs and preferences. (Brusilovky & Millán, 2007)
- Consider different types of media content (Mirri, 2007)
- Be collaborative-oriented (Kumar et al., 2007)

Nevertheless, current research works about adaptivity and personalization in m-learning systems recognize the pedagogically meaningful and technically feasible process of learners' contextual information as an important learning design and delivery factor (Beetham & Sharpe, 2007; Luckin, 2010). Thereafter, TeL researchers have remarked that adaptive educational scenarios design additionally should:

- Be foresight to consider the emergence of new technologies and new trends in users whose nomadic and ubiquitous access have grown incrementally (Heath et al., 2005)
- Be aware of ever changing learning situations in time and space (Dye, K'Odingo & Solstad, 2006)
- Be aware of the heterogeneity in contextual information. (Economides, 2008)

Properties and affordances of learner's situation vary enormously and hence context in learning become even more important, such as the specific location, the task or goal of the user; the ubiquity of network access (GPS, Wi-Fi etc); the time of the year or day or even the weather. Being aware of and exploiting contextual information can lead to context-aware m-learning systems that can dynamically adapt to the changing context during a learning process towards to more effective, convenient and enhanced learning experiences.

In the last decade, TeL has been introduced to a variety of blended learning scenarios, and in all these scenarios the learner's situation or context have been an essential asset in designing and delivering the learning process (Liu & Hwang, 2009). Moreover, it has been suggested that adaptive and personalized learning, as a research area, may provide solutions to the problem of considering context's heterogeneity in the process of designing and delivering an adaptive education through e-learning and m-learning (National Academy of Engineering, 2012).

However, an overarching research challenge in the design of context-aware adaptive educational scenarios and delivery through mobile systems for learning is to determine what explicitly can be influenced by contextual information in the learning process and what can be adapted to provide 'awareness' learning activities and materials that learners, individually or collectively, can perform and use when following a learning flow, when supporting is needed and when interaction with others facilitates collaboration for knowledge construction (Sharples, 2007).

3.4.1 Adaptation types

Based on relevant studies in the literature, three main types of adaptation that can be carried out for context-aware educational mobile scenarios design and delivery were identified, namely:

i) Learning flow navigation and sequencing,

ii) Problem solving support and feedback (scaffolding) and

iii) Interactive users' communication.

All of them use contextual information as input (received from learners, detected by systems or measured by sensors) for learning delivery systems, provided during the learning process and aim to tune the activities and actions of the learner to get the best learning experience as possible (Hwang, Tsai & Yang, 2008).

Learning flow navigation and sequencing

In this type, the learning process, through a procedural plan of sequence of activities (aka. learning flow), is dynamically adapted to explain the contents of a course in different ways considering the learner's situation. Affordances of mobile technologies let consider in this type a navigation through different learning activities, spaces and educational materials in which sequencing is mostly aware of learner's location and learner's temporal information, and thereafter planning of suitable learning activities can be design and delivered for real-world situations (e.g. visiting a museum or botanical garden, experimenting in field trips, among others). In m-learning educational scenarios, learners can be guided to perform context-aware learning activities according to a dynamically structured navigation path, which can be mainly constructed based on learner's location and situation (Tan et al., 2009).

Thus, a learning delivery system should rearranges or reorders the navigation and sequencing possibilities of different educational materials (activities and resources) that are linked to each other towards creating adapted learning paths by taking into account different criteria derived from learners' contextual elements.

Characteristically such criteria consider learner's previous knowledge, current location, and available time to learn, as well as It can include learners' personal information such as their needs, preferences, and other temporal information.

Consistently, current research efforts have been focusing on studying if contextual information can affect a learning flow (Schmidt & Winterhalter, 2004), as well as identifying the cases in which context can be influenced when learners are following the structure of a procedural learning plan. Hereafter, related research work have pointed three different ways in which context affect the flow and/or is affected when learners are following it (Derntl & Hummel, 2005):

1) *Activity updates context*

In this case, there exists a dependency relation between activity and context when an activity is completed, that is, for example if a learner completes a learning activity (e.g. a test) this event, may cause an update of the learner's contextual information in terms of progress (depicted in Figure 3-7). The implementation of this case relies on updating learner's information such as prior knowledge, grades, completed contents, etc. As a general requirement for implementation of this way, a context parameter/object needs to expose appropriate methods for updating.

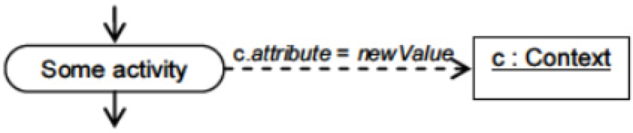


Figure 3—7 Activity updates context. Extracted from (Derntl & Hummel, 2005)

2) *Context alters activity*

Depending on the current context, some activities might be altered slightly (depicted in Figure 3-8). Implementation of this relationship rely on changing the activity-based recommendation of activities paths depending on contextual information such as learner's location, physical conditions of the place, learner's temporal information (interests, preferences, etc.), among other information. Implementations of this case will mostly be based on presenting or delivering conditioned learning activities, i.e. a learning activity related to a context parameter/object can be altered in presentation (hided or showed/delivered).

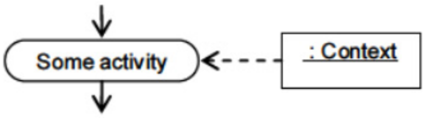


Figure 3—8 Context alters activity. Extracted from (Derntl & Hummel, 2005)

3) *Context as guard:*

In this case a learning activity may be influenced by learner's decision based on choosing from different options. Depending on contextual information, the selection of alternative learning activities is provided.

The learner's context guards the firing of one or more transitions between nodes in the activity procedural plan. In this case, the guard condition on the respective transition refers to some context parameter/object's value(s). Figure 3-9 shows a case where a context object acts as the decisive element for multiple possible control flows after a decision node.

For example, in this case a learner can choose between a set of activities the option (user-choice) that accommodates better to her/his situation based on her/his decision (influenced by temporal information such as preferences, needs, attitude, mood, etc.)

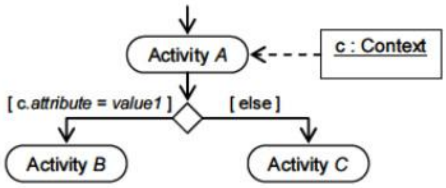


Figure 3—9 Context as guard. Extracted from (Derntl & Hummel, 2005)

Problem solving support and feedback (scaffolding)

A typical m-learning activity could be built in more opportunities for digitally-facilitated site-specific activities, and for ownership and control over what the learners do (Laurillard, 2007). An additional type of adaptation that can be carried out in context-aware educational scenarios design and delivery is supporting the learner by giving her/him personalized hints, supportive or assistive resources, tools or services, and/or feedback when a problem or an activity is faced or performed respectively.

Commonly, in this type the learner can be provided with two kind of support:

1) Guides about the next step to take in order to get the right solution of a problem, and/or
2) Assistance at the right time with suggestions of appropriate learning resources, tools, services, etc. in order to help her/him on his process of knowledge construction.

Mobile technologies have a very special role in achieving a closer relationship between a physical location, the information it may offers and the meaning-making that is enabled by the availability of supporting resources.

This type of adaptation may depend on different criteria derived from learner's contextual elements, including: learner's location (Ogata, Akamatsu & Yano, 2005; Paredes et al., 2005) and its physical conditions (Chistopoulou, 2008), learner's personal temporal information (Economides, 2009) and learner's previous knowledge (Al-Mekhlafi, Hu & Zheng 2009) among other criteria.

Interactive learners' communication

Mobile technologies can be used as a way to facilitate interaction between learners when performing activities that involve sharing knowledge construction (Yang, 2006). Socio-cultural perspective of learning views that learning takes place in a social context, and the forming of concepts need not necessarily take place only at the level of the individual, but that collaborative group work and sharing with peers (and others) can be a powerful way of confronting one's own conceptions (pre-conceptions) (Taylor & Sharples, 2006).

Context-aware and adaptive educational scenarios design and delivery should also focus on the use of mobile technologies to promote, facilitate and enhance interactions and collaborations between students. Mobile devices can easily communicate with other devices of the same or similar type, enabling learners to share data, files and messages, as well as they can be connected to a shared data network, further enhancing possibilities for communication (Kukulska-Hulme, 2008).

Thus, an m-learning environment can make a significant contribution to this process. By facilitating the rapid access to other users any time/any place, sharing content, knowledge, experience, learners can develop 'communities of practice' (Lave & Wenger,

1991) as well as informal discussion groups, as and when needed to optimize their learning processes (Kukulska-Hulme, et al., 2009).

Consistently, m-learning systems also may supply activities considering the fact that mobile devices suited to support social context and collaborative learning which have relevance for learning (Malek et al., 2008).

This type is characterized by ad hoc creation of groups of users and/or facilitated by people contributions (Luckin, 2010) as collaborative support for carrying out specific learning activities. Thus, this adaptation facilitates learners during the execution of learning activities in:

- Finding peers based on their location with whom they can meet virtually, build learning groups and share knowledge or experts with whom they can communicate for asking advice or help for specific issues (Martín et al., 2006)
- Selecting appropriate communication and collaboration tools based on peers' individual information, availability, as well as learners' location and preferences and needs (Economides, 2008b).

3.4.2 Overview of context-aware and adaptive mobile delivery systems

There a lot of activities that may benefit from multiple multimedia and mobile tools and services that can be designed, edited, produced and delivered to the learners in a m-learning scenario (Kukulska-Hulme & Shield, 2008). Nevertheless, systems for processing contextual information and delivering context-aware adaptive educational scenarios via mobile devices are needed.

A context-aware system can extract, interpret and use contextual information and adapt its behavior and functionalities to the current context of use (Byun & Cheverst, 2004). In previous subsection, we discussed the concepts of adaptation types for context-aware educational scenarios delivery, namely *learning flow navigation and sequencing*, *problem solving support and feedback (scaffolding)*, and *Interactive learners' communication*, which can be considered as the output of context-aware m-learning systems. Here, the author of this thesis provides an overview of existing context-aware m-learning systems based on the output that they provide to the learners following the classification of adaptation types discussed in previous section. Later, in chapter 6 (section 6.1), a comparison between these systems and the mobile delivery system developed in this research work is presented based on the adaptation types they implement and the contextual information they process.

Learning flow navigation and sequencing

A context-aware m-learning system has been proposed by Hwang et al. (2008), which automatically construct a navigation path to perform certain learning activities in a university campus based on learner's location. Other context-aware m-learning system is CMMCUL (Hwang et al., 2011), which with the help of the RFID technology, is able to detect the location of the students and guide them with a procedural learning tasks flow and related learning materials so as they can find target objects of study during the learning process. Tan et al. (2009) describe a context-aware m-learning system that automatically constructs a navigation path to perform certain learning activities in a university campus according to learners' previous knowledge and learner's location. Two similar systems are the one presented by Chiou et al. which aims to support navigation of learning activities in a museum by proposing two navigation algorithms (Chiou et al., 2010), and the PNSS system (Chiou et al., 2012), which aims to support a personalized navigation strategy for learning activities so as to guide learners in context-aware ubiquitous learning environments. Moreover, Hwang et al. (2010) presents a mobile system for determining personalized context-aware ubiquitous learning paths to maximize the learning efficacy for individual learners. Hwang et al. (2009) and other researchers present a similar context-aware m-learning system that automatically navigates learners to conduct learning activities within a laboratory and by exploiting learners' previous knowledge and learner's location. One more system is presented in (Wang & Wu, 2011) which aims to help learners realize personalized learning goals based on providing context-aware recommendations. Recommendations module in that system can provide adaptive courseware in real-time based on the learner's location, learner's learning behavior and personal preferences.

Problem solving support and feedback (scaffolding)

Cui & Bull in (Cui & Bull, 2005) introduces TenseITS, a language learning environment that adapts the interaction to the individual learner's understanding, current location, and available time to learn, as represented in a learner model constructed during the interaction. It adapts by rearranging the support possibilities of different educational materials. TANGO (Ogata et al., 2005), is a context-aware m-learning system that aims to support English language learning and provides adaptive feedback and support based on learners' location. Another similar context-aware m-learning system is LOCH (Paredes et al., 2005) that aims to support Japanese language learning and provides adaptive feedback and support to the learners based on their location. Nguyen, Pham & Ho presents CAMLES, a context–aware m-learning system for supporting student to learn English as foreign language in order to prepare for TOEFL test by suggesting topics that learner need to learn based on their test results. It provides adaptive content for different learners based on context, including location, time, and learner's knowledge (Nguyen, Pham & Ho, 2010). In (Wu et al., 2012) a context-aware m-learning system is developed for nursing training courses. The major benefit of that system is to provide personalized scaffolding and support for students to observe and experience real-world situations so as to construct personal knowledge. CAMCLL (Al-Mekhlafi et al., 2009) is a context-aware m-learning system that aims to support Chinese language and provides adaptive feedback and support to the learners based on learner's location and learner's previous knowledge. Other similar context-aware m-learning systems are the HELLO (Liu, 2009), which aims to support English language learning based on learner's location and learner's previous knowledge and JAPELAS2 (Yin et al., 2010), which aims to support Japanese language politeness learning based on learner's location and learner's previous knowledge. In a system presented in the MOBIlearn project (Lonsdale et al., 2004) location is detected for generating recommendations of both relevant learning resources and peers who are nearby in a museum depending on learners' current situation, preferences and learning history. One more system is presented by Petersen, Markiewicz & Bjørnebekk (2009) named PALLAS, which enables real life language learning scenarios by providing personalized and contextualized access to learning resources via a mobile device. Moreover, CAERUS (Naismith, Sharples & Ting, 2005) is other context-aware adaptive system, specifically a handheld guide for visitors of the University of Birmingham Botanic Gardens, which aims to deliver location-specific information, tailored to the user's interests, through the presentation of themed multimedia. Another system is presented by Yau and Joy in (Yau & Joy, 2011) who propose a context-aware personalized m-learning application based on m-learning preferences so as to deliver appropriate learning objects retrieved from a learning object repository based on retrieved contextual information. SCROLL (Li et al., 2012) is other system, which aims to recommend learning objects for a specified learner taking into account both the context and her/his study needs based on monitoring learners' current context (including their activities involving whether they are running, walking, listening to the music or surfing on the Internet and so on), and the environmental information (including the location, time, temperature, and humidity and so on). Finally, PCULS is a system that enables adaptation of learning content to effectively support English vocabulary learning in a school environment based on learner location, learning time, individual English vocabulary abilities and leisure time (Chen & Li, 2010).

Interactive learners' communication

Martín et al. propose a system that can deliver activities on the learner mobile device and help learners on finding peers based on their location with whom they can meet virtually, build learning groups and share knowledge or experts with whom they can communicate for asking advice or help for specific issues (Martín et al., 2006). Other similar systems are the PERKAM (El-Bishouty, Ogata & Yano, 2007), which allows the learners to interact and collaborate with recommended peer helpers while doing learning tasks in accordance with detected current location and detected objects in the environment, and the Social KAM (El-Bishouty et al, 2010), which aims to support learners doing learning activities by providing a social map of peer helpers that are dynamically recommended in context. Another context-aware m-learning system has been proposed by Martin et al., (2008), which give information about people who are close to the learner by exploiting learner's location during the execution of learning activities in a university campus. One more context-aware m-learning system has been proposed by Economides (2008), which automatically selects appropriate communication and collaboration tools by exploiting learners' preferences and needs.

In Table 3-2, a summary of the identified context-aware m-learning systems, with regards to the types of adaptation they address is presented. Later in chapter 6, a comparison between identified systems and a proposed system in this work is presented, so as to explain how the system it is complemented to provide educational scenarios delivery and is able to provide adaptations with regards to each type of adaptation.

Table 3-1 Overview of existing context-aware m-learning systems

Adaptation Type	Context-Aware and Adaptive M-learning Systems
Learning flow navigation and sequencing	Hwang et al., 2008
	CMMCUL (Hwang et al., 2011)
	Tan et al., 2009
	Chiou et al., 2010
	PNSS (Chiou et al., 2012)
	Hwang et al., 2010
	Hwang et al., 2009
	Wang & Wu, 2011

Problem solving support and feedback (scaffolding)	TenseITS (Cui & Bull, 2005)
	TANGO (Ogata et al., 2005)
	LOCH (Paredes et al., 2005)
	CAMLES (Nguyen, Pham & Ho, 2010)
	Wu et al., 2012
	CAMCLL (Al-Mekhlafi et al., 2009)
	HELLO (Liu, 2009)
	JAPELAS2 (Yin et al., 2010)
	MOBIlearn (Lonsdale et al., 2004)
	PALLAS (Petersen, Markiewicz & Bjørnebekk, 2009)
	CAERUS (Naismith, Sharples & Ting, 2005)
	Yau & Joy, 2011
	SCROLL (Li et al., 2012)
	PCULS (Chen & Li, 2010)
Interactive learners' communication	Martin et al., 2006
	PERKAM (El-Bishouty, Ogata & Yano, 2007)
	Social KAM (El-Bishouty et al, 2010)
	Martin et al., 2008
	Economides, 2008

3.5 Summary and discussion

An important factor for achieving meaningful learning experiences with m-learning is the capability of capturing and processing learner's contextual information so as to provide adaptations of the learning process to learners. This is an emerging issue since major computer-based learning activities and digital educational resources are mainly designed assuming access and delivery through desktop computers and, moreover, contextual information can facilitate the development of content and educational scenarios adaptation mechanisms for delivery of educational elements to learners' mobile devices.

This chapter goes into aspects of adaptivity for m-learning environments by explaining first, some main issues to take into account to achieve an adaptive m-learning design and delivery. Then, two scopes for adaptation are presented, namely *educational content adaptation* and *context-aware educational scenarios adaptation*. In each scope, some mechanisms and methods of adaptation are described.

More precisely in this chapter, it was discussed the issue of mobile educational content adaptation for m-learning and it was presented identified research works which proposes content adaptation solutions. Moreover, it was discussed the issue of context-aware educational scenarios adaptation for m-learning and it was presented identified context-aware adaptive educational scenarios delivery systems which proposes adaptation solutions with regards to three identified types of adaptation, namely, *learning flow navigation and sequencing*, *problem solving support and feedback (scaffolding)* and *interactive users' communication*.

Nevertheless, there is an existing challenge and need to construct context-aware adaptive mobile delivery systems that integrates these adaptation types so as to provide a *General Adaptation* of context-aware educational scenarios. Aiming to generate automatic individual learning activities and materials based on different criteria derived from learners' contextual information. A *General Adaptation* combines the three types of context-aware educational scenarios adaptation (Martin & Carro, 2009). This issue will be addressed in chapter 6.

In chapter 4, an overview of the proposal design for this research work is presented. The proposal is based on the development of two adaptations engines that can be implemented for the design and the delivery approaches. These engines are based on designed adaptation mechanisms from both scopes presented in this chapter.

CHAPTER 4

PROPOSAL FOR DESIGNING AND DELIVERING CONTEXT-AWARE ADAPTIVE M-LEARNING

This chapter focuses on the explanation of the proposal and the defined approaches for implementation during the research work. The definition of the proposal emphasizes the implementation by focusing on two approaches that involve implementation of the learning design process, namely: the *design approach* and the *delivery approach*. Aditionally, it describes in general terms the implementation process followed in each approach, by applying the concepts presented in previous chapters and providing solutions that overcomes the limitations in existing alternatives. Moreover, the parts of the proposal are described with details so as to address how the defined objectives are achieved.

4.1 General scope

The author of this thesis addressed the objectives proposed for this research work, by developing specific proposals for each objective, which are described below. Figure 4-1 shows a brief illustration of the relationship of the proposals made for each objective, so as to depict the whole picture.

- ***O1:*** *Defining a* ***context model*** *for identifying and describing the information that can be used to characterize the situation of a particular entity (i.e. anything relevant) participating in the interaction between an individual learner and a mobile system.*

  Proposal: With a defined *context model*, the author of this thesis also aims to present a ***Taxonomy*** of contextual elements and a set of exemplary instances (pre-defined data or values) for those elements, which are proposed for designing context-aware educational scenarios and for being processed by a mobile delivery system so as to provide learners with adapted learning activities and educational materials. Thus, these elements can be used by authors (e.g. instructors, teachers, tutors, etc.) as part of the learning design process. Moreover, these elements characterize the information of the *context model* which, represented within the structure of a learning design, can be processed by an adaptation engine.

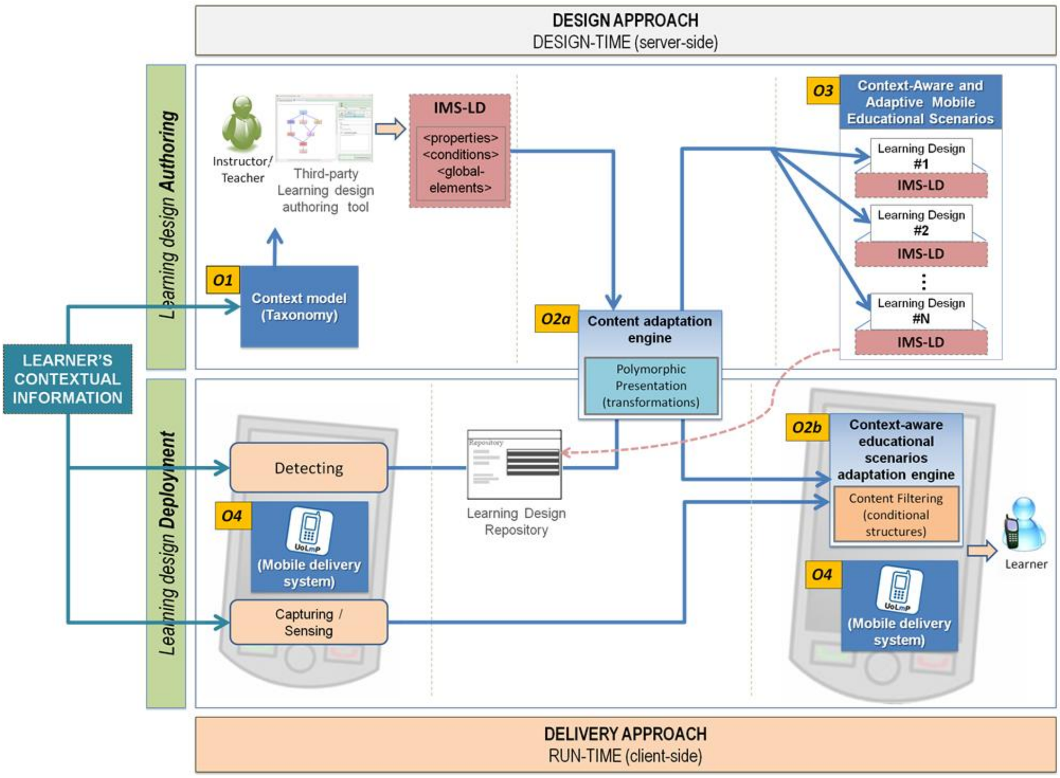


Figure 4—1 Model of general research proposals

- ***O2:*** *Implementing* ***context-aware and mobile adaptation processes*** *for both design and delivery approaches of the learning design.*

The key component of an adaptation process in a context-aware educational adaptive system is the adaptation engine (Su et. al. 2011; Fudzee & Abawajy, 2008). The adaptation engine acquires input data and produces the adaptation results. Input data into such an adaptation engine is the learner's context. Output results of the adaptation engine are adapted educational elements (content, activities, resources, tools, services, etc.) (Economides, 2009).

Proposal: In terms of designing and delivering context-aware educational scenarios with adapted educational elements, the author of this thesis considers two adaptation engines, that is:

O2a) a ***content adaptation engine*** which should incorporate an adaptation mechanism for educational digital content (namely *polymorphic presentation*), and

O2b) a ***context-aware educational scenarios adaptation engine*** which should incorporate an adaptation mechanism for context-aware educational scenarios (namely, *content filtering*).

There are several approaches in the field of context-aware mobile adaptation for implementing adaptation engines, which include:

- *Adaptation rules,* that is, when the resultant types of mobile content adaptation are derived from conditional structures of IF /THEN/ ELSE statements, which are based on the instances of learner's contextual characteristics (Arai & Tolle, 2011; Al-Hmouz & Freeman, 2010; Bhaskar & Govindarajulu, 2009).

- *Adaptation algorithms,* that is, when the resultant types of mobile content adaptation are derived from different types of algorithms such as heuristic algorithms, similarity algorithms, decision–based algorithms, etc., which are processing the instances of a learner's context model (Su et. al. 2011, Madjarov & Boucelma, 2010; Zhao et al., 2010).

Nevertheless, existing approaches follow hard-wired implementations of their adaptation engines, which are based on pre-defined instances of a learner's contextual model. As a result, adaptation engines cannot be extended with new instances of learners' contextual information towards providing more accurate educational material adaptations to the learner's mobile devices. Furthermore, hard-wired implementations of adaptation engines limit their potential to be inter-exchanged and transferred to other adaptive learning systems and they keep them embedded (local) to the particular system in hand. Finally, these approaches consider dynamic adaptations, which adapts the educational content in real-time during the learner's request and in some cases (especially during adaptive content adaptation) this introduces significant delays to the delivery of adapted educational scenarios to learner's mobile device (Zervas et al., 2012).

A possible solution to these problems could be the formal description of the adaptation engines by using a notation language that is independent of the particular implementation of the mobile content adaptation mechanism in hand. This will enhance the flexibility of these engines in terms of extensions and inter-exchange with other systems and applications. A possible implementation for this solution could be the adoption of ***IMS-LD*** Specification, mainly due to this specification has been proposed as a possible notation language for describing learning designs, as well as being populated with educational content, accompanying educational content-based adaptations and following a machine readable format (Martínez-Ortiz, Sierra & Fernández-Manjón, 2009; Specht & Burgos, 2007).

Thereby, on the one hand, the adaptation mechanism *polymorphic presentation* is achieved by *transformations* (see Figure 4-1) in the packaging process of a Learning Design. More precisely, the ***content adaptation engine*** is based on a transcoding process to customize the file format or the properties of the educational resources, which are populating the learning activities of a Learning Design, according to different parameters related to the capabilities of specific mobile device profiles (adapting the content). On the other hand, the adaptation mechanism *content filtering* consists in making selections in run-time by using IMS-LD level B *conditional structures* to evaluate learner's mobile contextual dimensions. Thus, the results of the ***context-aware educational scenarios adaptation engine*** is adaptations to the learning flow (showing or hiding educational activities) and adaptations to the available learning materials such as resources, tools and services (filtering the information).

- ***O3:*** *Designing exemplary* ***context-aware and adaptive mobile educational scenarios*** *so as to explain and present how possible adaptations, that are realized based on learner's contextual information, can be incorporated.*

Proposal: Covering this objective implies to adopt a possible method for designing and delivering adaptive educational scenarios, as well as considering that this method follows a machine readable format so it can be processed through a mobile system. As first approach, the IMS-LD Specification can be adopted as a possible method for this proposal, so as to consider the particularities of the context-aware adaptation mechanisms.

Moreover, attempting to design these scenarios, the author of this thesis clearly should focus on considering traditional pedagogical models which have relevancy on a constructive (individual and social) and situated perspective of how learning process can be taken and be described for contextual and m-learning as has been recognized by other research works (Ally, 2005; Sharples, Taylor & Vavoula, 2010; Patten, Arnedillo Sanchez & Tangney, 2006; Herrington, 2009; Taylor & Sharples, 2006).

- ***O4: Delivering*** *pedagogical-enhanced and structured adaptive and context-aware educational scenarios via mobile devices.*

  Proposal: Developing a ***mobile delivery system*** aiming to address delivering pedagogical-enhanced and structured adaptive and context-aware educational scenarios via mobile devices. Thereafter, through the development of this mobile system, *contextual instances can be retrieved (i.e. detected, captured, sensed)* and processed so as to adaptively deliver educational activities, learning resources, mobile tools and communication services (considered within the structure of a learning design) to the learners' device at hand. Moreover, achieving this objective involves a research challenge that includes taking into account other aspects not yet considered in context-aware m-learning systems development such as parsing defined learning paths designed by the teacher (based on a notation language) and processing different instances for contextual elements (which normally are changing variables with different values) accordingly to a designer's plan and learner's situation.

To sum up, with the proposals illustrated in Figure 4-1 the author of this thesis is attempting to define a model for contextual information which can be processed by an adaptation engine. Moreover, in the proposals *polymorphic presentation* and *content filtering* are considered as key mechanisms for both *educational content adaptation* and *context-aware educational scenarios adaptation* respectively. Consistently, these mechanisms are part of two adaptation engines. Besides, it is described how implementation of the learning design process through the IMS-LD specification can be considered so as to represent context-aware and adaptive educational scenarios that can be delivered to mobile devices. In order to explain how this specification is used and how learner's contextual information can be incorporated for processing possible adaptations, exemplary context-aware educational scenarios were designed and proposed. Attempting to design these scenarios, the author of this thesis clearly focused on considering traditional pedagogical models which have relevancy on a constructivist (individual and social) and situated perspective of how learning process can be taken and be described for contextual and m-learning. Finally, a mobile delivery system aims to address delivering pedagogical-enhanced and structured adaptive and context-aware educational scenarios via mobile devices.

Regarding the levels in which the adaptation can be implemented and performed (i.e. *client-side*, *server-side* and *proxy-based*, see section 3.3.2 for further description of these levels), the adaptations were defined to be performed through a combination between the *server-side* and *client-side* levels (see Figure 4-1). Although in the *client-side* level the client platform has the entire device's capabilities description (Lei & Georganas, 2001), performing a transcoding process is limited due to the lack of computing power and bandwidth. On the other hand, the *server-side* level overcomes the limitations of the client-side level. A server can compute clients' content delivery requests and optimize and adapt the content according to the technical capabilities of the device (Xinyou, Xin & Toshio, 2010).

- On the ***server-side***, a learning design authoring tool and/or learning designs repository with context-aware adaptation capabilities (Gómez & Fabregat, 2012) can be installed and executed. Moreover, a server can receive requests and the capabilities of a mobile device and responds with adapted resource delivery. Server-side level presents two advantages: (i) Educational content properties, device capabilities, IMS-LD files, information about context, adaptation rules, and other data can be stored in repositories located on the server, as well as a transcoding server and multimedia resources can be deployed and stored there too. (ii) Transcoding processes (request reception, transformation and response delivery) and user interaction with the server can be performed simultaneously.
- On the ***client-side***, an IMS-LD-oriented mobile system can be installed on the mobile device which let deploying context-aware adaptive educational scenarios on it and executing learning activities and context-aware adaptation rules without internet connection (Gómez & Fabregat, 2012). This is important because mobile devices are not constantly connected to the internet and the learner should be able to retrieve contextual information by using her/his mobile device and run adapted learning activities.

Next, in this chapter the author of this thesis describes in general terms the adaptation process for both design and delivery approaches and presents a set of design requirements that attempts to facilitate producing tools for context-aware adaptive m-learning design and delivery. In this research work, these requirements were followed to produce three tools that are components of the proposals presented in Figure 4-1, namely:

i) a ***content adaptation engine*** that can be incorporated in learning design authoring systems and/or learning design repositories,

ii) a ***context-aware educational scenarios adaptation engine*** that can be incorporated in a context-aware mobile delivery system, and

iii) a ***context-aware mobile delivery system, namely UoLmP***, with the context-aware educational scenarios adaptation engine incorporated for delivering IMS-LD-oriented context-aware adaptive educational scenarios.

4.2 Adaptation process and requirements for the design approach

In the design approach, 3 main phases to achieve context-aware adaptations in the learning design process were defined (Gómez & Fabregat, 2010). These phases are illustrated in Figure 4-2 and they are briefly described below. Details of the development of these phases are presented and discussed in chapter 5:

1) ***Learning Design Construction*** *(phase 1) – related to* ***O1***: During this phase, a Learning Design (i.e. an educational scenario) can be authored including adaptations rules based on a learner's context model that include conditional structures to evaluate data (captured in run-time) related to contextual elements: learner's temporal information, people, place, time and physical conditions. *Considering that IMS-LD can be used* for describing in a machine readable format content adaptation rules (based on different instances of a learner's context model), which can produce different types of adaptation during the mobile delivery process, here, the author of this thesis proposed the adoption of IMS-LD Level B elements (*properties, conditions* and *global elements*) for modeling in a machine readable format the adaptation rules for the adaptation engines.
2) ***Content Transformation*** *(phase 2) – related to* ***O2***: During this phase, educational resources that have been used in the previous phase for populating the developed Learning Design are transcoded within a *content adaptation engine* that uses a transcoding mechanism and according to different parameters (capabilities) of different generic types of mobile devices. The content adaptation engine is based on the *polymorphic presentation* mechanism, specifically a transcoding process, which consists of a set of steps to transcode the properties (format, type, size dimensions, quality, etc.) of used educational resources by considering the technical capabilities of a mobile device (i.e. browser, display, media support, etc.).
3) ***Adapted Learning Designs Creation*** *(phase 3) – related to* ***O3***: During the final phase, a number of different adapted context-aware Learning Designs are created (one per each generic type of mobile device) populated with context-aware adaptation rules and transcoded versions of educational resources suitable for each specific generic type of mobile device.

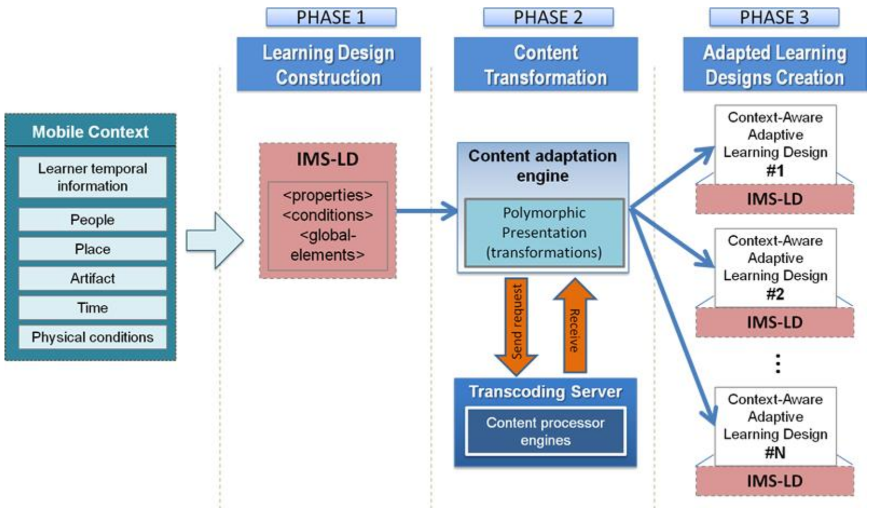


Figure 4—2 Adaptation approach for designing

Moreover, in this section we present design requirements for an IMS-LD-compliance authoring tool and an adaptation engine that can be integrated in this tool and/or in a

Learning Design repository in order to facilitate authoring and packaging of Learning Designs that incorporate context-aware adaptation features (Zervas et al., 2011).

A set of design requirements for an Authoring Tool (AT) that can integrate an adaptation engine for context-aware learning designs (compatible with the IMS-LD specification) so as to incorporate content adaptation rules for educational *content filtering* and *polymorphic presentation* could be summarized as follows:

- ***AT-Requirement 1***: The author should be able to define appropriate content adaptation rules according to the different values of a learner's context model for the entire Learning Design. These rules should be inherited by all the learning activities, which constitute the Learning Design. This functionality aims to reduce the effort for defining content adaptation rules, as well as to provide a consistent way to define content adaptation rules for all learning activities that constitute the Learning Design.
- ***AT-Requirement 2***: The author should be able to define content adaptation rules for each individual learning activity that a Learning Design incorporates. This is necessary, since the educational resources of an individual learning activity may need to be adapted based on different adaptation rules from those defined for the entire Learning Design, when specific learner's mobile contextual conditions are detected. This functionality aims to enhance flexibility for defining adaptation rules.
- ***AT-Requirement 3***: The author should be able to create profiles of content adaptation rules (for certain values of learner's context model), which can be used during the authoring process of a new Learning Design. This requirement enables end-users to reuse profiles of content adaptation rules among different Learning Designs.
- ***AT-Requirement 4***: The tool should have the capability to automatically transform the content adaptation rules inserted by the author to IMS-LD properties and conditions and save this information to the produced IMS-LD XML manifest, which is exported by the tool. This requirement is important because it makes this process accessible to non-XML experienced users.
- ***AT-Requirement 5***: The author should be able to graphically design Learning Designs based on the interconnection of user defined learning activities. This requirement makes the Learning Design process efficient and user-friendly.
- ***AT-Requirement 6***: The tool should provide the capability to directly assign educational resources to the learning activities of the Learning Design. This should be facilitated by providing access to Learning Object Repositories (LORs) with recommendations facilities about the appropriate available educational resources for the given learning activities, based on metadata descriptions. Nevertheless, this requires access to enhanced LORs that store metadata descriptions, which capture the context of educational resources' intended use. This requirement is essential for reducing costs and efforts in selecting educational resources.

4.3 Adaptation process and requirements for the delivery approach

An important issue for designing appropriate mobile and context-aware delivery systems for learning is the exploitation of learner's mobile contextual information to provide what the learners need in different situations (i.e. relevant information or enabled tools and services to assist and support the learning process). (Madjarov & Boucelma, 2010; Bhaskar, & Govindarajulu, 2009).

An educational adaptive system is any educational system that can process some learner's characteristics represented in a model for adapting some visible aspects of the system to the learner (Brusilovsky, 1996).

In order to achieve adaptivity for context-aware educational scenarios in m-learning environments these systems should consider that a model of the learner's situation or context can be incorporated. Thus, this process involves identifying what aspects or variables of a learner's context must be taken into account for defining the model; it also involves establishing how these aspects can be represented in a data set, as well as setting the data retrieval and model update mechanisms and finally proposing an adaptation engine to implement the whole process.

In the delivery approach, also 3 main phases to achieve context-aware adaptations in the delivery of the learning design process were defined (Gómez & Fabregat, 2010). These phases are illustrated in Figure 4-3 and they are briefly described below. Details of the development of these phases are presented and discussed in chapter 6:

1) ***Retrieval*** *(phase 1) – related to* ***O4***: During this phase, learner's mobile context dimensions, namely *learner's temporal information, people, place, artifact, time* and *physical conditions* are detected/sensed by the learner's mobile device or they can be entered by the learner herself/himself.
2) ***Mobile Content Adaptation Execution*** *(phase 2) – related to* ***O2***: In this phase, the results of *Content Transformation* performed for an educational scenario are presented to the learner's mobile device. Thus, based on the detected mobile device capabilities, it is evaluated whether learner's mobile device is capable of delivering context-aware educational scenarios created during design-time. If this is the case then an adapted context-aware Learning Design created during design-time can be downloaded to learner's mobile device. Otherwise, a similar transcoding process as in design-time should be executed, so as to transcode the educational resources for populating the selected Learning Design.
3) ***Adapted Educational Scenarios Delivery*** *(phase 3) – related to* ***O4***: In this phase, content-filtering-based adaptation rules of the current Learning Design are executed based on current detected learner's contextual information related to learner's temporal information, supporting people, place, time and physical conditions. Output of this phase is the delivery of adapted learning activities, educational resources, mobile tools and communicative services.

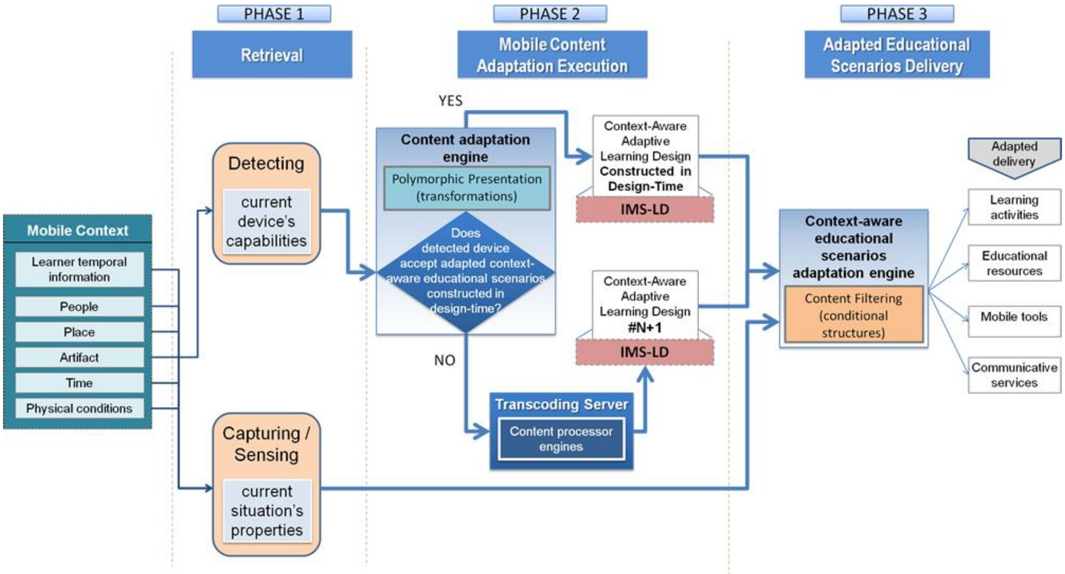


Figure 4—3 Adaptation approach for delivering

Moreover, in this section we present a set of design requirements for an IMS-LD-compliance Delivery System (DS) that incorporate an adaptation engine to facilitate context-aware adaptive educational scenarios delivery (Zervas et al., 2011). The design requirements could be summarized as follows:

- ***DS-Requirement 1***: The tool should be able to automatically detect learner's mobile context dimensions, namely, learner's temporal information, place, device, time and physical conditions according to the learner's situation and it should be able also to allow learner insert contextual information that it is not possible to be detected automatically. This is an essential requirement so that the learner's current situation can be fully detected and recorded by the tool.
- ***DS-Requirement 2***: The tool should be able to import context-aware learning designs compatible with IMS-LD and this process should be facilitated by providing the learner access to Learning Design Repositories (Paquette et. al, 2006; Sampson, Zervas & Sotiriou, 2011), where the learner can search and find appropriate Learning Designs according to his/her needs and preferences. This requirement makes the process of selecting Learning Designs more flexible for the end-users of the tool.
- ***DS-Requirement 3***: The tool should be able to handle the adaptation rules of the delivered context-aware Learning Design and match them with the values of learner's mobile context dimensions automatically detected or provided by the learner, so as to deliver adapted educational resources according to the learner's available mobile device. This is an important requirement for providing the learners with valid adapted mobile educational content.
- ***DS-Requirement 4***: The tool should be client-side, so it can be installed on the mobile device and no internet connection should be required during the execution of learning activities. Internet connection should be required only during real-time content transformation process, when the tool should communicate with the transcoding server. This requirement is important because mobile devices are not

constantly connected to the internet and the learner should be able to execute the learning activities even if he/she is not connected to the internet.

- ***DS-Requirement 5***: The learner should be able to view the graphical structure of the learning activities that a Learning Design incorporates and navigate to these learning activities. This requirement makes navigation to learning activities more usable for end-users.

4.4 Summary and discussion

An overarching challenge in the design of appropriate context-aware educational scenarios adaptation mechanisms is to determine when explicitly to model context and when to provide generic ‘awareness’ tools or services that learners, individually and together, can employ (Sharples, 2011)

An important factor for achieving meaningful learning experiences with m-learning is the capability of capturing and processing learner’s contextual information (defined in a context model) so as to provide adaptations of the learning process to learners. This is an emerging issue since major computer-based learning activities and digital educational resources are mainly designed assuming access and delivery through desktop computers and, moreover, contextual information can facilitate the development of content and educational scenarios adaptation mechanisms that can be incorporated in the design process of educational scenarios and the delivery of educational elements to learners’ mobile devices.

In this chapter, an overview of the proposal for this research work is presented. The proposal is based on the implementation of context-aware adaptation mechanisms for the design and the delivery approaches of the learning design. Thus, two context-aware adaptations engines were proposed, one for the design and one for the delivery approach. The adaptation engine for the design approach is able to process context-aware educational content adaptations in design-time and the adaptation engine for the delivery approach is able to process and deliver context-aware educational scenarios adaptations in run-time. Moreover, it was argued that the formal description with a notation language of the adaptation engines could be a possible solution for overcoming identified limitations of existing adaptations engines. The implementation of the proposed solution can be achieved by adopting the IMS LD specification, so as to model in a machine readable format the context-aware educational scenarios and the adaptation rules to provide adapted elements.

Finally, we present design requirements for a set of tools that enable context-aware adaptations in the design and the deliver approaches of the learning design process. As first approach of the development of the proposals, some requirements for context-aware design tools are addressed in chapter 5 and requirements for context-aware mobile delivery tools are addressed in chapter 6.

The research work presented within the next chapters (5, 6 and 7) of this dissertation describes the development of the objectives and proposals presented in this chapter. Chapter 5 presents specific details of the proposal implementation for design-time (design approach), chapter 6 presents details of the proposal implementation for run-time (delivery approach) and chapter 7 presents the evaluation of the developed solutions.

CHAPTER 5

DESIGNING CONTEXT-AWARE AND ADAPTIVE EDUCATIONAL SCENARIOS FOR M-LEARNING (DESIGN-TIME)

This chapter emphasizes on the implementation in the *design approach* of the learning design process. This implementation is presented as follows: i) a context model is described, ii) an adaptation process to achieve authoring context-aware and adaptive educational scenarios is explained phase by phase, and iii) some testing made of the implementation is described.

In general terms, it is presented how contextual information in the structure of a notation language for designing the learning process can be modeled and described. An architecture that allows us to retrieve and process contextual information considering context-aware adaptive mechanisms and deliver adapted educational activities and educational content to the learner mobile device is presented. Implementation of the architecture was made for design-time using a content transcoding mechanism and defining some conditional statements in the structure of the IMS-LD standard taking into account contextual information related to the elements of the presented context-model.

5.1 Context model

Recent TeL research have been considering the benefits of the inclusion of contextual information while learners are following learning paths and constructing knowledge in situations in which they can take control of their personal learning progress (Gómez & Fabregat, 2010; Mavroudi, Hadzilacos & Kalles, 2010).

The context has different approaches and uses according to TeL purposes (Najjar et al., 2010). As an example, the approach of (Edmundson, 2007) is mainly related to the cultural view, but depending on the definition of culture, also includes further aspects. Different to this approach, in (Lonsdale, Baber & Sharples, 2004) the work for the MOBIlearn project has developed an interactional model of context for m-learning. Authors in (Guetl, Garcia-Barrios & Moedritscher, 2004) focus on the user needs as the key context aspects, whereas the approach of (Brusilovky & Millán, 2007) is related to Adaptive Hypermedia Systems. According to a specific approach of use, also context involve data influence factors which affect the learning process and, in particular, adaptation and personalization (i.e. contextual information should be characterized according to the approach and use purposes).

In particular, in the research work presented in this dissertation, contextual information can be integrated to propose adaptive educational scenarios for m-learning, so that, we are focused on the learning design process as the basis to model the learner's contextual information and proposing to integrate and represent context-related data in that process to support personalized learning at anytime and anywhere.

These concepts are basic to the work presented in this section since its goal is centered in a context model to facilitate adaptation in learning design and delivery systems.

5.1.1 Overview of contextual characteristics

At present, there are not a defined standard that describes the characteristics that represents the learner's context for m-learning environments which can be applied to the implementation of adaptation processes. However, mentioned modeling techniques in section 2.1.5 and work carried out based on them to take into account the context, are mechanisms that have been used to attempt to describe context aspects.

In m-learning the context may assist and support the learning process providing relevant information or enabled services that the learner may need when following a learning procedural plan in different situations. Moreover, m-learning systems and adaptation mechanisms design needs to be based on the identification of variables that involve users' common aspects related to their work environment.

According to this, context can be classified into two general categories, one related to the structure of a learning pedagogical model, considering learning paths that learners must follow so as to construct knowledge, and other related to a ubiquitous and mobile environment in which learners complete learning activities and interact with surrounding resources. Siadaty named these two categories as *learning context* and *mobile context* (Siadaty et al., 2008).

In this research work, on the one hand the *learning context* is described by the components of the learning design process. Thus, some components of this context are: learning activities in a procedural learning structure, different objectives that students have to achieve, learners' competence profiles (knowledge, skills, attitudes), participating roles, different techniques, resources and tools that teachers prepare in order to support the students' learning process, as well as learners' personal characteristics (learning style, physical or other disabilities, etc.) related to the learning process.

On the other hand, *mobile context* referred to the information that can characterize the elements participating in a learning situation and which can be captured by the delivery medium. In this category we refer to contextual information such as supporting people, technological artifacts, learner's location and its physical conditions, available spare time used for learning and individuals' preferences, needs, interests which can be input by learners, captured by hardware or measured by sensors.

Since the past years, there have been a number of attempts to propose context's characteristics, so as to describe the elements that could participate in learner's interaction with learning systems (Schmidt, 2005; Derntl & Hummel, 2005; Richter & Pawlowski, 2007; Christopoulou, 2008; Luckin, 2010; Das, Chithralekha & SivaSathya, 2010; Kurti, 2008; Nino et al., 2007; Peña et al. 2012; Economides, 2009)

For example, Schmidt highlights key challenges in context-aware learning systems construction. He discuss that context is learner-centered and identified three groups in which its features can be divided, namely: personal context (like predispositions and preferences), social context (like relationship quality, presence information), and organizational context (like role, task) (Schmidt, 2005). In (Derntl & Hummel, 2005) Derntl & Hummel introduces a UML-based modeling extension for explicitly including relationships between context aspects and learning activities. They proposed five categories for context: world context (location and time), physical context (learning resources and persons), digital context (digital learning resources), device context (hardware, software and connectivity), and learner information context (personal information). Richter & Pawlowski use a metadata approach, defining a base criteria catalogue of 160 attributes as a summary of potential context elements with the purpose of building application profiles (Richter & Pawlowski, 2007). Proper staging of context proposed in (Christopoulou, 2008) describe five parameters (User, Place, Time, Device and Physical Environment) in which characteristics of the context can be divided. Christopoulou used them to define an ontology that allows modeling the context for mobile applications building. Other perspective for context in learning with relation to the connection among learners and resources (such as people, technology, things, locations and events) is proposed by Luckin. She called this connection ecology of resources and remarks its use for creating technologies that meet learners needs (Luckin, 2010). Other proposal was made by Das, Chithralekha & SivaSathya who grouped context's characteristics in three categories: personal context (learner's personal details), abstraction context (learner's preferences, intention and learning style) and situation context (network and used device). Moreover, they present an overview of related work proposing contextual characteristics that match with their categories (Das, Chithralekha & SivaSathya, 2010). The work presented by Kurti introduces a time dependent context model based on a three pole structure that can be used to design and support context awareness in m-learning environments. The three-pole structure consists of: location/environment attributes, activity/task attributes and personal/interpersonal attributes and this placed in a certain time (Kurti, 2008). Nino et al., present a context model implemented in GlobalEdu, a software architecture that manages a large-scale pervasive environment. Their context model consists of a Social Context (people and resources related to a location) and a Physical Context (resources accessed by the learner, such as network, locations and devices). The work presented by Peña et al. proposes a context modeling process to help tutors adapt their tutorship actions based on students' profiles and performance on TeL environments. They present a meta-model representation of context which involves and links context of: a particular learning design (for adaptive e-learning); students who will carry out the learning activities; teachers/tutors/trainers who will support these learning activities; the interactivity context (hardware, software, connectivity, institutional policies, learning rules, etc.) as means to allow, motivate and ensure the whole life-cycle of learning (Peña et al. 2012). Finally, a broader context model is presented in (Economides, 2009). Economides presents a general framework for adaptive context-aware pervasive and ubiquitous learning in which he defines the context to consist of the Learner state, the Educational Activity state, the Infrastructure state and the Environment state. Each state has described some dimensions and variables. He highlighted that the framework may help learning designers and developers of adaptive learning systems at their decisions (Economides, 2009).

In Table 5-1 an overview of context-modeling related research works and our proposal is illustrated.

Table 5-1 Overview of context models

Context models	Learning context		Mobile context					
	Learning design	**Learner profile**	**Learner temporal information**	**People**	**Place**	**Artifact**	**Time**	**Physical conditions**
Schmidt, 2005	-	√	√	√	-	-	-	-
Derntl & Hummel, 2005;	-	√	-	√	√	√	√	-
Richter & Pawlowski, 2007	-	-	√	√	√	√	-	-
Christopoulou, 2008	-	-	√	-	√	√	√	√
Luckin, 2010	-	√	√	√	√	√	-	-
Das, Chithralekha & SivaSathya, 2010	-	√	√	-	√	√	-	-
Kurti, 2008	-	√	-	-	√	√	√	-
Nino et al., 2007	-	-	-	√	√	√	-	-
Peña et al. 2012	√	√	-	-	√	√	-	-
Economides, 2009	√	√	√	√	√	√	-	-
Our proposal (Gómez & Fabregat, 2012)	√	√	√	√	√	√	√	√

Most of those research works have focused on addressing mobile context characteristics based on grouping some characteristics from five main aspects: learner's personal information (learner), technical characteristics of the device at hand (artifact), learner's situation with regards to location and time (place and time) and surrounding people (people). However, the concept of context in m-learning environments should consider the existing relation between components of learning design (learning context) and mobile context categories, as attempted by (Peña et al. 2012; Economides, 2009), so as its descriptive features and relationships can be applied to construct enhanced adaptive systems which help to support a personalized learning process.

Hereafter, in next section this research work focused on modeling the context by means of adopting context variables and characteristics identified from related work and considering a combination between *learning design* and *mobile context* categories is presented.

5.1.2 Context model and Contextual elements taxonomy

Recalling the objectives in this research work, a context model has been defined as the first part of the proposal presented in chapter 4. We are considering a classification of the learning context characteristics in two dimensions and the mobile context characteristics in six dimensions (see Table 5-2) based on characteristics remarked by context-related research work in (Derntl & Hummel, 2005, Christopoulou, 2008; Luckin, 2010; Economides, 2009; Richter & Pawlowski 2007).

Table 5-2 Learning and Mobile context characteristics (Gómez & Fabregat, 2012)

Learning context		
Dimensions	**Characteristics**	**Description**
LEARNING DESIGN	learning objectives, pedagogical models, learning activities, participating roles, tools and resources.	In this dimension learning context is represented by pedagogical models and definition of learning activities as procedural structures, planning different objectives that learners have to achieve and considering the use of different techniques, resources and tools that teachers define in order to support the learners' learning process.
LEARNER PROFILE	competence profile (knowledge, skills, attitudes), role, semi-permanent personal characteristics (learning style, physical or other disabilities, etc.).	Possible learner's profiles which involve competence profiles (related with knowledge, skills, attitudes) and possible semi-permanent personal characteristics such as learning style, physical or other disabilities, among others.
Mobile context		
Dimensions	**Characteristics**	**Description**
LEARNER TEMPORAL INFORMATION	temporal personal information (mood, preferences, needs, interests, etc.).	Contextual information related to learner's self evaluated capacity to describe herself/himself in different situations. Information that reflects the learner's attitudes and willingness of assuming the control of the learning process. Variable and ever changing mobile learner information.
PEOPLE	role, relationship, contributions and constraints.	Information that the learner's More Able Partners (MAP) (Luckin, 2010) may bring to their interactions with the learner that are of particular relevance for the individual learning process.
PLACE	location, zones, interactive space, cultural background and learning setting.	Immediate and enclosed environment of the learner's lived body, an arena that is at once physical, historical, social and cultural. Information in terms of physical description (geospatial) and its attributes.
ARTIFACT	technological: physical properties and digital properties, and non-technological.	Technological and non-technological devices participating in the interaction between the learner and a system.
TIME	task duration, task scheduled, when action happens, availability.	Temporally situated narrative of tasks (duration or scheduled plan), learner actions and/or resources availability of the people and surrounding artifacts.
PHYSICAL CONDITIONS	illumination, noise level, weather conditions, etc.	State of the place where the learning process is taken with regards to the physical environment conditions.

Since the research work presented in this dissertation focused on the basis of designing and delivery context-aware adaptive educational scenarios to the learner's mobile device at hand, we focused on proposing a taxonomy of contextual elements (meta-model) for the characteristics of the *mobile context* in our context model (See Appendix A). This taxonomy aims to facilitate designing context-aware adaptive educational scenarios that can be processed by a mobile delivery system.

The modeling process consists initially in identifying the elements and relationships between elements (Gómez et al., 2009), which can be obtained from the dimensions and characteristics of the context proposed in Table 5-2. Subsequently detect possible instances (examples of contextual data) and tentative sources that can be used to represent them over a mobile machine readable format. The proposed *mobile context* taxonomy is the result of this act. In our work, we adopt the dimensions and elements of the *mobile context* presented in Appendix A as the key dimensions and elements for modeling learner's context towards constructing our adaptation mechanism which can be used in design authoring tools (design approach) and m-learning delivery systems (delivery approach) for personalization and adaptation.

In the design approach contextual values definition relies on author's (teachers, designers, tutors, etc.) perspective for defining contextual elements that can be considered in the learning design process. Designers and authors interpret how contextual information can be used to design a course core curriculum. Some contextual elements may have a known instance (pre-defined), and thus can be taken into account in a decision-making process. Contextual information can be considered to define and describe the learning script that the learners should follow and which elements would affect the learning flow.

In the delivery approach contextual values are detected, captured or retrieved by a delivery system/player in real-time. Here, known instances of contextual elements can be input by learners, captured by hardware or measured by sensors. Nevertheless, there are some values of contextual elements which can be previously known, but their instantiations may not be pre-defined. In this case, known as context-awareness, the instance of contextual elements will change or will be known only in run time. In run-time contextual information is related with the learner's lived situation (what is happening on the go). Contextual Information retrieval is needed in order to deliver (planned and structured, adapted or recommended) learning activities, resources, tools and services defined in the learning design process at design-time.

Thus, our context model aimed to present a taxonomy of contextual elements (meta-model) with a set of instances (pre-defined data or values) for the *mobile context* (presented in Appendix A), so as to facilitates authors to design context-aware adaptive educational scenarios that can be processed by a mobile delivery system. In section 5.3 two exemplary educational scenarios that aim to present how learner's mobile contextual information can be used for adapting its learning flow towards implementing and demonstrating these adaptations in our developed mobile delivery system (UoLmP) are presented.

Bearing in mind that the IMS-LD specification let design the learning process and its implementation can take place in two different approaches, namely design and delivery (executed in design-time and run-time respectively); in next sections of this chapter, we are considering the contextual information representation and processing in the design-time approach. Research work done on the delivery approach is presented in chapter 6. In the design approach, contextual information is considered to define conditional statements for educational materials (activities, resources, tools, services) adaptation over educational scenarios (*learning scripts)*. Moreover, it is used to achieve mobile content adaptation in order to deliver educational scenarios populated with adapted digital content. The developed content adaptation engine can be incorporated in Learning Design authoring systems to facilitate semi-automatic (i.e. a designer is supported by the decisions made by the adaptation engine) authoring of context-aware Learning Designs.

5.2 Phases of adaptation in design-time

The proposed adaptation process in the design approach consists of three different phases (see Figure 5-1), of which two phases, namely *Content transformation* and *Adapted Learning Designs creation*, describe a dynamic content adaptation (Gómez & Fabregat, 2010). Outcomes of this content adaptation process are adapted IMS Learning Designs populated with adapted content (i.e. transformed content according to mobile device capabilities) and designed with a defined set of context-aware conditional statements (adaptation rules). These conditional statements are based on processing the elements of the mobile context (learners temporal information, people, place, time and physical conditions) presented in Appendix A.

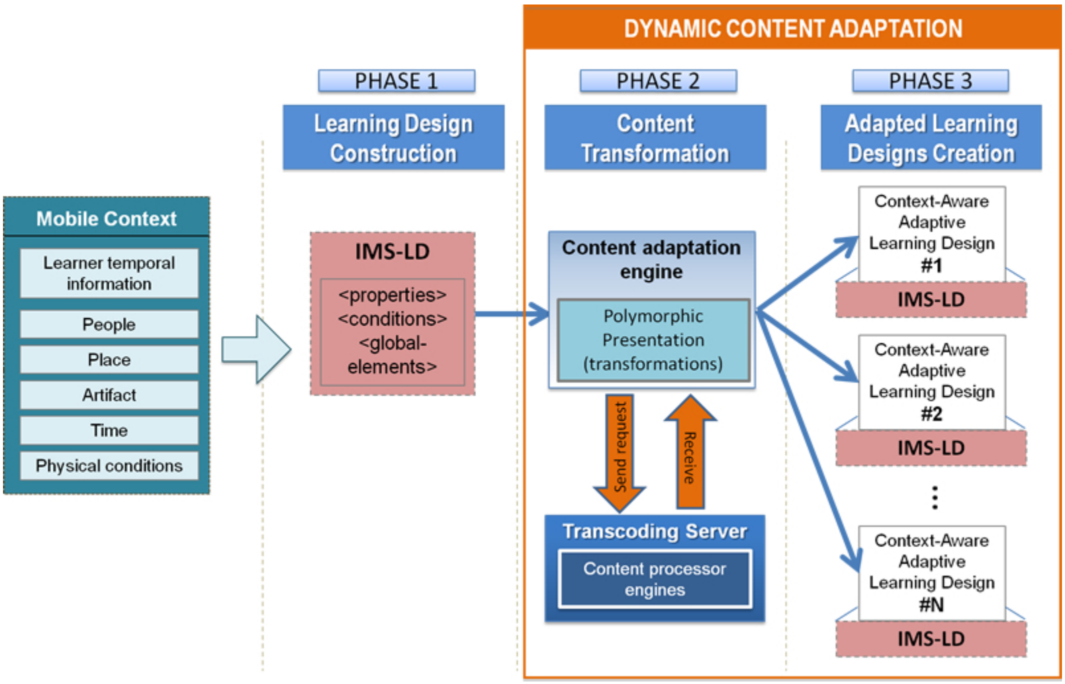


Figure 5—1 Phases of the adaptation process in design approach (Gómez & Fabregat, 2010)

These phases were introduced in chapter 4, section 4.2. Here, each phase is briefly described as follows:

1) ***Learning Design Construction***: during this phase, a Learning Design can be authored including adaptations rules based on a learner's context model. To design and implement this adaptation mechanism, the guidelines of the IMS-LD specification (IMS-LD, 2003) are considered because it defines a structure that uses different elements that let designing the learning process and let defining properties and conditions in the structure of a UoL to implement some adaptation mechanisms (Burgos, Tattersall & Koper, 2006).
2) ***Content Transformation***: during this phase, educational resources that have been used in the previous phase for populating the developed Learning Design are transcoded within a content adaptation engine that uses a transcoding mechanism and according to different parameters (capabilities) of different generic types of mobile devices.
3) ***Adapted Learning Designs Creation***: During this final phase, a number of different adapted context-aware Learning Designs are created (one per each generic type of mobile device) populated with the transcoded version of educational resources suitable for each specific generic type of mobile device.

In next sections (5.3, 5.4 and 5.5) these three phases are explained with more details.

5.3 Constructing context-aware and adaptive mobile educational scenarios

Common authors (e.g. teachers, lecturers, tutors, etc.) are not typically learning design specialists, and while they may develop expertise in conventional teaching methods, it is much harder to do so for new technology-based methods. However, there exist several ways and attempted models so as to represent some learning design components such as learning activities, participating actors, used resources, among others. An overview of several models and use cases for representing learning design were reviewed in (San Diego et al., 2008), each of which have a particular set of pedagogical benefits. In most cases, those models are based on basic requirements by local institutions or authors' preferences, including: narrative text, concept maps, lists, flowcharts, diagrams, schedules, charts, tables, pie-charts, etc. Moreover, in some cases those models and their combination are transformed into templates. Hence, there exist attempted templates so as to represent and integrate aforementioned learning design models to describe the components of a learning procedural plan, as well as the inclusion of new technologies in that process (Conole et al. 2005).

For instance, Cockburn (2001) propose a template to describe learning design as a case use narrative. He stated that a starting point for the creation of a design is doing it in narrative text. According to Cockburn for the narrative to contain sufficient detail, it should conform to a structure containing a title, a general description of the use case in educational terms, actors, scope, preconditions, among others described in his work (Cockburn, 2001). Another example is presented by Beetham (2007), who explains an approach to TeL activity design combining tables and lists. She describes a learning activity as a specific interaction of learner(s) with other people, using specific tools and resources, oriented towards specific outcomes. Her approach is based on four main design considerations for learning activities: learning outcomes, learners, digital resources and technologies, and interaction with others (Beetham, 2007,). Another quite different example is presented by Sharpe & Oliver (2007). They present a much longer template which has been designed to promote the collation of case studies nationally in UK. Moreover, they highlighted that the template serves as exercise to support curriculum design by practitioners working with digital technologies so as they can describe the broad scope of a course: why it exists, why it is special and how students and teachers will experience it (Sharpe & Oliver, 2007).

Summarizing, existing templates allow designers to describe, during the process of learning design authoring, the structured flow of learning activities populated with resources and facilitated by certain tools, where teachers and students participate assuming certain roles (Griffiths et al., 2005); nevertheless, little work has been done so as to combine m-learning characteristics with existing components in a learning design template. One effort has been made in (Sampson, Zervas & Sotiriou, 2011) for describing mobile technologies as part of m-learning pedagogical strategies in the learning design process.

In addition, existing learning design templates or educational scenarios construction guidelines have not considered describing in the learning design process what contextual information can be useful to provide what learners may need in different learning settings. Here, we are considering the template proposed in (Sampson, Zervas & Sotiriou, 2011) so as to include elements of our contextual information taxonomy (see Appendix A). Furthermore, how context-aware conditional statements can be illustrated by using a graphical flowchart is represented on this template. Another relevant aspect in this research work is the contribution to represent produced context-aware educational scenarios (in a template) over a *learning script* by means of using the elements of the IMS-Learning Design specification as a notational language that can be parsed and processed by a mobile delivery system. Thereafter, adaptation rules and conditions defined in a context-aware educational scenario can be added through IMS-LD elements at the design process (Towle and Halm, 2005; Berlanga and Garcia, 2005). These aspects are further described in next sub-sections.

5.3.1 Examples of educational scenarios and contextual elements description

In this section, the design of two exemplary educational scenarios by using the template proposed in (Sampson, Zervas & Sotiriou, 2011) and the attempt on considering our context-oriented design approach is presented. The design of the scenarios aims to present how learner's contextual information (based on characteristics of the *Learning and Mobile context* categories presented in Table 5-2) can be used for adapting its learning flow towards implementing and demonstrating these adaptations in our developed mobile delivery system (presented in chapter 6). Thus, each educational scenario is based on our context-aware design approach, considering contextual elements presented in Appendix A, to support personalized and adaptive m-learning.

Background

The two educational scenarios were adopted from two learning scenarios that are used in a real language learning center, namely Official Language School at Girona, Spain ("EOI" in Spanish language). In this center, teachers are concentrating his efforts in teaching languages "integrating language learning skills (reading, listening, writing, and speaking) in real-life tasks" so as to provide different and innovative learning activities that suit to students needs and their context. According to this, students will be able to improve their skills while they are completing activities related with a real-life task such as setting up a business, sharing a flat, travel experiences, make a presentation, etc.

Both educational scenarios are based on the Second Language Learning discipline, which according to related literature (Kukulska-Hulme, 2006; Cui & Bull, 2005; Al-Mekhlafi, Hu & Zheng, 2009; Paredes et al., 2005) it looks potentially assisted and set to target the opportunities for m-learning (described in section 2.1.3):

- *Encourage 'anywhere, anytime' learning*: enabling learners, who are not dependent on accessing fixed computers, to access language learning materials anytime and anywhere by means of using mobile and wireless technologies.
- *Engage learners in context*: facilitating the engagement in language learning activities that relate more closely to their real-life surroundings (direct connection with real world experiences).
- *Enable an informal, situated, personalized learning experience*: extending the participation possibilities in language learning activities that relate directly to the learners' changing location and needs (an ever-changing environment for learning).

The educational scenarios are not attempting to be replicated or even augmenting the adopted learning scenarios for m-learning but rather tried to create new learning opportunities in which, from a constructivist perspective, learners may construct knowledge through active learning experiences. Moreover, these educational scenarios present appropriately pedagogical characteristics that suits to a constructive individual and social pedagogical theory: i.e. on the one hand, learners can learns actively by her own means (using a mobile device), by controlling their progress and by what they have available in real-life environments (learning activities, resources, tools, services, surrounding resources, etc.). On the other hand, learners can benefit from dialogue and collaborative activities. The interaction of learners with people allow supporting the individual discover of principles, enable support to develop skills and internalize new knowledge (Mayes & de Freitas, 2007).

Each exemplary educational scenario is based on utilizing a subset of contextual elements from the "*Mobile context*" category presented in Table 5-2, which can be processed by UoLmP (see Table 5-3) and provide language learners with adapted learning activities, resources, tools and services while they are following the learning activities flow. This contextual information provides the tool with the necessary input to react and respond once it detects and retrieves certain context instances. Real, living contexts have to be generated by the participants in the context. This brings to the fore the important distinction between context as an abstract frame and context instantiation (a lived-in experience) (Boyle & Ravenscroft, 2012).

Some of the considered contextual elements may have known instances (pre-defined data or set of values) as shown in Table 5-3 (Gómez & Fabregat, 2012), and, thus, they can be taken into account in a decision-making process held by UoLmP in run-time. Different values of these elements can result to different adaptation results (explained in chapter 6 and 7). Other contextual elements may be known, but their instantiations may not be pre-defined. In this case, the instances of these contextual elements will be known only in real time (Burstein, Brézillon & Zaslavsky, 2011).

Exemplary adaptive context-aware educational scenario 1 – Project based learning

In this section, we present an exemplary educational scenario that involves learning activities related to a real-life task (referred to as "sharing a flat") in which learners (namely, intermediate English level students) must achieve goals individually and collaboratively to present a project work about "finding a new flat mate" (Gómez et al., 2012). The educational scenario is based on the *project based learning* pedagogical model [which is one appropriate pedagogical model of the constructivist theory proposed for m-learning as recognized by the literature (Ally, 2005; Chang, Wong & Chang, 2011)] and it have been appropriately designed, so as to include a subset of elements of the mobile context category (see Appendix B). Moreover, it has been appropriately processed so as to incorporate the possible adaptations that are realized based on learner's contextual information (see Figure 5-2). These adaptations includes: (a) adaptations to the learning activities that are presented to the learner, (b) adaptations to the learning content that is used for the learning activities and (c) adaptations to the tools and services that are used to support the learning activities.

Table 5-3 Contextual elements and instances considered in the exemplary educational scenarios

Element		Description	Data (instances)	Data source
Dimension: LEARNER				
Temporal personal information	Interest	Learner's attention on language learning skills to improve.	Listening, Reading, Making notes, Oral presentation, Oral communication, Written communication.	Dialog Plus (Context: Skills) (Conole & Fill, 2005)
	Need	Learner's request for language support (e.g. vocabulary, grammar, examples).		
	Preference	Learner's inclination for an action (e.g. selecting a learning tool or service).		
Dimension: PEOPLE				
Contribution		Information that the learner's More Able Partners (MAP) (Luckin, 2010) may bring to their interactions. e.g. peer's language learning strong skills.	Listening, Reading, Making notes, Oral presentation, Oral communication, Written communication.	Dialog Plus (Context: Skills) (Conole & Fill, 2005)
Dimension: ARTIFACT				
Technological	Digital property	Software technical capabilities of the access mobile device.	[Audio support, Image support, Video support, Text support, Dynamic content support, Markup language support, Browser]	W3C-MBP (W3C-MBP, 2008), WURFL (WURFL, 2008)
	Physical property	Hardware technical capabilities of the access mobile device.	[Screen: type, colors and resolution (pixels)]	W3C-MBP (W3C-MBP, 2008), WURFL (WURFL, 2008)
Dimension: PLACE				
Location		Spatial coordinates or point in a map.	[latitude, longitude]	mobile device integrated GPS.
Environment		One-word physical description of where the learner stands.	[home, language school, workplace, university, outdoors]	Own instances definition
Dimension: TIME				
Availability		Peer's available time for second language learning.	[dd-mm-yyyy] [hh:mm]	People's planned time
Dimension: PHYSICAL CONDITIONS				
Illumination level		State of the illumination level in the place where the learner is located.	[low, high]	Own instances definition
Noise level		State of the noise level in the place where the learner is located.	[low, high]	Own instances definition

As presented in Figure 5-2, first the teacher organizes the learners into groups and presents them with a problem related to a real-life task (Act 1: Definition of the project goal). After that, the different groups discuss the problem set by the teacher and allocate sub-tasks (Act 2: Planning the project). Next, each group member collects information about his/her part of the project work (Act 3: Doing the project work). During this act, based on learner's contextual information the learning activities flow is affected according to the environment (Env) where the learner is located. After collecting the appropriate information individually, group members compose together the collected pieces of individual work by discussing the different characteristics of a flat mate and by reaching a consensus on a common list of flat mate's characteristics. During these learning activities, if a learner is located in a place different from the language training center, he/she should check for group members' available time (AT), so as to communicate with them and complete collaborative activities.

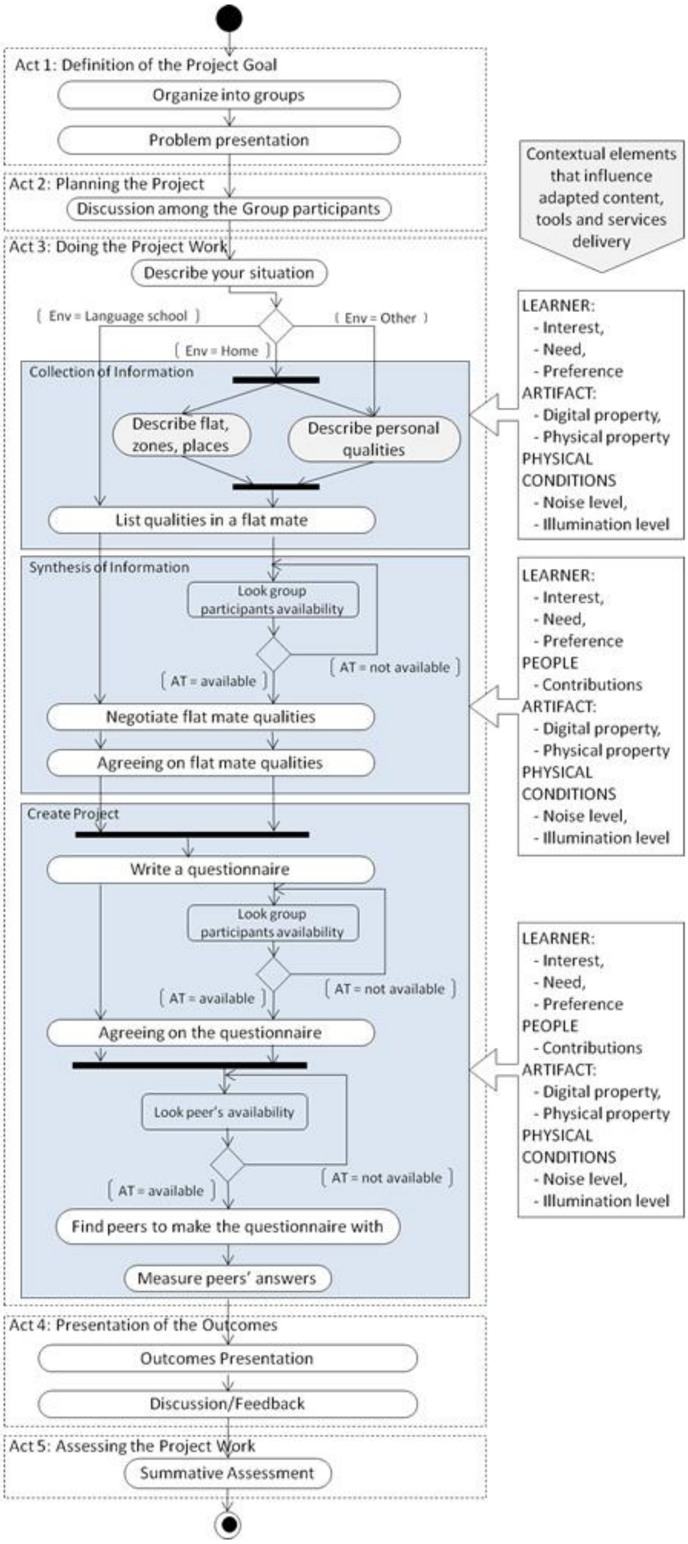


Figure 5—2 Learning activities flow diagram of the exemplary educational scenario 1

Next, learners are requested to (a) write a questionnaire (that allows them to assess the flat mate's characteristics) and (b) work collaboratively to agree on a commonly accepted questionnaire. After that, each group member identifies different peers to ask the questions presented in the questionnaire and assess them according to their replies. Finally, each group prepares a short report based on the results and the decision made, that is, the selection of the new flat mate (Act 4: Presentation of the outcomes). The project outcomes are then presented to other groups and to the teacher, who assesses attainment of educational objectives by each group (Act 5: Assesing the project work).

General data about the educational activities and materials designed and used for this educational scenario are presented in Table 5-4. As shown above in the learning activities flow diagram (see Figure 5-2) the educational scenario consists of 16 learning activities considering different types of activities: 3 assimilative, 10 productive and 3 collaborative activities (see Table 5-4).

Table 5-4 Educational activities and materials for the exemplary educational scenario 1

Context-aware and adaptive educational scenario 1: "Sharing a flat: Finding a new flat mate"			
Learning activities:			
Number of atomic assimilative activities in the scenario:		3	
Number of atomic productive activities in the scenario:		10	
Number of atomic collaborative activities in the scenario:		3	
	Total number of activities in the scenario:		**16**
Learning materials:			
Resources:			
Assimilative resources in the lesson (including grammar and vocabulary resources):	Support (examples, instructions, tips, guidelines, etc.)		
	Listening:	10	
	Reading:	25	
	Total		35
	Support (grammar and vocabulary)		
	Reading:	10	
	Total		10
	Total		**45**
Tools:			
Mobile device's assimilative tools:	*Reading*: web content viewer, image viewer *Listening*: audio player, video player.		
Mobile device's productive tools:	*Writing*: text editor, camera, *Speaking*: audio recorder, video recorder.		
Services:			
Mobile device's communicative services:	*Listening-Speaking*: phone calling, voice messaging, video calling *Writing-Reading*: SMS, email editor, instant messaging, discussion forums		

The context-aware and adaptive educational scenario consists also of different learning materials: 45 resources (listening-based and reading-based resources), different reading-based and listening-based assimilative tools, different mobile-embedded writing-based and speaking-based productive tools, and some mobile communicative services for listening/speaking and writing/reading so as the students are able to decide which learning materials adjust better to their needs or preferences and let them to complete each learning activity.

Exemplary adaptive context-aware educational scenario 2 – Experiential learning

In this section, we present a second exemplary educational scenario. In this case, the scenario involves learning activities related to a real-life task, referred to as "setting up a business", in which learners (namely, advanced Intermediate English level students) must achieve goals individually and collaboratively to present a project work about "starting a new business" (Gómez et al., 2013a; Gómez et al., 2013b). Moreover, the educational scenario is based on the *experiential learning* pedagogical model, which is also an appropriate pedagogical model related to the constructivist theory and proposed for m-learning as recognized by the literature (Lai et al., 2007; Dyson et al., 2009).

The presented scenario in this sub-section has been also appropriately designed so as to include a subset of elements of the *mobile context* category (see Appendix C)., as well as it has been appropriately processed so as to incorporate the possible adaptations that are realized based on learner's contextual information (see Figure 5-3). Similar to scenario 1, these adaptations includes: (a) adaptations to the learning activities that are presented to the learner, (b) adaptations to the learning content that is used for the learning activities and (c) adaptations to the tools and services that are used to support the learning activities.

As presented in Figure 5-3, at the beginning contextual data is detected by the system through learner's input. During this act (Experiential learning), based on detected contextual information the learning activities flow is affected according to the environment (Env) where the learner is located, and the content, mobile tools and services are adaptively delivered with regard to other contextual information (learner's interest and need, artifact's digital and physical properties, peer's contributions and physical conditions of the place related to the noise and illumination level). Afterwards, the learner is presented with a set of adapted materials to complete the delivered activities. First, each learner analyzes a presented case study (related to a real-life case of setting up a business) in which the product or service offered, the business plan and the description of the marketing strategy should be identified (Concrete experience). Then, individually each student reflects about the main elements considered in the case study for setting up a business (Reflective observation). A set of questions would help the learner to extract the main steps for starting a business. After analyzing the case study, the learner is presented with a set of theory-based instructions, guidelines, experiences, etc., explaining the steps that should be taken to set up a business (Abstract conceptualization). Here the learners have the opportunity to interpret the presented events related to the real-life task so as they can understand the relationships among them.

Next, learners are presented with activities related to a project work (active experimentation) so as they can achieve goals individually and collaboratively. In these activities each group member collects information about his/her part of the project work. First, a problem related to the real-life task is presented which consist in starting a small business with the group members. Then, group members look at the problem from a personal perspective and based on the individual reflection of the case study and theory studied, each of them considers alternative solutions for a small business. Thus, they should define a list of tentative products/ services that may be sold/offered in the town they are living, and afterwards organize some market research based on a small questionnaire or survey.

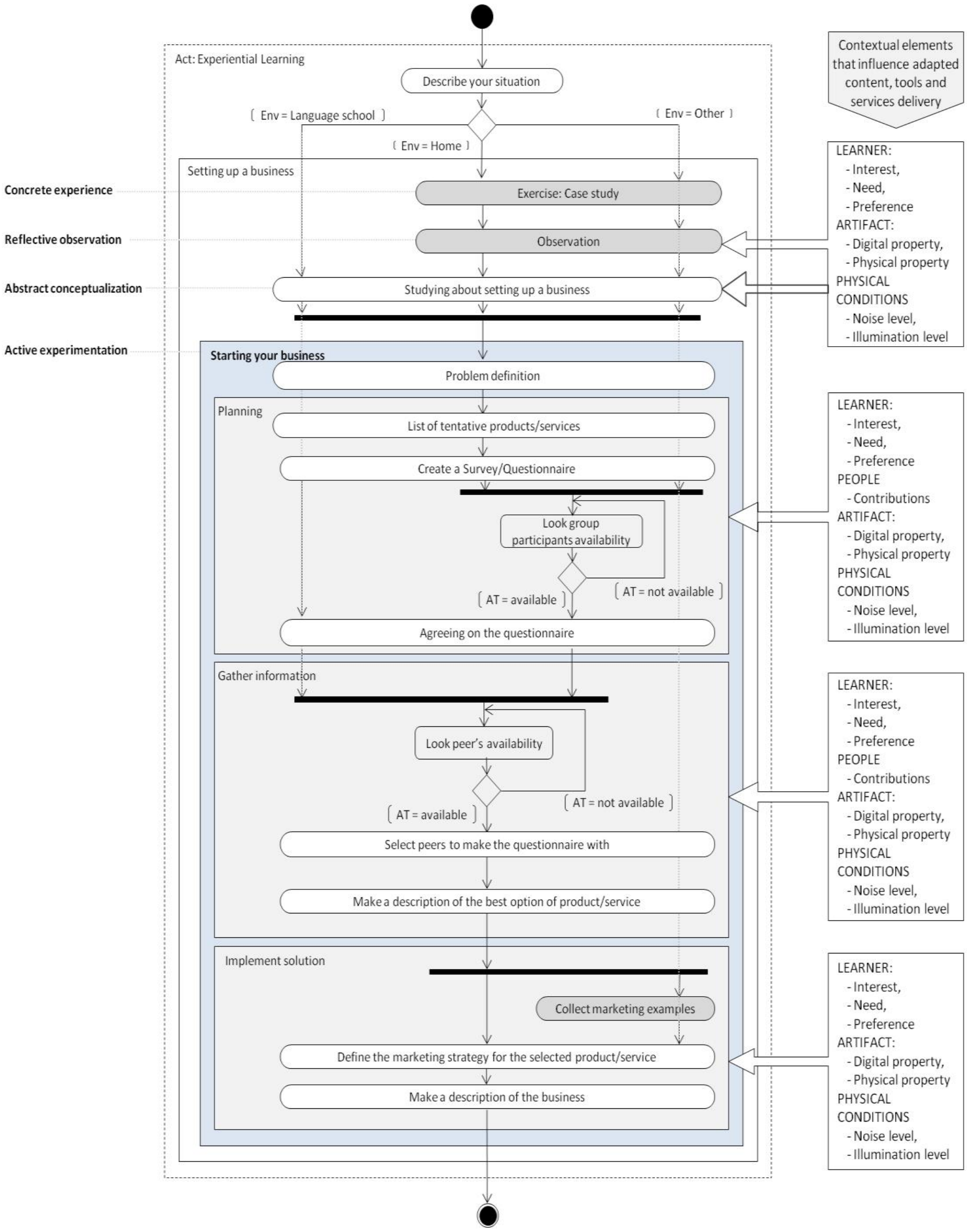


Figure 5—3 Learning activities flow diagram of the exemplary educational scenario 2

At the end of this phase, group members should reach a consensus on a common questionnaire or survey. During these learning activities, if a learner is located in a place different from the language training center, he/she should check for group members' available time (AT), so as to communicate with them and complete collaborative activities.

After that, each group member identifies different peers to ask the questions presented in the questionnaire and assess them according to their replies. Then, a description of the best product/service option (based on the peers' answers analysis) should be made so as they can implement the solution of the project which consists of (a) defining the marketing strategy for the selected product/service and (b) making a description of the business proposal. To support task (a), learners can collect different marketing examples from the places they are located, different from the language school and their homes.

Finally, each group prepares a short report based on the results and the decision made, that is, the proposal of a small business. The project outcomes are then presented to other groups and to the teacher, who assesses attainment of educational objectives by each group.

General data about the educational activities and materials designed and used for this educational scenario are presented in Table 5-5. As shown above in the learning activities flow diagram (see Figure 5-3) the educational scenario consists of 12 learning activities considering different types of activities: 3 assimilative, 7 productive and 2 collaborative activities (see Table 5-5).

Table 5-5 Educational activities and materials for the exemplary educational scenario 2

Context-aware and adaptive educational scenario 1: "Setting up a business: Starting your business"		
Learning activities:		
Number of atomic assimilative activities in the scenario:		3
Number of atomic productive activities in the scenario:		7
Number of atomic collaborative activities in the scenario:		2
	Total number of activities in the scenario:	**12**
Learning materials:		
Resources:		
Assimilative resources in the lesson (including grammar and vocabulary resources):	Support (examples, instructions, tips, guidelines, etc.) *Listening*: *Reading*: Total	 13 38 51
	Support (grammar and vocabulary) *Reading*: Total	 10 10
	Total	**61**
Tools:		
Mobile device's assimilative tools:	*Reading*: web content viewer, image viewer *Listening*: audio player, video player.	
Mobile device's productive tools:	*Writing*: text editor, camera, *Speaking*: audio recorder, video recorder.	
Services:		
Mobile device's communicative services:	*Listening-Speaking*: phone calling, voice messaging, video calling *Writing-Reading*: SMS, email editor, instant messaging, discussion forums	

This scenario consists also of different learning materials: 61 resources, assimilative and productive tools, and some mobile communicative services.

5.3.2 Defining adaptation rules based on IMS Learning Design

IMS-LD is a notation language for the description of educational scenarios (introduced in section 2.3.2). Through IMS-LD standard the learning design can be modeled, implemented and expressed in XML structures. In the authoring phase, authors of Learning Designs can create educational scenarios (as the ones presented in previous section 5.3.1) following the guidelines of the IMS-LD specification (IMS-LD, 2003; IMS-LD BPG, 2003). To create these educational scenarios, authors can use an authoring tool that complies with the IMS-LD specification Level B such as Reload LD Editor (Reload, 2004), Recourse (Griffiths et al., 2009) among others.

In order to design and implement our proposal of *content filtering* adaptation mechanism (introduced in chapter 4), the guidelines of the IMS-LD specification (IMS-LD, 2003; IMS-LD BPG, 2003) are considered since it defines a structure that uses different elements that let designing the learning process and let defining properties and conditions in the structure of a UoL to implement some adaptation mechanisms (Burgos, Tattersall & Koper, 2006). More specifically, in order to implement the IMS-LD specification the IMS-LD Level B guidelines are considered. IMS-LD Level B let the possibility of defining conditions to evaluate different expressions based on properties related to a single user or different roles in order to enable the personalization and adaptation. Research work in (Burgos, 2008) remarks that properties, global elements and conditions are elements of IMS-LD level B to represent adaptation approaches.

Hereafter, in design-time *content filtering* consists of constructing an adaptation engine based on IMS-LD Level B conditional rules (Gómez & Fabregat, 2012). Thus, in order to define conditional rules based on processing contextual elements and achieve the adaptation of the educational activities and resources in the Learning Design, properties, conditions and global elements of the IMS-LD level B structure are proposed to be used as follows:

Declaring properties

According to (IMS-LD, 2003), the element "<properties>" can be used to set variables or constant values related to aspects of a user. In this work, these aspects are the elements of the context (Appendix A). Thereafter, an author can define a set of properties to store data of contextual elements which then in run-time will be evaluated with respect to current captured data by the mobile system. Thus, in the case of the exemplary context-aware educational scenarios above presented, properties includes: learner's interests, peers' contribution, access place and environment, peer's availability and physical conditions (illumination and noise level) of the place (see Table 5-3). There are some contextual elements that can be previously known, but their instantiations may not be pre-defined, so that, the instance of those contextual elements may change or may be known only in real time. For instance in the exemplary educational scenarios: learner' needs (learner's request for language support, e.g. vocabulary, grammar, examples) and preferences (learner's inclination for an action, e.g. selecting a m-learning tool or service) instantiations are not pre-defined (see Table 5-3). Furthermore, the artifact element is taken into account in the Dynamic Content Adaptation phases (see Figure 5.1) which are explained later in this chapter in sections 4.4 and 4.5.

Possible data (instances) for each element shown in the taxonomy of contextual elements (appendix A) may vary according to the design of a new scenario. This indicates that the properties can save values related to different design features. For example, an instance for environment element in other scenario could be a laboratory, museum, public transportation station, etc.; or for the physical conditions the values could be sound level, temperature, etc.; similarly, different instances may be defined for time, namely weeks, seconds, etc.

Hereafter, contextual information may be characterized according to use purposes and the design approach of an author. Then, It could be said that contextual information for learning design in m-learning environments may be considered by authors according to different perspectives as follows:

i) Contextual information *perceived* by the learning designer (teacher, tutor, instructor, etc.) which could affect a learner's learning flow and can be used to pre-define different instances assuming different learner's learning situations.

ii) Contextual information *exposed* by the learner (student, apprentice, newcomer), i.e. real-time contextual information that varies and that can be captured by a learning design delivery system from user's inputs according to his/her preferences, need, mood, among other personal considerations regarding the actions the user reveals is doing.

iii) Contextual information *detected* by the system, i.e. contextual information which is not being input directly by the learner but the system may detect by sensing and location technologies.

Regarding that each perspective considers the learner as the main influenced actor and in each perspective *contextual information* involved *every piece of information that* is essentially influencing *a personal learners' given situation*, in this work it is assumed that context-related properties should be *local* and *personal*, i.e. they can have a different value for each learner in a specific run of the educational scenario in the mobile system. In the XML code below (see Table 5-6), an extraction of the description of the exemplary educational scenario 2 where properties are declared is presented.

Table 5-6 XML code representing an example of IMS-LD Level-B properties declaration

```
<imsld:properties>
  <imsld:locpers-property identifier="learner_tpi_interest_assimilative_skill">
        <imsld:title>How do you want to receive the learning resources?</imsld:title>
        <imsld:datatype datatype="string" />
        <imsld:initial-value>Listening</imsld:initial-value>
        <imsld:restriction restriction-type="enumeration">Listening</imsld:restriction>
        <imsld:restriction restriction-type="enumeration">Reading</imsld:restriction>
  </imsld:locpers-property>
  <imsld:locpers-property identifier="learner_tpi_interest_ productive_skill ">
        <imsld:title>Which Productive Skill are you interested to develop?</imsld:title>
        <imsld:datatype datatype="string" />
        <imsld:initial-value>Making notes</imsld:initial-value>
        <imsld:restriction restriction-type="enumeration">Making notes</imsld:restriction>
        <imsld:restriction restriction-type="enumeration">Oral presentation</imsld:restriction>
  </imsld:locpers-property>
  <imsld:locpers-property identifier="learner_tpi_interest_communicative_skill ">
        <imsld:title>Which Communicative Skill are you interested to improve?</imsld:title>
        <imsld:datatype datatype="string" />
        <imsld:initial-value>Oral communication</imsld:initial-value>
        <imsld:restriction restriction-type="enumeration">Written communication</imsld:restriction>
        <imsld:restriction restriction-type="enumeration">Oral communication</imsld:restriction>
  </imsld:locpers-property>
  <imsld:locpers-property identifier="place_environment">
        <imsld:title>Where are you located?</imsld:title>
        <imsld:datatype datatype="string" />
        <imsld:initial-value>Home</imsld:initial-value>
```

```
            <imsld:restriction restriction-type="enumeration">EOI</imsld:restriction>
            <imsld:restriction restriction-type="enumeration">Home</imsld:restriction>
            <imsld:restriction restriction-type="enumeration">Workplace</imsld:restriction>
            <imsld:restriction restriction-type="enumeration">University</imsld:restriction>
            <imsld:restriction restriction-type="enumeration">Outdoors</imsld:restriction>
            <imsld:restriction restriction-type="enumeration">Other</imsld:restriction>
  </imsld:locpers-property>
  <imsld:locpers-property identifier="physicalconditions_noiselevel">
            <imsld:title>Is the environment noisy?</imsld:title>
            <imsld:datatype datatype="boolean" />
            <imsld:initial-value>false</imsld:initial-value>
  </imsld:locpers-property>
  <imsld:locpers-property identifier="physicalconditions_illuminationlevel">
            <imsld:title>Is the environment illuminated?</imsld:title>
            <imsld:datatype datatype="boolean" />
            <imsld:initial-value>true</imsld:initial-value>
  </imsld:locpers-property>
</imsld:properties>
```

In order to achieve an adaptive and personalized m-learning it is relevant to provide the adaptive system with contextualized data for successful decision making. A subset of contextual elements from the Mobile context category presented in Table 5-3 and their pre-selected and pre-defined instances for each property are presented in the above XML code example.

Defining conditions

The element <conditions> allows customization actions in the learning process to be defined based on captured values for each defined property when a UoL is running. Conditional statements consist of IF / THEN / ELSE rules in which properties' values can be evaluated and thereafter visibility of educational entities can be further refined. Thereafter, a Learning Design author can define a set of conditions to evaluate the captured data for the contextual elements in order to decide what learning activities, resources, tools or services can be filtered.

Actions of filtering that can be executed when conditions are evaluated are:

- <*show*>: a choice of educational elements to specify what has to be shown when a condition (if) is true.
- <*hide*>: a choice of elements to specify what must be made hidden when the condition (if) is true.
- <*change-property-value*>: this element is used to change values of properties after an event (e.g. completion of something). For example, when a activity is completed, a property value may be changed to reflect this fact. In the dossier of UoLmP also an automated record of completed activities is kept, so it is not necessary to record the completion as such, but to register (or change) other things.

Since delivering adapted learning activities, educational resources, mobile tools and communicative services are considered to achieve implementation of adaptations, an association between instances of these educational elements was defined so as to represent influence relationships that lead to learning activities and educational materials adaptations (see Table 5-7).

Table 5-7 Association between instances of activity types, techniques and resources/tools/services

Learning activity type	Technique	Resource / Tool / Service	
Assimilative	Reading, Viewing, Listening	Textbook	*
Reading		PDF	*
Viewing		Web content	
Listening		Dictionary	*
		Videos/Video player	*
		Audios/Audio player	*
		Images/Image viewer	*
		QR codes	*
		Flash cards	*
		Cue sheets	*
Productive	Assignment, Book report, Dissertation/thesis, Drill and practice, Essay, Exercise, Journaling, Presentation, Literature review, Puzzles, Portfolio, Product, Reporting, Test, Voting	Text editor	*
Writing		Slides editor (presentation)	*
Composing		Blog editor	*
Synthesizing		Wiki editor	*
Listing		Audio recorder	*
Recording		Video recorder	*
Drawing			
Simulating			
Communicative	Articulate reasoning, Arguing, Coaching, Debate, Discussion, Fishbowl, Ice breaker, Interview, Negotiation, On the spot questioning, Pair dialogues, Panel discussion, Peer exchange, Performance, Question and answer, Rounds, Scaffolding, Socratic instruction, Short answer, Snowball, Structured debate	Face-to-face talking	*
Discussing		Phone calling	*
Presenting		Voice messaging	*
Debating		Video conferencing	
Critiquing		MMS	*
		Instant messaging	
		Emails	
		SMS	*
		Discussion forums	*
		Blogs	
Information Handling	Concept mapping, Brainstorming, Defining, Mind mapping, Web search, Translating	Search engines	
Gathering		Web browsing	*
Ordering		Mind map editor	
Classifying		Wiki browsing	*
Selecting		Translator	*
Analyzing		Buzz words	*
Manipulating		Crosswords	*
		Brainstorming	
Experiential	Case study, Experiment, Field trip, Game, Role play, Scavenger hunt, Simulation	Social networks	*
Practicing		Game	*
Applying		Virtual worlds	
Mimicking		Modeling software	
Experiencing		Simulation software	
Exploring		Camera (photos)	*
Investigating		GPS	*
Performing		QR-code reader	*
Modeling			
Simulating			

* Identified Resources/Tools/Services and proposed for designing context-aware and adaptive mobile educational scenarios.

This association was carried out considering the research work presented in (Kukulska-Hulme & Shield, 2008) which presents a list of mobile assisted language learning activities that took advantage of mobile device portability. Moreover, the DialogPlus taxonomy for learning design (Conole & Fill, 2005) was adopted to describe a set of learning activity types, associated learning techniques and some tools/resources/services in Table 5-7. Furthermore, an additional set of mobile resources/tools/services is presented in this association due to context-aware adaptive educational scenarios can be assisted by mobile and wireless technologies (Gómez & Fabregat, 2012).

According to this, context in m-learning may assist and support the learning process providing, in real time, relevant information and activities or enabled resources, tools or services that the learner may need to complete and follow the procedural learning plan in different situations.

Here, a practical example based on the educational scenarios (1 and 2) presented in previous sub-section is presented. Since, in these scenarios learners' temporal personal information is considered with regards to their interests on improving language learning skills (reading, listening, writing, speaking), designed activities of the learning flow correspond to assimilative, communicative and productive learning activity types which can brings different opportunities to perform an action (i.e. using a resource, a tool or a service) related to a language learning skill (see Table 5-8). In Table 5-8 the activity types, techniques and resources/tools/services selected for the scenarios (extracted from Table 5-7) and the relationship between instances of these activity types, techniques and resources/tools/services with the language learning skills is presented.

Table 5-8 Relationship between Language learning skills and activity types, techniques and tools/resources/services for the exemplary educational scenarios

Learning activity type	Technique	Resource / Tool / Service	Associated Language learning skills
Assimilative	Reading Viewing Listening	Textbook	Reading
Reading Viewing Listening		Web content	Reading
		Images	Reading (Viewing)
		Videos	Listening
		Audios	Listening
Productive	Assignment Questionnaire Journaling Reporting	Text editor	Writing
Writing Composing Synthesizing Listing Recording		Slides editor (presentation)	Writing (Synthesizing)
		Blog editor	Writing
		Audio recorder	Speaking
		Video recorder	Speaking
Communicative	Pair-dialogues Interviews Pair-discussions Pair-debates Arguing	Face-to-face talking	Listening, Speaking
Discussing Presenting Debating Critiquing		Phone calling	Listening, Speaking
		Voice messaging	Listening, Speaking
		Instant messaging	Reading, Writing
		Emails	Reading, Writing
		SMS	Reading, Writing

Different learning activities provide different ways of performing a language learning task and practicing corresponding grammar rules and vocabulary to a specific subject in the moment and the place that the student wants or needs. This means that contextual information can be gathered to benefit learners providing useful and situated information and to let them improving language learning skills while they are in different situations.

According to this, different supportive resources and actions related to a learning activity type, can be proposed by the teacher (e.g. if the learner has to complete a communicative activity, she/he can be proposed to talk face-to-face with a peer, email a peer, sending short or instant messages to a peer, or make a phone call to a peer, etc.). These actions occur instantaneously in the moment the learner choose how to do the activity. Hence, the supportive resources, tools and services can be adapted according to the learner’s contextual information retrieval and they can be used by learners to perform an activity. This exemplary description is illustrated in Table 5-9.

Table 5-9 Communicative learning activity – Pseudo code example of the applied adaptation approach

Activity: “Share your flat, personal qualities and place preferences descriptions to a classmate.”
Contextual information
- IMS-LD Properties: Environment: assimilative_skill, communicative_skill, productive_skill, noiselevel, illuminationlevel. Peer’s contributions: Language learning strong skills profile. Time: Peer’s availability. Learner’s preference: user’s choice.
Example of Context-aware adaptation approach
- IMS-LD Conditions: IF environment IS home AND assimilative_skill IS listening, AND productive_skill IS oral presentation AND communicative_skill IS oral communication, AND noiselevel IS low AND illuminationlevel IS high THEN: SHOW: face-to-face talking, phone calling, voice messaging HIDE: instant messaging, emails, SMS, discussion forums - Learner´s real-time decision based on her/his situation: Between talking face-to-face, phone calling and voice messaging actions, the learner may chose to phone a peer because she is at home and has not any classmate close to talk with. When choosing to phone a peer, the learner can decide who she is going to communicate with based on analyzing peers’ individual Language skills and their available times.

In the XML code below (see Table 5-10), the representation of conditional rules described in above description is presented so as to show how a subset of contextual elements may affect the activities and content delivery decision process.

Table 5-10 XML code representing context-aware adaptation rules examples based on IMS-LD Level-B Conditions definition

Example 1: Context-aware conditional rules for learning activities delivery

```
<imsld:conditions>
        <imsld:title>Context 6 - Activities Filtering</imsld:title>
        <imsld:if>
          <imsld:and>
            <imsld:is>
                <imsld:property-ref ref="learner_tpi_interest_1" />
```

```
                <imsld:property-value>Listening</imsld:property-value>
            </imsld:is>
            <imsld:is>
                <imsld:property-ref ref="place_environment" />
                <imsld:property-value>Home</imsld:property-value>
            </imsld:is>
            <imsld:is>
                <imsld:property-ref ref="physicalconditions_noiselevel" />
                <imsld:property-value>false</imsld:property-value>
            </imsld:is>
            <imsld:is>
                <imsld:property-ref ref="physicalconditions_illuminationlevel" />
                <imsld:property-value>true</imsld:property-value>
            </imsld:is>
        </imsld:and>
    </imsld:if>
    <imsld:then>
        <imsld:show>
            <imsld:learning-activity-ref ref="P1-A1-A1" />
            <imsld:learning-activity-ref ref="P1-A2-A1" />
```

Learning activities

```
        </imsld:show>
        <imsld:hide>
            <imsld:learning-activity-ref ref="P1-A4-A7" />
```

Learning activities

```
        </imsld:hide>
    </imsld:then>
</imsld:conditions>
```

Example 2: Context-aware conditional rules for educational resources delivery

```
<imsld:conditions>
    <imsld:title>Context 6 - Resources Filtering</imsld:title>
    <imsld:if>
        <imsld:and>
            <imsld:is>
                <imsld:property-ref ref="learner_tpi_interest_1" />
                <imsld:property-value>Listening</imsld:property-value>
            </imsld:is>
            <imsld:is>
                <imsld:property-ref ref="place_environment" />
                <imsld:property-value>Home</imsld:property-value>
            </imsld:is>
            <imsld:is>
                <imsld:property-ref ref="physicalconditions_noiselevel" />
                <imsld:property-value>false</imsld:property-value>
            </imsld:is>
            <imsld:is>
                <imsld:property-ref ref="physicalconditions_illuminationlevel" />
                <imsld:property-value>true</imsld:property-value>
            </imsld:is>
        </imsld:and>
    </imsld:if>
    <imsld:then>
        <imsld:show>
            <imsld:learning-object-ref ref="E2-LO2" />
            <imsld:learning-object-ref ref="E3-LO2" />
            <imsld:learning-object-ref ref="E3-LO4" />
            <imsld:learning-object-ref ref="E4-LO2" />
```

Listening-based learning resources

```
        </imsld:show>
```

```
          <imsld:hide>
              <imsld:learning-object-ref ref="E2-LO1" />
              <imsld:learning-object-ref ref="E3-LO1" />
              <imsld:learning-object-ref ref="E4-LO1" />
          </imsld:hide>
        </imsld:then>
</imsld:conditions>
```

Reading-based learning resources

Example 3: Context-aware conditional rules for mobile tools delivery

```
<imsld:conditions>
        <imsld:title>Context 6 – Tools Filtering</imsld:title>
        <imsld:if>
  <imsld:and>
            <imsld:is>
                <imsld:property-ref ref="learner_tpi_interest_2" />
                <imsld:property-value>Oral presentation</imsld:property-value>
            </imsld:is>
            <imsld:is>
                <imsld:property-ref ref="place_environment" />
                <imsld:property-value>Home</imsld:property-value>
            </imsld:is>
            <imsld:is>
                <imsld:property-ref ref="physicalconditions_noiselevel" />
                <imsld:property-value>false</imsld:property-value>
            </imsld:is>
            <imsld:is>
                <imsld:property-ref ref="physicalconditions_illuminationlevel" />
                <imsld:property-value>true</imsld:property-value>
            </imsld:is>
          </imsld:and>
        </imsld:if>
        <imsld:then>
          <imsld:show>
              <imsld:learning-object-ref ref="E5-LO1" />
              <imsld:item-ref ref="E5-LO1-item1" />
              <imsld:item-ref ref="E5-LO1-item2" />
              <imsld:item-ref ref="E5-LO1-item3" />
          </imsld:show>
          <imsld:hide>
              <imsld:learning-object-ref ref="E5-LO2" />
          </imsld:hide>
        </imsld:then>
</imsld:conditions>
```

Speaking-oriented mobile productive tools

Writing-oriented mobile productive tools

Example 4: Context-aware conditional rules for communicative services delivery

```
<imsld:conditions>
        <imsld:title>Context 6 – Services Filtering</imsld:title>
        <imsld:if>
  <imsld:and>
            <imsld:is>
                <imsld:property-ref ref="learner_tpi_interest_3" />
                <imsld:property-value>Oral communication</imsld:property-value>
            </imsld:is>
            <imsld:is>
                <imsld:property-ref ref="place_environment" />
                          <imsld:property-value>Home</imsld:property-value>
                        </imsld:is>
            <imsld:is>
```

```
                        <imsld:property-ref ref="physicalconditions_noiselevel" />
              <imsld:property-value>false</imsld:property-value>
                    </imsld:is>
           <imsld:is>
              <imsld:property-ref ref="physicalconditions_illuminationlevel" />
              <imsld:property-value>true</imsld:property-value>
           </imsld:is>
         </imsld:and>
       </imsld:if>
       <imsld:then>
         <imsld:show>
            <imsld:learning-object-ref ref="E6-LO1" />
         </imsld:show>
         <imsld:hide>
            <imsld:learning-object-ref ref="E6-LO2" />
         </imsld:hide>
       </imsld:then>
</imsld:conditions>
```

Speaking/Listening-oriented mobile communicative services

Writing/Reading-oriented mobile communicative services

The four examples of conditional rules in the previous xml codes represent the provisional statements for presentation filtering (showing or hiding) of learning activities (Example 1), assimilative educational resources (Example 2), productive mobile tools (Example 3) and communicative mobile services respectively (Example 4).

Therefore, in previous exemplary scenarios the adaptation process is proposed to include the evaluation of a set of conditions based on student's current learning situation in order to implement show or hide actions for learning activities or resources. Moreover, contextual information will support and assist leaner's decisions about performing an action (just-in-time actions based on people's contributions and available time).

Using global-elements

As IMS-LD has a separate group of elements, defined as <global-elements>, to read and set properties from all sorts of XML-based content schemas, global elements implemented in XHTML web forms are proposed to be used in order to let the learner to view and the learner or system to edit/modify data entries for the context-related properties according to learner's input.

Hereafter, to explain by an example in the exemplary educational scenarios, global elements can be used to capture (set and get) data related to peer's contributions and peer's availability. Initial instances for the case of both peers' contribution (peer's language learning strong skills) and peers' availability can be previously known and stored in XML-based content schemas. For the exemplary scenarios an XHTML file is used to store such information in a remote server. However, learners can edit/modify their personal information by setting a new value that accommodates to their situation (e.g. changing their availability or strong skills values). This information can be used by a learner when she/he decides is necessary to complete a communicative activity and afterwards, updated information will be shown.

Authoring phase meets its end point here. The final product of this phase is an educational scenario translated to the IMS-LD specification, which describes the learning flow of a course/lesson and contains references to the location of different learning resources. Moreover, it contains tools and services which can be used as support for performing the learning activities, as well as properties and conditions used to evaluate contextual information related to the *mobile context* category (learner's personal temporal information, people, place, artifact, time and physical conditions) in order to implement adaptation actions (show, hide or change the value of a property). Having authored educational scenarios, the next step for adaptation to be taken in design-time is to have these scenarios adapted to the leaner's mobile device without restrictions of the device capabilities. To achieve this, a content adaptation process that dynamically adapts the multimedia resources considering a set of generic mobile device capabilities is needed. This process is explained with details in next section.

5.4 Content Transformation in design-time

In previous section details of a *content filtering* mechanism based on using properties and conditions from the IMS-LD specification is explained. This mechanism aims to achieve adaptation in design-time so as produce context-aware adaptive educational scenarios by describing how presentation of activities, resources, tools and services can be filtered considering dimensions of the mobile context category, namely: leaner's temporal personal information, people contribution, place of access, time and physical conditions. In this section, artifact dimension is taken into account so as to explain how mobile devices' capabilities can be used to implement a *polymorphic presentation* mechanism that generates transcoding requests for digital content after an educational scenario has been authored.

The work presented in this section describes the first phase of the Dynamic Content Adaptation process, namely *Content Transformation* (see Figure 5-1). The aim of this process is that a content adaptation process can be dynamically executed when an authored educational scenario for m-learning is ready to be packaged and published (this process was introduced in section 2.4) for learners. Within this process capabilities of different mobile devices to transform the properties of the resources that are populating an authored educational scenario are considered. Hereafter, the author of this dissertation attempts to present an adaptation engine architecture (Gómez & Fabregat, 2010) based on this process so as to explain its components and the technologies used to implement it (See Figure 5-4). Thus, developers of Learning Design authoring tools (design-time) and repositories (run-time) can consider this engine in their tools to facilitate packaging and publishing of learning designs that incorporate content adaptation features for m-learning.

Development of the components of the *Content Transformation* process is based on Java programming language and web services technology. Moreover, the architecture is based on using the OMA Standard Transcoding Interface (OMA-STI, 2005) to manage communication requirements for sending transcoding requests to the server and creating responses to those requests specifying the results of transcoding jobs, as well as a transcoding server, namely Alembik (Bellinzona, Raibulet, 2012), to perform transcoding jobs.

Basically, the transforming functionality of the content adaptation process is implemented as a web service to allow targeted clients in design-time (i.e. authoring Learning Design systems) to invoke learning design adaptations for mobile devices. In next sub-sections components of the architecture and implementation issues are explained with more details.

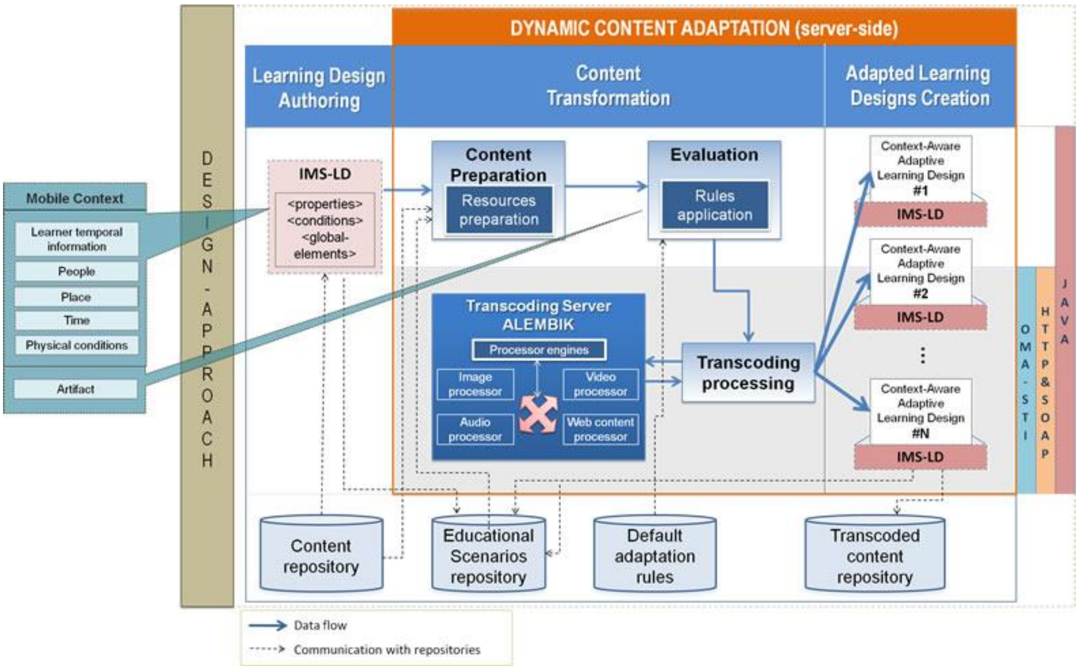


Figure 5—4 Architecture of the adaptation engine in design-time

5.4.1 Content preparation

From this step and onward, contextual information related to the technological properties of the mobile device is considered to achieve educational digital content to be transformed. When an authored educational scenario is ready to be packaged, the adaptation engine first step consists in locating the resources within the structure of the Learning Design XML file, namely imsmanifest.xml, and preparing those resources to be transformed (see Figure 5-5).

Figure 5—5 Content preparation

Localization of resources means, to gather all digital content within the imsmanifest.xml and the href addresses to which each learning resource is pointing. Hence, in an imsmanifest.xml file each resource is referenced within an element <resource> and each element has an "href" attribute describing the URL where the resource is located. An example of a set of resources extracted from the code of the imsmanifest.xml for the exemplary educational scenario 2 is presented below in Table 5-11.

Table 5-11 Example of resources attributes within a manifest file (XML code)

```
<resource identifier="RES-E7-LO4-item4" type="webcontent" href="image/adv_magazine.gif">
    <file href="image/adv_magazine.gif" />
  </resource>
<resource identifier="RES-E7-LO2-item1" type="webcontent"
href="Environments/Extra_resources/8a_adv_text.html">
    <file href="Environments/Extra_resources/8a_adv_text.html" />
</resource>
<resource identifier="RES-E2-LO1-item1" type="webcontent" href="audio/describing_my_house.wav">
    <file href="audio/describing_my_house.wav" />
</resource>
<resource identifier="RES-E2-LO1-item5" type="webcontent" href=" video/dream_flatmates.mpeg">
    <file href=" video/dream_flatmates.mpeg" />
</resource>
```

Once all resources are gathered they are separated in four groups based on four digital content types: image, audio, video and web content. Initially, only these four digital content types are considered in the implementation of the adaptation engine because they are common used formats to create web-oriented learning content by designers (Lee, Rho & Park, 2011). The identification of each resource type is performed through their file formats extensions and, to achieve this, some of the file formats proposed in (IANA) were considered.

5.4.2 Evaluation

When used resources within an educational scenario have been identified, gathered and grouped, a set of predefined adaptation rules based on the relation between technical capabilities of mobile devices with the properties of digital content are executed so as to produce a set of transcoding parameters that can be used to create transcoding requests (see Figure 5-6). In this step, how these adaptation rules arise and are defined is explained.

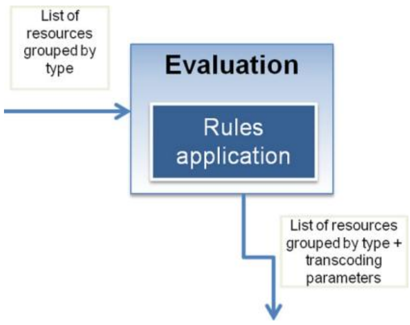


Figure 5—6 Evaluation

Previous analysis of technological capabilities of handheld devices

When designed learning paths of a learning script for m-learning are followed by learners, activities and content in that learning script can be accessed from different access devices. Thereafter, different learners can own a different mobile device or they can change the device at any time, and therefore, this change needs that learning content can be modified so as it can be adapted to the mobile device at hand.

In this section an analysis of the properties and characteristics of different client platforms that can be used for m-learning environments is presented. The analysis of these features let identifying the desired adaptation targets that learning content should meet and for this, defining a set of adaptation rules considering different transformation parameters for digital content.

Hereafter, firstly we focused on studying different approaches for describing the technical characteristics of mobile devices in related work literature. Thus, an initial search was made on existing specifications which presents a data structure to describe those characteristics and which can be applied and incorporated in the design and development of our proposed content adaptation process. Currently, there are some specifications based on representing mobile technical characteristics (physical properties, digital properties, interaction interfaces, etc.) in standard XML format files and that can be used for developing applications for mobile environments. Three of the main specifications are:

- The W3C composite capability-preferences profile (CC/PP) which is a specification for defining capabilities and preferences of user agents (CC/PP, 2007),
- The user agent profiles UAProf (UAProf, 2008) containing the information about the browser used by the client device and the technological characteristics of the device.
- The configuration Wireless Universal Resource File (WURFL, 2008) that contains information about the capabilities and features of different mobile devices. The main purpose of this file is to collect as much technical information from every mobile device on the market as possible, so that application developers can build better services for mobile users.

Although, there exist such solutions that let describing the device capabilities (e.g. UAProf, CC/PP, etc.), WURFL was selected because is an up to date specification that brings reliability in device data manipulation.

As first scope, WURFL specification is used in this work to gather information of the capabilities and characteristics of different access mobile devices. Moreover it is used as mobile capabilities detection mechanism in run-time (this will be explained in chapter 6). This specification allows working with a configuration file, namely wurfl.xml, based on the universal standard markup language XML. The favorable aspect to work with WURFL relies on the continuous update of the configuration file by the community of developers using WURFL in their projects. WURFL was built to support the evolution in the emergence of new mobile devices. The file is structured based on the concept of family of devices, that is, as new devices appear on the market, they can be added as new entries in the files since there is a chain of hierarchies and inheritance of the capabilities from one device family member to another. This mechanism allows developers to easily find the capabilities of a device through its descendants in the hierarchical chain. For example, if a new device with a brand X and a model Y is available in the market and not yet added to the WURFL file, searching the family of this device is possible by referring to its brand X and then add it in that chain. Thus, the capabilities already added in that family are inherited by the new device without having to retype all its capabilities.

The analysis consisted of studying the technical capabilities related to connectivity, network, display, memory, operating system, browser and support of audio, video, images, text, dynamic content and markup language generally presented in different mobile device types (see Table 5-12). Thus, the author of this thesis focused on analyzing the technical characteristics of mobile devices considered in WURFL (in previous work done (Gómez, 2009) a set of identified characteristics from this specification is presented. These characteristics are appropriated for the development of a content adaptation process, and the report of the Australian Flexible learning Framework project presented by O'Connell and Smith as a guide for using m-learning standards (O'Connell & Smith, 2007).

The outcome of this previous analysis is a list of identified mobile technical characteristics divided in devices' capabilities and sub-capabilities, which is presented in Table 5-12 (Gómez et al., 2009b). A broad and detailed description of the technical characteristics for each device type can be seen in (Gómez, 2009). Sub-capabilities in shaded cells represent data that can be obtained from WURFL Specification (Gómez, 2009). The other capabilities (unshaded) identified in (O'Connell & Smith, 2007) are not obtained from a specification. However, these capabilities are identified because they have been used to design an adaptive process in some related work (Li et al., 2006, Lum & Lau, 2002) different to the process proposed in this research work and they can be used to extend the capabilities considered in our solution.

Table 5-12 Technological characteristics of mobile devices

Characteristics			
Capability	**Sub-capabilities**		**Short Description**
Network	Type		Network technologies used in the device.
Screen	Type		Screen technology
	heigh	*	Height size of the screen, in pixels
	width	*	Width size of the screen, in pixels
	columns	*	Number of columns supported by the screen
	rows	*	Number of text lines supported by the screen
	Max. image width	*	Maximum width of the images, in pixels.
	Max. image height	*	Maximum height of the images, in pixels.
Ring tones	Type		Technology and supported formats for audio playback
	Vibrate		Does it vibrate?
Memory	Phonebook		Does it have phonebook storage?
	Call records		Does it have call recording feature?
	External card slot		Technology supported for external memory management.
Connectivity	GPRS		Does It use GPRS technology? Features of the technology used.
	HSCSD		Does it use HSCSD technology?
	EDGE		Does it use EDGE technology? Features of the technology used.
	3G		Does it use 3G technology?
	Bluetooth		Does it use Bluetooth technology? Features of the technology used.
	Infrared port		Has IR port?
	USB		Has USB port?
	Max. bandwidth transfer rate	*	Maximum bandwidth achievable by the device. Possible values: UMTS (3G) = 384, EGPRS / EDGE = 200, GPRS = 40, HSCSD = 29
	WLAN / Wi-Fi*	*	Can it access WLAN / Wi-Fi connections?
Functionalities	Operative syste	*	Information about the Operating System.
	Messaging		Types of messages it can send (SMS, MMS, etc.)
	Browser	*	Information about the device browser (Openwave, Nokia, Opera, Teleca, ...)
	Applications		Does it let running applications?
	Camera		Does it have embedded camera?

Characteristics			
Capability	**Sub-capabilities**		**Short Description**
	Calendar/Organizer		Does it have calendar / agenda included?
	PDF	*	Does it has pdf support?
Other digital properties	Markup language	*	Markup language supported by the device's browser. Possible values of this capability include: wml_1_1, html_wi_imode_compact_generic or html_wi_oma_xhtmlmp_1_0.
	Image capabilities	*+	Features related to the image capabilities (formats, color scales, etc.)
	Video capabilities	*+	Features related to the capabilities of video (formats, codecs, size, bitrate, frame rate, etc.)
	Audio capabilities	*+	Features related to the audio capabilities (formats, channels, bit rate, sample rate, etc.)
	Interactive media	*	Does it let run Interactive media (flashlite, java, etc.)?

* It can be obtained from WURFL specification.

\+ It is a group of capabilities that gathers more detailed characteristics (Gómez, 2009).

Based on the different existing types of handheld devices (presented in section 2.1.2) and the previous analysis of the capabilities categories in which WURFL represents the technical characteristics of mobile devices, four main generic groups in which mobile device types can be grouped were defined (see Table 5-13), so as adaptation rules for learning resources can be defined based on the capabilities of a selected device profile from each generic group which attempts to encompass the mobile device types in each group.

Table 5-13 Mobile Devices Groups

Group	Type	Examples
Mobile phones	Feature phone	LG EnV Touch, Samsung Mythic, Sony Aino
	Smartphone	Blackberry, Samsung Galaxy, iPhone, HTC, Nokia N900
Personal Digital Assistants (PDA)	Low-end PDA	Palm Zire
	High-end PDA	Pocket-PC, HP-iPAQ, Dell Axim
Tablet Computers	Ultra-mobile PC (UMPC)	Microsoft UMPC, VilivX70, Samsung Q1
	Tablet PC	iPad, HP Slate, Samsung galaxy Tab, Dell mini 5
Media players	Media player	iPod, Samsung S3, Creative Zen X-Fi
	Portable gaming console	Sony PSP, Nintendo DS

Accordingly, four default delivery device profiles (smartphone, high-end PDA, Tablet PC and portable gaming console) were identified based on the analysis of the characteristics of the mobile devices types, because they present generic technical capabilities that can be used to obtain a first set of adapted resources that can be delivered in the majority of users' mobile devices. Moreover, to achieve adapted resources only some technical capabilities were selected from the complete analysis due to, in this work only a set of capabilities are considered from the beginning. In Table 5-14 the four selected default delivery device profiles are presented, as well as their considered technical capabilities and the recommended values for the capabilities. Values in Table 5-14 were obtained from suggested recommendations in (W3C-MBP, 2008) and (Low, 2007).

Table 5-14 Default delivery device profiles

	Default delivery device profiles			
Technical capabilities	**Smartphone**	**High-end PDA**	**Tablet**	**Portable gaming console**
Display: type, colors and resolution (pixels)	TFT touch screen, 256K colors, 480 height x 320 width.	TFT touch screen (stylus), 256K colors, 320 height x 240 width.	TFT, True colors, 600 height x 1024 width.	LCD 256K colors, 272 height x 480 width
Audio support	Polyphonic (64 channels), MP3, 3GP.	Polyphonic (40 channels), MP3, AAC.	MP3, AAC	MP3, AAC.
Image support	JPEG, GIF.	JPEG, GIF.	JPEG, GIF.	JPEG, GIF.
Video support	H.263, MPEG-4, 3gpp.	H.263, MPEG-4, 3gpp.	H.264, H.263, MPEG-4, 3gpp, WMV, AVI.	H.263, MPEG-4.
Markup language support	XHTML, HTML, CSS	XHTML, HTML.	XHTML, HTML, CSS	XHTML, HTML.
Text support (documents, spreadsheets, presentations)	Yes	Yes	Yes	-
Dynamic content support	Java.	Java (MIDP 2.0).	Java (MIDP 2.0).	Java.

Previous analysis of digital content's properties

Multimedia content has been a relevant part of any technology-based learning design process. In our context-aware adaptation process in design approach its transformation is proposed so as to they can be suited to the capabilities of the learner's delivery device at hand. Thus, we perform a previous analysis of the digital content properties and their possible values that can be customized.

Related work done in (Low, 2007) presents a set of recommendations on how different digital contents can be built based on good practices for m-learning. The recommendations are described as a report of the analysis of various elements (platforms, content, support standards and delivery technologies) involved in a process of delivering m-learning experiences and as an approach for defining m-learning standards.

In our work some of the recommendations described in (Low, 2007) for designing content were used, involving properties' values for audio, video, images and web content (Gómez et al., 2009a). A detailed description of content features and recommended design aspects can be found in (Low, 2007).

Hereafter, some properties that can be used for transformation process were identified (see Table 5-15). Next, properties values considered for designing mobile content were analyzed and attempted to be used so as to identify transformation parameters for content properties and define the adaptation rules. The adaptation rules are presented in next subsection.

Table 5-15 Resource types and properties

Resource	Properties
Audio	content type, sampling rate, channels, bit rate
Image	content type, color scheme, width, height
Video	content type, Visual (width, height, frame rate, bit rate), Audio (sampling rate, channels, bit rate)
Web content	content type, width, height

Adaptation rules definition and evaluation

Adaptation rules describe the transcoding values that should be assigned to some parameters for transforming resources' (e.g. audio, image, video, web content) properties according to the capabilities of the selected four delivery device profiles.

Transcoding parameters were selected by means of studying and analyzing that selected content properties are compatible with content properties description made in the OMA Standard Transcoding Interface specification (OMA-STI, 2005) proposed by the Open Mobile Alliance (OMA). OMA-STI let describing how content properties can be set to produce a group of transcodification requests, as well as it provides a standardized interface for applications hosted on an application server, allowing them to manage a communication protocol for sending transcoding requests to a transcoding server and receive appropriate responses for those requests.

At the end, definition of these rules is carried out after performing the analysis on the technical capabilities of handheld devices and the analysis of properties of content that can be customized by a transformation process (Gómez & Fabregat, 2010). Table 5-16 describes the defined adaptation rules according to the default delivery device profiles. The adaptation parameters for the resources used the names proposed by the OMA-STI for generating transcoding jobs.

Table 5-16 Resource adaptation rules for the default delivery device profiles

Resource		Default delivery device profiles			
		Smartphone	**High-end PDA**	**Tablet**	**Portable gaming console**
Type	**OMA-STI parameters**	**Transcoding values**			
Audio	content-type	audio/mpeg	audio/mpeg	audio/mpeg	audio/mpeg
	sampling-rate (Hz)	44100	44100	44100	44100
	channels	Stereo	Stereo	Stereo	Stereo
	bit-rate (bps)	96000	96000	128000	96000
	codec	audio/mp3	audio/mp3	audio/mp3	audio/mp3
Image	content-type	image/jpeg	image/jpeg	image/jpeg	image/jpeg
	colorScheme.scheme	PaletteColor	PaletteColor	PaletteColor	PaletteColor
	width (pixels)	480	240	960	320
	height (pixels)	320	200	640	272
Video	content-type	video/mp4	video/mp4	video/mp4	video/mp4
	videoVisual.width (pixels)	480	240	960	320
	videoVisual.height (pixels)	320	200	640	272
	videoVisual.framerate (fps)	24	20	30	24
	videoVisual.bitrate (bps)	768000	50000	1500000	225000
	videoVisual.codec	mpeg4	mpeg4	mpeg4	mpeg4

	videoAudio.sampling-rate (Hz)		44100	44100	44100	44100
	videoAudio.channels		Stereo	Stereo	Stereo	Stereo
	videoAudio.bit-rate (bps)		96000	32000	128000	96000
	videoAudio.codec		audio/mp3	audio/mp3	audio/mp3	audio/mp3
Web content	content-type		XHTML_BASIC_1_1	XHTML_BASIC_1_1	XHTML_BASIC_1_1	XHTML_BASIC_1_1
	Width (pixels)		480	240	960	320
	Height (pixels)		320	200	640	272

The described values in the adaptation rules are assigned to the parameters for transcoding audio, image, video and web content resources according to default delivery device profiles. In Table 5-16 some transcoding values are the same for some device profiles, therefore, only one request is created for those cases.

Presented rules are stored in a database and are available to be consulted by the evaluation module, which then is in charge of sending the list of resources grouped by resource type along with the transcoding parameters respectively to the transcoding request creator (see Figure 5-4)

5.4.3 Transcoding processing

After evaluating a set of adaptation rules to obtain transcoding parameter values for the resources, a set of transcoding requests are created, which then are sent to a transcoding server (see Figure 5-7). The outcome of performing transcoding jobs are four sets of new transformed resources (audios, videos, images and web contents) adapted to the capabilities of each delivery device profile (smartphones, high-end PDA, tablets and portable gaming consoles) and available to populate and create four new adapted educational scenarios (one per each device profile) (Gómez & Fabregat, 2012).

As stated by Zhang, "*it takes considerable time to produce in run-time the adaptive content delivery dynamically according to a learning lived context* (Zhang, 2007)". In this work it was proposed that transcoding content and producing context-aware adapted educational scenarios in design-time would avoid learners and the system to execute transcoding processes in run-time from the beginning. Real-time transcoding is when the transcoding is being done on-the-fly or as the content is being played back and this can represent a delay for delivering adapted m-learning materials (Thomas, Yannis & Vana, 2009). However, combining transcoding processes in both design-time and run-time will provide learners with educational scenarios that can be accessed anytime, anywhere without restrictions of the capabilities of the delivery end and in the right time.

A transcoding process consists of a set of steps to transform the technical properties of one or more digital content (if you want to see examples of transcoding types, please see section 3.3.1). In the execution of a transcoding process it is necessary to determine what formats and transcoding parameters are used to have a desired outcome. Hereafter, in this module a set of transcoding requests (XML files) are described following the guidelines of the OMA-STI to request a transcoding job (OMA-STI, 2005).

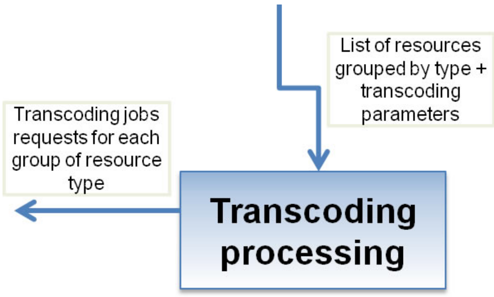


Figure 5—7 Transcoding requests creation.

The functionality of the transcoding requests creation module is to receive all transcoding parameters and the list of resources grouped by resource type (audio, image, video and web content) to create XML structures that describe one or a set of transcoding jobs.

Requests are created for each resources group of the same type. Multiple transcoding jobs are supported by the OMA-STI through a single request (see Figure 5-8). Currently OMA-STI specification only supports generation of transcoding jobs to resources of type image, audio, video, and web content.

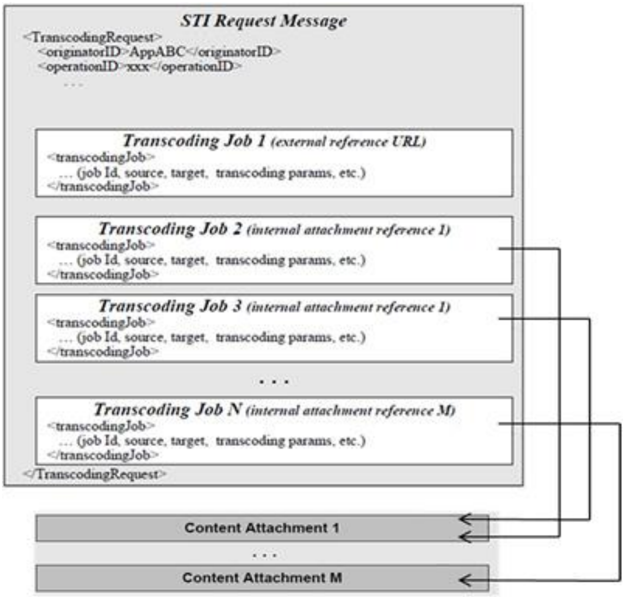


Figure 5—8 Structure of a group of transcoding jobs request. Extracted from (OMA-STI, 2005).

An example of the structure of these files for the educational scenario 2 is shown in Table 5-17. The example shows a transcoding job request for an audio resource.

Table 5-17 Example of structure of a OMA-STI transcoding request for an audio resource of the educational scenario 2

Transcoding request

```
<?xml version="1.0" encoding="UTF-8"?>
<env:Envelope                               xmlns=http://www.openmobilealliance.org/schema/sti/v1_0
xmlns:env=http://schemas.xmlsoap.org/soap/envelope/>
<env:Body>
  <TranscodingRequest>
    <originatorID>authoring_1</originatorID>
    <operationID>001</operationID>
    <transcodingJob>
      <jobID>audio_1</jobID>
      <source>
        <contentType>audio/amr</contentType>
        <location>
           http://pack.udg.edu/scenarios/ Set_up_your_business/audio/radio_adv.wav
        </location>
      </source>
      <target>
        <externalLocation>
          <path>
            http://pack.udg.edu/scenarios/smartphone/Set_up_your_business/audio/radio_adv.mp3
          </path>
          <name>radio_adv</name>
        </externalLocation>
       <transcodingParams>
          <contentType>audio/mpeg</contentType>
          <samplingRate>44100</samplingRate>
          <channels>Stereo</channels>
          <bitRate>96000</bitRate>
        </transcodingParams>
      </target>
    </transcodingJob>
  </TranscodingRequest>
</env:Body>
</env:Envelope>
```

Although, the example in Table 5-17 presents a single transcoding request, the elements of OMA-STI specification for transcoding requests let defining several transcoding requests in a single transcoding XML file (see Figure 5-8). Table 5-17 highlights the elements which are filled with the information of transcoding parameters for and audio resource based on audio resource properties recommendations for the *smartphone* profile, which are:

- contentType = audio/mpeg
- samplingRate = 44100
- channels = Stereo
- bitrate = 96000

This process ends with the creation of 16 transcoding jobs structured as follows: 1 job for each resource type (audio, image, video, web content) and for each delivery device profile (smartphone, high-end PDA, Tablet, and portable gaming console). Then, these jobs are sent to the transcoding server.

After transcoding jobs are created, a *Transcoding server* receives and performs the transcoding jobs so as to deliver adapted resources and responses with the results of these performed jobs as outcomes (see Figure 5-9).

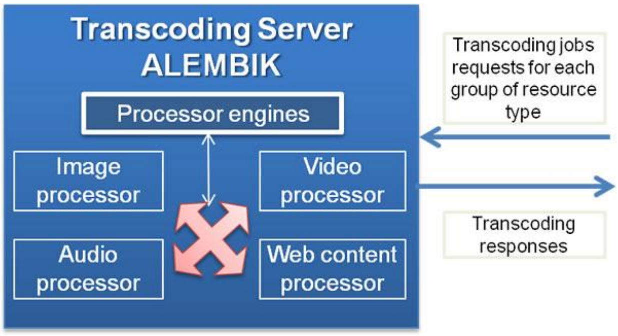


Figure 5—9 Transcoding server

Transcoding server

In this phase, Alembik transcoding server (Bellinzona, Raibulet, 2012) is used to run content transformations according to the capabilities of mobile devices. Here, Alembik receives transcoding requests to transform resources properties and to generate adapted resources to the delivery device profiles. Alembik is an open source server developed in java and whose architecture is based on the use of the HTTP and SOAP protocols to manage the communication with an application (for example an authoring Learning Design tool or a Learning Designs repository) that send transcoding requests to it. Moreover, the architecture of Alembik server is compatible with OMA-STI specification so as it let providing a standardized interface that allow communicating with different transcoding resource processors (image, video, audio and web content processors).

Transcoding jobs with the new properties for each resource are performed by Alembik. Hereafter, transcoding jobs are performed based on received transcoding parameters. Each transcoding job is done consecutively in the order in which requests have been received. After the resources are transcoded they are stored on a transcoded content repository, which is defined as a cache repository because the adapted content can be reused insofar as an adapted educational scenario uses that content in its structure.

A transcoding server has become the appropriate tools to perform proper execution of multiple transcoding processes synchronously, as well as asynchronously (to avoid big delay times). A transcoding server is a service provider of transformation and recoding of different types of digital content (such as images, audio, video, among other content types) as well as other specific transformation processes as described in (Vanderheiden, 2003).

Generally, the architecture of such a server consist in waiting for requests that contain one or more transcoding jobs on a list, in which, each transcoding job consist of a set of data related to the location path of a resource and a set of transcoding parameters that specify the transformation properties that are desired for that resource. After the server received that information and has validated the request, a transcoding process can be initiated. Then, the server can select the appropriate resource processor that executes the transformations and generates the right results for the request. The result returned to the client (e.g. an authoring tool, a learning design repository or a mobile device) is a response containing the list of results for all transcoding jobs. The data structure of the results also follows the guidelines of the OMA-STI specification. In general, each result contains a URL that points to the location of the transcoded file and a successful or error message that refers to a successful or possible failure in transformation respectively. An example of a transcoding process response for an audio resource from the exemplary educational scenario 2 is shown in Table 5-18.

Table 5-18 Example of structure of a OMA-STI transcoding response for an audio resource from the educational scenario 2

Transcoding response


```
<?xml version="1.0" encoding="UTF-8"?>
<env:Envelope xmlns=http://www.openmobilealliance.org/schema/sti/v1_0
xmlns:env=http://schemas.xmlsoap.org/soap/envelope/>
<env:Body>
  <TranscodingResponse>
    <originatorID>app_1</originatorID>
    <operationID>001</operationID>
    <mainReturnResult>
      <returnCode>2000</returnCode>
      <returnString>Success – Successful Result</returnString>
    </mainReturnResult>
    <totalDuration>30</totalDuration>
    <jobResult>
      <jobID>audio_1</jobID>
      <mainReturnResult>
        <returnCode>2000</returnCode>
        <returnString>Success – Successful Result</returnString>
      </mainReturnResult>
      <totalDuration>30</totalDuration>
      <output>
        <contentType>audio/x-mpeg</contentType>
        <location>
            http://pack.udg.edu/scenarios/ smartphone/Set_up_your_business/audio/radio_adv.mp3
        </location>
        <mediaSize>3478</mediaSize>
      </output>
    </jobResult>
  </TranscodingResponse>
</env:Body>
</env:Envelope>
```


The response contains the resulting transcoding data. This example highlights the path corresponding to the location of the new transformed resource so as it can be used by the adjustment and creation module.

In the structure of the response, output parameters (<output>) refer to the results of the transcoding operation. For example, the size of the resource (<mediaSize>) is the size in bytes of the file after being transcoded.

5.5 Adapted Learning Designs creation

After transcoding jobs have been performed by the *Transcoding server*, a set of content adaptation results for each job is created and the results of that process are received by the *Transcoding processing* module, in which, the creation of new adapted context-aware learning scenarios is performed.

Adapted content creation is the last phase of the content adaptation in design approach, and here, learning resources are transformed and new adapted educational scenarios are created. Specifically, during this final phase, a number of different adapted context-aware educational scenarios are created (one per each selected profile of mobile device) populated with the transcoded versions of educational resources suited to the capabilities of each mobile device profile (see Figure 5-10).

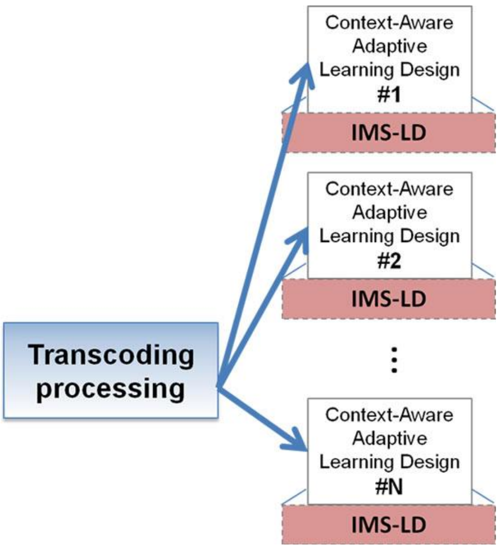


Figure 5—10 Adapted Learning Designs creation

This process consists in using the same xml structure (i.e. imsmanifest.xml file) of the original educational scenario so as to generate four copies of that XML file, i.e. one copy per each delivery device profile. In each new educational scenario the values in the attribute "href" of the <Resources> elements are modified, indicating the new path where the new adapted resources are located. At the end, those adapted scenarios are stored in a repository where they will be available for delivery at the run-time.

5.6 Testing

In order to verify the adaptation outcome after passing through the transcoding process, some adapted resources were reviewed (Gómez & Fabregat, 2012). In Table 5-19 are presented four adapted versions of an image type learning resource, from the educational scenario 2, which were reviewed on different mobile browser emulators. Also, in Table 5-19 the values of the parameters (content type, color scheme, height and width) that were used to perform the transcoding process are illustrated.

Table 5-19 Transcoded versions of an image resource from the educational scenario 2

<table>
<tr><th colspan="2">Original resource *</th></tr>
<tr><td colspan="2">
</td></tr>
<tr><td colspan="2">Name: adv_magazine.png
ContentType: png
ColorScheme: True
Height: 1215 pixels
Width: 2000 pixels
Size: 6,65 Mb</td></tr>
<tr><th colspan="2">Transcoded versions of the resource**</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th>Smartphone **
(Blackberry Storm 9530 emulator)</th><th>High-end PDA **
(HTC Blue Angel PDA browser emulator)</th></tr>
<tr><td>Name: _tnsc_adv_magazine.jpeg
ContentType: jpeg
ColorScheme: True
Height: 292 pixels
Width:480 pixels
Size: 108 KB</td><td>Name: _tnsc_adv_magazine.jpeg
ContentType: jpeg
ColorScheme: True
Height:200 pixels
Width: 240 pixels
Size: 34 KB</td></tr>
</table>

<table>
<tr><td>
</td><td>
</td></tr>
<tr><th>Tablet ***
(iPad Browser emulator - http://ipadpeek.com/)</th><th>Portable gaming console **
(Sony PSP browser emulator)</th></tr>
<tr><td>Name: _tnsc_adv_magazine.jpeg
ContentType: jpeg
ColorScheme: True
Height: 583 pixels
Width: 960 pixels
Size: 368 KB</td><td>Name: _tnsc_adv_magazine.jpeg
ContentType: jpeg
ColorScheme: True
Height: 272 pixels
Width: 320 pixels
Size: 55 KB</td></tr>
</table>

* Image reduced to 12% of its original size
** Image reduced to 50% of its original size
*** Image reduced to 25% of its original size

5.7 Summary and discussion

This chapter emphasizes on the development of the proposals for the design approach presented in chapter 4. The implementation for the design approach is presented as follows: i) the context model is described. This model is based on a set of contextual elements gathered and grouped from different identified elements from the reviewed literature. Here, it can be confirmed that at present, there are not a defined standard that describes the characteristics that represents the learner's context for m-learning environments which can be applied to the implementation of adaptation processes; ii) an adaptation process to achieve authoring context-aware and adaptive educational scenarios is explained phase by phase. The proposed adaptation process in design-time approach consists of three different phases, of which two phases describe a dynamic content adaptation. Outcomes of this adaptation are: a) transformed content (populating a developed Learning Design) according to mobile device capabilities, and b) adapted IMS Learning Designs populated with adapted content and designed with the definition of context-aware conditional statements with regards to the elements of the mobile context (learners temporal information, people, place, time and physical conditions) presented in Appendix A; and iii) some testing made of the implementation is described at the end of the chapter.

In addition, two exemplary educational scenarios were presented so as to explain how an educational scenario can be authored and how contextual information is intended to be described in its structure. To achieve this, the IMS-LD specification was adopted and it is used to describe the learning design elements as well as context-related properties and a set of conditional rules that are evaluated to provide context-aware adaptations.

Moreover, the design of the scenarios aims to present how learner's contextual information (based on characteristics of the *Learning and Mobile context* categories presented in Table 5-2) can be used for adapting its learning flow towards implementing and demonstrating these adaptations in our developed mobile delivery system (presented in chapter 6). Thus, each educational scenario is based on our context-aware design approach, considering contextual elements presented in Appendix A, to support personalized and adaptive m-learning.

With regards to the dynamic content adaptation, work presented in this chapter describes a *content transformation* process (oriented as web services) that can be integrated with an authoring tool so as to facilitates adaptations of the educational content, used by the author and that is populating an educational scenario to the learners' mobile devices. The aim of this process is that a content adaptation process can be dynamically executed when an authored educational scenario for m-learning is ready to be packaged and published for learners. Here it can be states that a so-called adaptation of content proposed in this research is not an isolated system, rather easily combined with other systems (such as a Learning Design authoring tool or a Learning Designs repository), which may get original contents from educational scenarios and adjust adaptive contents according to learning context awareness: device's capabilities.

To sum up, it has been presented how contextual information in the structure of a notation language for designing the learning process, such as the IMS-LD specification, can be modeled and described. An architecture for retrieving and processing contextual information considering context-aware adaptive mechanisms and deliver adapted educational activities and educational content to the learner mobile device is presented. Implementation of the architecture was made for design-time using a content transcoding mechanism and defining some conditional statements in the structure of the IMS-LD standard taking into account contextual information related to the elements of the presented context-model.

CHAPTER 6

DELIVERING CONTEXT-AWARE AND ADAPTIVE MOBILE EDUCATIONAL SCENARIOS (RUN-TIME)

This chapter emphasizes on the implementation in the *delivery approach* of the learning design process. This chapter along with Chapter 5 addresses the activities defined in the implementation phase of the followed engineering research methodology.

Generally speaking, this chapter emphasizes on the development of the proposals for the *delivery approach* (presented in chapter 4) as follows: i) an introduction to the developed context-aware mobile delivery system, namely UoLmP, is described. UoLmP is able to support learners through every step in the learning flow of an educational scenario, providing them with learning activities that suit to the current learner's situation, as well as offering personalized learning resources, tools and services that support the activities and which are best suited to learner's current context; ii) an adaptation process, undertaken by UoLmP, to achieve delivering context-aware and adaptive educational scenarios is explained phase by phase, and iii) an usability study made for UoLmP and its results are described.

6.1 Units of Learning mobile Player (UoLmP)

In previous chapter the author of this thesis presented an adaptation approach that can be executed in design-time and it can be incorporated in learning design authoring tools. This approach allows learning designers to consider contextual information from the *mobile context* category (see Table 5-2) such as the place and physical conditions of where the learner can be located, the support of surrounding people, the availability of peers as well as their personal characteristics (interests, needs, preferences, etc.) and the capabilities of the mobile device at hand. Hence, Learning Design authors have the possibility to decide what contextual characteristics can consider for adaptations in a procedural learning plan from a set of pre-defined attributes and values (see some examples of these values in Appendix A) that afterwards can be represented on set of adaptation rules (i.e. conditions). Moreover, that approach considers a dynamic adaptation of content when an authored Learning Design is ready to be packaged, so as to facilitate creation of adaptive educational scenarios that suits to the capabilities of different mobile devices.

In this chapter, the author aims to propose an adaptation approach that supports the delivery of created adaptive context-aware educational scenarios through a mobile delivery system, namely UoLmP. This system aims to exploit and process information from the presented context model so as it can dynamically adapts to the changing context during the learning process in run-time, and provides learners with tailored learning experiences to their personal context (Gómez et al., 2012).

UoLmP can process created and packaged educational scenarios (i.e. UoL) via mobile devices by parsing IMS-LD elements of the manifest file included in a Learning Design package. Moreover it can retrieve instances for defined context-aware properties, as well as it can processes context-aware conditional rules that influence the paths defined in the learning flow and the delivery of educational materials (resources, tools and services). Thus, authored context-aware educational scenarios that were created in design-time can be adaptively delivered and run in this system.

Similar to the design approach, adaptivity in the delivery approach is also based on both adaptation mechanisms: *polymorphic presentation* and *content filtering* (further description of each mechanism can be seen in section 3.3.1). Nevertheless, in run-time these mechanisms work slightly different as follows:

- *Polymorphic presentation*: its aim is the same as the mechanism in design-time: execute content adaptations. However, in run-time this mechanism considers the digital capabilities of the current learner's device. The implementation of this mechanism is based on web services and can be executed independently and previously to the execution of an educational scenario (i.e. when a published authored Learning Design is selected by a learner to be downloaded into her/his mobile device). The process of this mechanism will be explained in section 6.4.
- *Content filtering*: in run-time this mechanism consists of making decisions based on the evaluation of a pre-defined structured context-based decision/conditional tree (i.e. each leaf (state) contains at least one context-aware conditional statement) within a created Learning Design manifest file in design-time. More specifically, the mechanism in run-time is based on processing IMS-LD Level B properties, global elements and conditions so as to evaluate current retrieved learner’s contextual instances in order to filter (showing or hiding) the presentation of learning activities, educational resources, tools and services. The process of this mechanism is explained in section 6.5.

Hereafter, UoLmP supports the delivery of educational materials through the interpretation of IMS-LD level B oriented learning scripts and it is able to retrieve contextual information and processes context-aware adaptation rules so as to enable adaptations. Both retrieving and processing aspects are held in run-time by the system which is installed in the learner’s mobile device.

Based on the aforementioned adaptation approach UoLmP aims to support adaptations derived from the identified three main types of adaptation presented in section 3.4.1, namely: *Learning flow navigation and sequencing*, *Problem solving support and feedback (scaffolding)*, and *Interactive learners’ communication*. Therefore, in this research work it can be declared that UoLmP aims to provide a *General Adaptation* that combines the three types of adaptation (Martin & Carro, 2009). A *General adaptation* then, deals with automatic generation of individual learning activities based on different criteria derived from learners’ contextual elements as described in the context model presented in section 5.1. CoMoLE is one other identified example of a system which also provides a General adaptation (Martin & Carro, 2009) based on a set of contextual elements form the context model. That system aims to support the generation and recommendation of different types of adaptive learning activities, which can have associated multimedia contents as well as collaborative tools to support the interaction between learners.

Here, a comparison between the identified context-aware m-learning systems (presented in section 3.4.2) and UoLmP, with regards to the types of adaptation they address and the contextual information they retrieve and process (referencing the classification made in the context model presented in Table 5-2) to provide such adaptations, is presented in Table 6-1 (Gómez et al., 2013b). Recalling the context model, learner's contextual information was divided into two main categories (namely, learning context and mobile context), in accordance with the characteristics and the dimensions of these categories described in Table 5-2.

Table 6-1 Comparison of existing context-aware m-learning systems

Adaptation Type	Context-Aware and Adaptive M-learning Systems	Learning Context		Mobile Context					
		Learning Design	Learner Profile	Learner temporal information	People	Place	Artifact	Time	Physical Conditions
Learning flow navigation and sequencing	Hwang et al., 2008	-	-	-	-	√	-	-	-
	CMMCUL (Hwang et al., 2011)	-	-	-	-	√	-	-	-
	Tan et al., 2009	-	√	-	-	√	-	-	-
	Chiou et al., 2010	-	-	-	-	√	-	-	-
	PNSS (Chiou et al., 2012)	-	-	-	-	√	-	-	-
	Hwang et al., 2010	-	√	-	-	√	-	-	-
	Hwang et al., 2009	-	-	-	-	√	-	-	-
	Wang & Wu, 2011	-	√	-	-	√	-	-	-
Problem solving support and feedback (scaffolding)	TenseITS (Cui & Bull, 2005)	-	√	√	-	√	-	√	-
	TANGO (Ogata et al., 2005)	-	-	-	-	√	-	-	-
	LOCH (Paredes et al., 2005)	-	-	-	-	√	-	-	-
	CAMLES (Nguyen, Pham & Ho, 2010)	-	√	√	-	√	-	√	-
	Wu et al., 2012	-	√	-	-	√	-	-	-
	CAMCLL (Al-Mekhlafi et al., 2009)	-	√	-	-	√	-	-	-
	HELLO (Liu, 2009)	-	√	-	-	√	-	-	-
	JAPELAS2 (Yin et al., 2010)	-	√	-	-	√	-	-	-
	MOBIlearn (Lonsdale et al., 2004)	-	-	√	√	√	-	-	-
	PALLAS (Petersen, Markiewicz & Bjørnebekk, 2009)	-	√	-	-	√	√	√	√
	CAERUS (Naismith, Sharples & Ting, 2005)	-	-	√	-	√	-	-	-
	Yau & Joy, 2011	-	-	√	-	√	-	√	
	SCROLL (Li et al., 2012)	-	-	√	-	√	-	√	√
	PCULS (Chen & Li, 2010)	-	√	-	-	√	-	√	-

Interactive learners' communication	Martin et al., 2006	-	√	-	√	√	-	-	-
	PERKAM (El-Bishouty, Ogata & Yano, 2007)	-	-	-	√	√	-	-	-
	Social KAM (El-Bishouty et al, 2010)	-	√	√	√	√	-	-	-
	Martin et al., 2008	-	-	-	-	√	-	-	-
	Economides, 2008	-	-	√	-	-	-	-	-
General adaptation	CoMoLe (Martin & Carro, 2009)	-	√	-	√	√	-	√	-
	UoLmP (Gómez et al., 2013a)	√	√	√	√	√	√	√	√

Consistently, UoLmP supports learners through every step in the learning flow of an educational scenario, providing them with learning activities that suit to the current learner's situation, as well as offering personalized learning resources, tools and services that support the activities and which are best suited to learner's current context. More details of this system are explained in next sections.

Although, UoLmP has initially been tested and evaluated with the delivery of educational scenarios constructed for language learning environments (this is further described in chapter 7), it has been implemented to be used in any field of learning that aims to deliver adaptive learning materials in mobile environments. Thus, it supports the delivered of other different educational scenarios in which the key is to adapt activities and create workspaces for individual learners, as well as groups that can interact in different contexts, for instance it can be applied for training in the business world.

In next sections, it is presented the details of the adaptation approach behind UoLmP by describing the overall architecture operation and specifically how each adaptation mechanism is performed. Moreover, a usability test and evaluation is presented as a previous step before its validation with learners of a real language learning center (described in chapter 7).

6.2 Phases of adaptation in run-time

Bearing in mind that implementation of Learning Design begins in the design approach, delivery approach characterizes because outcomes from design-time are used and executed in real time. Thus, real contextual information exposed by and retrieved from the learner's situation is considered so as it can be processed in run-time. To achieve this, a mobile device and an integrated adaptation engine can be used to detect/capture and process real contextual information respectively.

The proposed adaptation approach in run-time consists of three phases (See Figure 6-1) in which a) *mobile content adaptation execution*, perform a dynamic content adaptation and b) *adapted educational scenarios delivery* perform a dynamic context-aware educational scenarios adaptation.

On the one hand, inputs of (a) are the current learner's device capabilities. Output of (a) is the delivery of adapted educational scenarios previously designed in design-time or new transformations to the learning resources (populating a constructed Learning Design) according to capabilities of the current mobile device at learner's hand. On the other hand, inputs of (b) are the output of (a) and the current learner's context instances. Outputs of (b) are: delivery of adapted learning flow sequence (i.e. filtered learning activities), adapted problem solving support (i.e. supportive resources and mobile tools) and adapted interactive learners' communication (i.e. appropriate communicative mobile services) according to detected/captured context-related real instances (i.e. from the lived learner's situation and environment) and the evaluation of previously defined adaptation rules (Gómez & Fabregat, 2010).

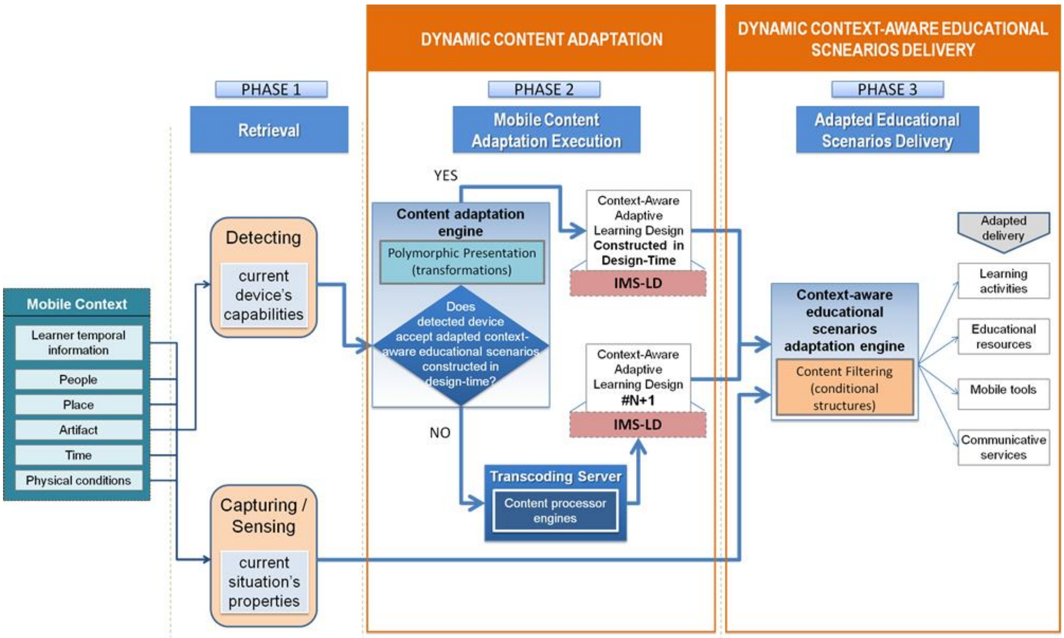


Figure 6—1 Phases of adaptation process in the delivery approach (Gómez & Fabregat, 2012)

These phases were introduced in chapter 4, section 4.3. Here, each phase is briefly described as follows:

1) ***Retrieval***: Instances/Values from the learner's context related to the dimensions of the *mobile context* category, namely learner temporal information, people, place, artifact, time and physical conditions (see Table 5-2 for further description of each dimension) are detected/sensed by the learner's mobile device or they can be captured by learner's input.
2) ***Mobile Content Adaptation Execution***: In this phase, the results of new Content Transformation (transcoding process) performed for an educational scenario are presented to the learner's mobile device, only if learner's mobile device is not able for delivering context-aware educational scenarios created in design-time. Otherwise an adapted context-aware Learning Design created during design-time can be downloaded to learner's mobile device.
3) ***Adapted Educational Scenarios Delivery***: In this phase, context-aware adaptation rules of the current Learning Design are processed based on current detected/captured learner's contextual information.

Adaptation at run-time differs from adaptation at design-time in the moment in which the phases are executed (i.e. in run-time), as well as the adaptation level (i.e. a combination between server-side and client-side). At run-time the adaptations are carried out in client-side with only one exception that can be ran at server-side, that is, when a learner is searching for a designed educational scenario. For instance, when a leaner is interacting with UoLmP and it is searching to download an educational scenario from an available repository, the capabilities of the leaner's device at hand are evaluated, so as to validate if the designed scenario that the learners selected can be delivered or a new transformation process needs to be executed regarding the current device's capabilities.

The presented phases of context-aware adaptive educational scenarios delivery at run-time can benefit from the results of the corresponding process at design-time level. This is due to the fact that the transcoding process at *Mobile Content Adaptation Execution* phase in run-time can be avoided if a learner's mobile device can deliver already transcoded educational resources that have been developed and adapted during design-time. Consequently, this can significantly reduce the time of delivering adapted mobile educational content to a learner's mobile device.

In next sections, the author of this thesis aimed to address delivering well-defined and structured adaptive and context-aware educational scenarios via mobile devices by describing the phases of the proposed adaptation approach incorporated in UoLmP.

6.3 Contextual information retrieval

At run-time, contextual information is retrieved on the go. In adaptive mobile environments contextual information retrieval consists in mobile data collection by mainly three different ways: i) detecting, ii) sensing or iii) capturing, so as to provide the resources, tools or services that better suits to user's personal context.

i) **Mobile detection** commonly refers to the action or process performed by systems to identify the type of mobile device visiting the system, so as to adapt the delivery resources, tools or services that suit the end user's device (Zhao, 2010).

ii) **Mobile sensing** consists in measuring physical data (e.g. location, physical conditions, etc.) that can be converted into readable signals by the learner's client device. Nowadays, mobile devices come with a growing set of cheap powerful embedded sensors, such as an accelerometer, digital compass, gyroscope, GPS, microphone, and camera that receive information from or send information to other identification, location or sensing technology devices (Lane et al. 2010).

iii) **Mobile capturing**, on the other hand, refers to data retrieved or recognized from user's direct inputs which commonly consist of keying, selecting, tapping, writing, etc. (Cui & Bull, 2005).

For instance, information of the *mobile context* category regarding the learner's access device and its capabilities can be detected by a server-side system (e.g. a Learning Design repository) by receiving information from the device profile, which mainly it is defined by the user agent of the learner's device. Alternatively, contextual information such as the learner's location, time and physical conditions of the place can be detected/sensed from the learner's client device by receiving information from or sending information to identification, location or sensing technology devices, which could be placed in places where students frequently interact with systems, for instance, in different zones of a campus, inside a museum, inside the house, etc. Moreover, contextual information that involves learner's personal temporal information such as interests, attitude, needs, etc., as well as people's contribution and available time can be captured by user's input into the mobile device.

In this research work, as first scope, detection and capturing were considered as retrieval mechanisms for mobile contextual information. Thus, devices' capabilities are detected by a system so as to decide whether a produced Learning Design can be delivered to the learner's mobile device at hand or otherwise a content adaptation is needed. Moreover, contextual elements regarding learner's personal temporal information and people's contributions are captured by user's input, as well as, learner's location, time and physical conditions retrieval is also proposed to be captured by user's input as first scope. In the work presented in this dissertation is not implemented sensing information from learner's context, that is, sensing mechanisms are not used to retrieve learner's location, time and physical conditions of the place. However, instances for those contextual elements are retrieved by user's input because they are part of the learner's mobile context considered in this research work.

6.3.1 Device capabilities detection

At run-time, a set of adapted educational scenarios (UoL), created at design-time, are available to be delivery on the learner's mobile device. When a learner requests to download a created Learning Design the proposed adaptation process initiates the evaluation of a set of validation rules (further details are explained in section 6.4) by retrieving learner's contextual information regarding to the mobile device capabilities. In this research work, contextual information related to some technological digital properties of the mobile device, namely: sound format, image format (format, colors), display resolution (width, height), video playback support and markup xhtml support are considered to automatically be detected from the current learner's device at hand.

At this phase, learner's mobile device capabilities are considered to be detected and to implement this detection the WURFL specification is adopted because it defines the profiles of different devices, mainly described by the user agent of each device (Gómez et al., 2009b). In our detection mechanism features of learner's current device are retrieved from WURFL's device repository by matching the value in the learner's device user-agent header (see Table 6-2), which is sent with the http headers from mobile device. Specifically, our detection mechanism adopts the algorithm of Levenshtein Distance (WURLF, 2008; Zhao, 2010) to match this value to WURFL's device repository.

WURFL's device repository is an XML configuration file that contains information about the capabilities and features of different existing mobile devices in market. The main objective of using the WURFL file is to collect as much information as possible about all mobile devices that may access an internet-oriented system or web site. Further details of WURFL were described in section 5.4.2. On the other hand, in this section the components from WURFL that were used in our detection mechanism are briefly described:

- <device> element

  <device> in WURFL contains a string "user-agent", an attribute "fall_back" and a unique ID. There may also be an attribute (actual_device_root = "true") that mark a device as "real". This attribute can be useful for the APIs that attempt to use WURFL to compile lists of readable devices by humans. Here, in Table 6-2 we present an example of the attributes presented in the <device> element for a Smartphone Samsung Galaxy II:

Table 6-2 Example of the description for a Samsung Galaxy mobile device in WURLF

<device id="samsung_sgh_t989_ver1"
user_agent="Mozilla/5.0 (Linux; U; Android 2.3.5; en-us; SGH-T989 Build/GINGERBREAD) AppleWebKit/533.1 (KHTML, like Gecko) Version/4.0 Mobile Safari/533.1"
fall_back="generic_android_ver2_3"
actual_device_root="true">

- Groups of capabilities

  The groups are intended to make WURFL more readable for people. The group names are self-explanatory. For example, there is a group called "mms" for the capabilities related with MMS messages, there is other group called "wml_ui" about the capabilities of the devices to support WML tags. An example of the definition of a group is as follows: <group id="sound_format">. The complete list of WURFL's groups of capabilities is shown in Table 6-3:

Table 6-3 Groups of capabilities in WURFL

product_info | wml_ui | chtml_ui | xhtml_ui | css | ajax | markup | cache | display | image_format | bugs | wta | security | bearer | storage | object_download | playback | wap_push | drm | streaming | mms | j2me | sms | sound_format | flash_lite | transcoding | rss | pdf | deprecated

- Capabilities

  Device capabilities are collected into the groups. The capabilities always have a value. Values can represent a boolean, a number or a string [including an empty string ("")]. An example of the definition of a capacity is as follows: <capability name="mp3" value="true"/>

  Some capabilities are self-contained, which means that you can see and understand some features of the device. Others must be used in combination with other capabilities. For example, if you want to know if a device is capable of displaying a GIF image you should check if "gif" capability is set to "true". In previous work reported (Gómez, 2009), a set of WURLF capabilities which can be appropriated for content adaptation was presented as appendix.

In Figure 6-2 a snapshot of an exemplary interface that shows detection of some capabilities for a smartphone (for the brand: LG-P500) device, is presented.

Figure 6—2 Device detection

6.3.2 Leaner's input capturing

In run-time, when a learner opens and starts completing the activities of a downloaded adaptive Learning Design through UoLmP using her/his mobile device, other adaptation process (i.e. *content filtering*) is initiated by capturing current learner's contextual information. Context's characteristics related to leaner's personal information, learner´s location, physical conditions of the place, people's contributions and peer's available time is retrieved by learner's input. In run-time, UoLmP is considered to execute adapted UoL and to let the user input contextual information that it is not possible to be gathered automatically (by sensors). This is an essential requirement so that the learner's current situation can be fully detected and recorded by the player.

UoLmP is able to capture during the run-time, the contextual elements instances of which were pre-defined in design-time (Gómez et al., 2012). Since contextual information is retrieved in run-time, the tool parses properties, global elements and conditions of the IMS-LD Level B specification in order to capture and evaluate values for the considered contextual elements.

In order to achieve delivering educational materials to the learner's device, it is relevant to provide the adaptive engine in UoLmP with contextualized data for successful decision making. Thus, some contextual elements can have a known instance, (i.e. a pre-defined value), and thus can be taken into account in a decision-making process.

Contextual elements instances from the "Mobile context" category presented in Appendix A can be gathered by means of using *global elements* of the IMS-LD level B structure. They are XML constructs that extend the W3C XHTML specification and IMS-LD property values can be manipulated by them. Four *global elements* can be used by UoLmP: <set-property>, <get-property>, <set-property-group> and <get-property-group> so as to enable contextual information retrieving. Those elements can be rendered by UoLmP as either entry fields providing the possibility for the learner to change a property value, or text fields showing the properties' value. For instance, considering the exemplary educational scenarios presented in section 5.3.1, Table 6-4 presents the code of an XHTML file used to capture contextual instances for the set of properties presented in Table 5-6. In this code, it is highlighted the **<**set-property-group**>** global element that refers to the group of properties defined in design-time. Moreover, Figure 6-3 presents the interface in UoLmP after rendering the used XHTML file. Using forms or checklists can be an easy and efficiently way to capture learner's inputs about their actual contexts (Lonsdale, Baber & Sharples, 2004; Cui & Bull, 2005).

Table 6-4 Example of Global element "set-property-group" definition within an XHTML file

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
"http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">
  <head>
    <meta http-equiv="content-type" content="text/html; charset=ISO-8859-1" />
    <title>Contextual Information</title>
  </head>
 <body style="font-family: Verdana; font-size: 10pt;"><br />
  <set-property-group xmlns="http://www.imsglobal.org/xsd/imsld_v1p0" ref="property_group-1" property-of="self" view="title-value">
  </set-property-group>
 </body>
</html>
```

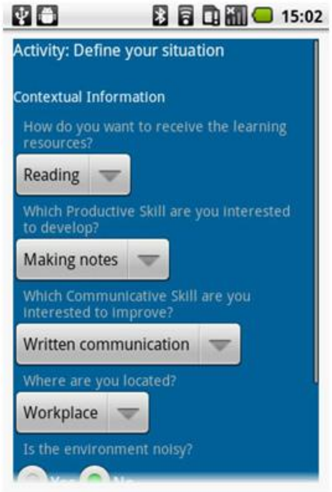


Figure 6—3 Contextual information capturing

However, there are some contextual elements that can be previously known, but their instantiations may not be pre-defined, so that, the instance of those contextual elements may change or may be known only in real time. For instance in the exemplary educational scenario 1 and 2 presented in chapter 5: learner' needs and preferences instantiations are not pre-defined but they are considered when the learner need of language support such as vocabulary, grammar and examples, and when the learner is inclined to an action such as selecting a m-learning tool or service, between a set of choices, to complete an activity respectively.

6.4 Mobile content adaptation execution (Content transformation in run-time)

In this section, it is explained how the capabilities of the learner's current device are validated in a adaptation engine that can be incorporated in content sharing systems (such as a Learning Design repository). Here, only the characteristics of the artifact dimension of the *mobile context* category is taken into account. The validation process evaluate whether the device at hand can appropriately run a designed educational scenario, or otherwise a *polymorphic presentation* process, as in design-time (see section 5.4), needs to be executed to produce a new personalized educational scenario that suits to the mobile device capabilities.

In the plethora of different mobile devices that learners can own, the author of this thesis focused on deliver adapted educational scenarios without restrictions of the different existing device capabilities. Hereafter, the work presented in this section describes a dynamic content adaptation process, namely *Mobile Content Adaptation Execution*, for run-time (see Figure 6-1). This process aims to adapt an existing and published authored context-aware adaptive educational scenario when the learner's device at hand is not able to run it. Within this process only the capabilities of the current learner's mobile device to transform the properties of the resources that are populating an authored educational scenario are considered.

Therefore, the author of this dissertation attempts to propose a content transformation engine for this process to be executed in run-time (See Figure 6-4) by content sharing systems as target end (Gómez & Fabregat, 2012).

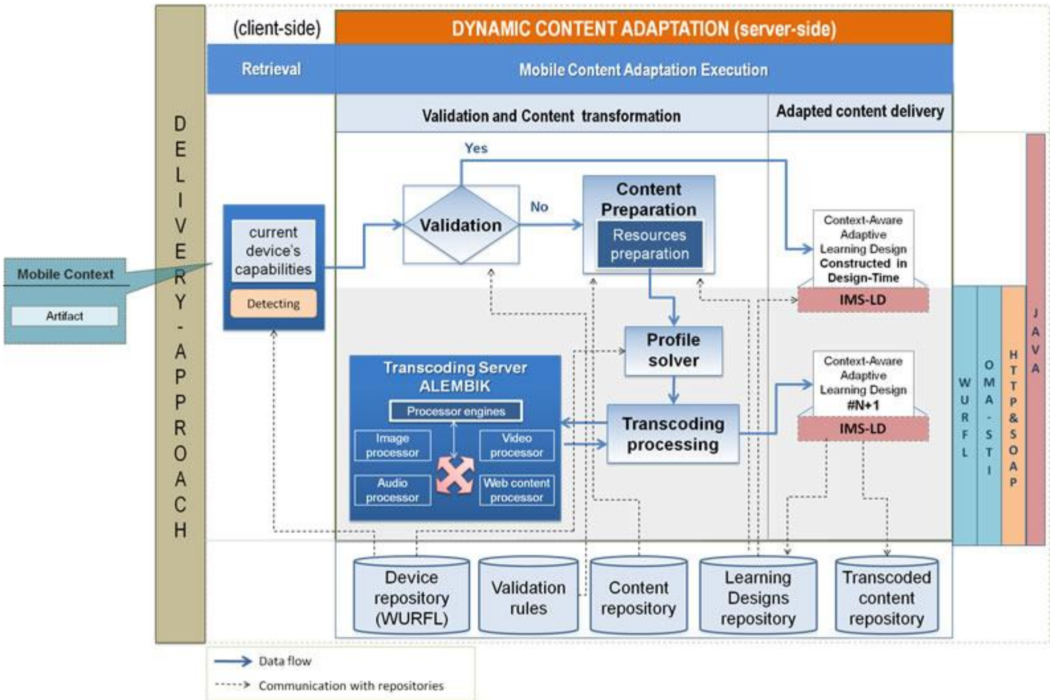


Figure 6—4 Architecture of the content transformation in run-time

Thus, developers of Learning Design repositories (run-time) can consider this engine in their tools to facilitate providing adapted Learning Designs in real time.

The architecture of this engine consists of two stages, which can be briefly described as follows (the next two sections present further details of them):

1) *Validation and Content transformation*: In this stage, values of current learner's device capabilities are validated so as to verify if they meet a set of defined acceptable capabilities' values. If the result of this validation is affirmative, then the learner's device accepts delivery of a requested educational scenario and the process finishes. If it is negative, the engine initiates a transforming adaptation process, similarly to one raised at design time, but with two differences:

   i) Transcoding parameters for resources are based on the capabilities of the learner's device used in real time.

   ii) Delivery of a new adapted educational scenario is performed in real time.

2) *Adapted content delivery:* In this stage, It is delivered only one adapted context-aware Learning Design populated with the transcoded version of educational resources suitable for the learner's mobile device profile.

Moreover, the proposed architecture is based on the combination of adaptation levels between client-side and server-side (i.e. the device client sends requests and capabilities to the system in the server, and the server deliver adapted content to the device client) because a transcoding process requires significant processing memory and this can only be provided by a server. Server technological characteristics may vary, but are still better than the characteristics of the client platform.

Programming and communications technologies of the components of the content transformation process at run-time are the same as the process in design-time [including Java language, web services protocols, OMA Standard Transcoding Interface (OMA-STI,

2005) and the transcoding server Alembik (Bellinzona & Raibulet, 2012)]. However, at run-time there are three new components: a) *WURFL device repository*, which provides data about the capabilities of every device in market and is used to identify capabilities of the learner's current device [main elements of WURLF's device repository were explained in section 5.4.2, for further information see (WURFL, 2008)], b) a *Validation* module that evaluates a set of validation rules so as to decide whether the current learner's device can receive authored Learning Designs or not, and c) a *Profile solver* module that generates a list with the transcoding parameters for digital content, associated to the new and current's device capabilities profile. The latter two components (b and c) are described in next sub-section.

Similar to design-time, the transforming functionality of the content adaptation process is implemented as a web service to allow targeted systems in run-time (i.e. Learning Design repositories) to invoke Learning Design adaptations for mobile devices. In next sub-sections, components of the architecture and development issues are explained with more details.

6.4.1 Validation and Content Transformation

From this stage and onward, contextual information related to the technological properties of the mobile device is considered to achieve educational content to be transformed. The validation of mobile access device capabilities may allow adapted Learning Designs and content to be delivered immediately.

In the *Validation* module it is determined whether the learner's mobile access device is capable of accepting the resources transcoded at design-time. Otherwise the delivery incompatibilities of the device are determined to generate more detailed transcoding requests considering its current capabilities.

Validation of device capabilities must be a process that avoid transcoding time delays, as there may be many contents available in the structure of a Learning Design that have to be delivered. Moreover, since transcoding is a CPU-intensive process (Liu, Chen & Shen, 2006) some related work have demonstrated that a transcoding process in real-time (i.e. at the moment when a resource is delivered to a user's mobile device), induced a certain time delay that can be translated to an unsatisfactory user's experience (Garcia, Kalva & Furht, 2010). Therefore, validation for starting a transformation process was defined to be performed before a Learning Design is delivered and not when is running.

Besides, this stage can benefit from the results of the corresponding process at design-time level. This is due to the fact that the transcoding process at *Mobile Content Adaptation Execution* phase in run-time can be avoided if learner's mobile device can deliver authored educational scenarios that have been transcoded during design-time level considering the four delivery default device profiles (i.e. smartphone, high-end PDA, tablet or portable gaming console). Consequently, this can significantly reduce the time of delivering adapted mobile educational content to a learner's mobile device. *Validation* consists of two options:

i) If learner's device capabilities present values that are included in a set of defined acceptable values, previously constructed and adapted context-aware educational scenarios at design-time can be immediately delivered to the learner's mobile device through UoLmP and *Mobile Content Adaptation Execution* is finished. The acceptable values of the capabilities defined for validation are presented in Table 6-5 (Gómez & Fabregat, 2012).

Table 6-5 Accepted parameters' values for the validation process

Target resource	OMA-STI parameters	WURFL group	WURFL device capabilities	Accepted values
Audio	contentType	sound_format	mp3, aac	true
Image	contentType	image_format	jpg	true
	colorScheme	image_format	colors	≥ 256
	width	display	max_image_width	Smartphone: 320 ≤ x < 720 High-end PDA: 240 ≤ x < 320 Tablet: 720 ≤ x ≤ 2048 Game console: 400 ≤ x ≤ 480
	height	display	max_image_height	Smartphone: 400 ≤ x ≤ 1136 High-end PDA 320 ≤ x < 640 Tablet: 640 ≤ x ≤ 1536 Game console: 192 ≤ x ≤ 272
Video	contentType	playback	playback_mp4	true
Web content	contentType	markup	xhtml_support_level	≥ 3

ii) Otherwise, if any of the access device capabilities do not meet with the acceptable values for those capabilities (i.e., the device has limitations to receive the adapted resources), a content transformation process is started (i.e. a similar transformation process as presented in design-time in section 5.4).

In the case that (ii) happens, after resources are identified and located within the structure of an authored Learning Design (which is intended to be downloaded by the learner) in the *Content preparation* module, the resources are sent to the *Profile solver* module to match their properties with the capabilities of the detected learner's mobile device. In run-time the transcoding values for the resource parameters correspond to the capabilities of the learner's mobile device at hand and they are obtained matching the mobile device user agent with its profile in the WURFL device repository. Thus, the *Profile solver* module will send a list with the transcoding parameters of the identified resources to the *Transcoding processing* module.

Finally, after receiving the transcoding parameters and the list of resources, the *Transcoding processing* module creates XML transcoding request structures (i.e. transcoding jobs) following the guidelines of the OMA-STI specification and they are sent to the *Transcoding server*.

As with design-time, transcoding jobs with the new parameters values for each resource are processed in the *Transcoding server*. The result of the transcoding process is the generation of transformed resources and an adapted educational scenario to the capabilities of the current access device that the learner is using. Then, new transformed resources are stored in the transcoded content repository, as well as the new adapted educational scenario in the Learning Designs repository.

6.4.2 Adapted content delivery

After transcoding jobs have been performed by the *Transcoding server*, a set of content adaptation results for each job is created and the results of that process are received by the *Transcoding processing* module, in which, the creation of a new adapted context-aware learning scenario (tailored to the current learner's mobile device capabilities) is performed.

This stage ends by delivering a single new adapted Learning Design (with transformed resources referenced within it) to the learner's mobile device Thus, the adapted educational scenario that the learner wants to execute through UoLmP is delivered to the mobile device at hand. In the new adapted educational scenario the values in the attribute "href" of the <Resources> elements, within the XML file, are modified, indicating the new path where the new adapted resources are located. At the end, the adapted educational scenario is stored in a repository from where it will be downloaded.

6.5 Adapted context-aware educational scenarios delivery

The work presented in this section describes the last phase of the proposed adaptation process in run-time, namely *Adapted Educational Scenarios Delivery,* which states for a dynamic context-aware educational scenarios adaptation process (see Figure 6-1). This process is proposed to run in UoLmP and it aims to present in the learner's mobile device at hand with authored context-aware educational scenarios that were designed with conditional structures (i.e. a set of adaptation rules) so as to deliver adaptively designed activities and materials based on learner's current context.

Besides that UoLmP was mainly designed as a Learning Designs delivery system aimed to enable the learner to follow the paths in a learning flow designed by the teacher, additionally, the system was implemented to address the use of mobile devices for capturing learner's contextual information (as previously described in section 6.3 within this chapter), which is exposed and can be retrieved from learners' situations at anytime and anywhere. Moreover, it was implemented to support the delivery of adapted and personalized educational activities and materials based on processing defined context-aware adaptation rules. Thus, designers of Learning Designs can consider UoLmP as a delivery system that facilitates providing context-aware adaptations within Learning Designs in real time.

Existent IMS-LD player systems are limited to be used in desktop computers as the delivery end. Moreover, related literature shows that only few of them support adaptativity, i.e. they are not IMS-LD Level B compliance (for further information, some reviewed delivery players/systems were described in section 2.3.2). Some researchers recommend choosing IMS-LD Level A for design as most of the players are limited to level A (Mueller & Zimmermann, 2010). Nevertheless, UoLmP was designed and developed to be compatible with IMS-LD Level B for delivering context-aware and adaptive educational scenarios (see IMS-LD level B compliance of UoLmP in Figure 6-5). UoLmP was developed following the guidelines presented in (IMSLD-BPG Binding, 2003) and (IMSLD XML Binding, 2003) and its implementation for handheld devices, as delivery end, was carried so as to benefit from the affordances of IMS-LD as a flexible learning design language (to describe mobile educational scenarios as structured instructional plans) combined with an adaptation process so as to consider new personalization trends for delivering suited learning experiences in mobile contexts.

Figure 6-5 illustrates main activities of UoLmP related with processing IMS-LD level B structures (highlighted in gray) for context-aware educational scenarios adaptation. According to (Burgos, 2008), adaptations in IMS-LD can be achieved by processing <properties>, <conditions>, <global-elements>, <monitor> or <calculate> elements which belongs to the IMS-LD level B structure. As first scope, in this research work <properties>, <conditions> and <global-elements> were attempted to be adopted to achieve context-aware adaptations.

Briefly, as shown in Figure 6-5 when a user "starts an educational scenario" the *Decision Engine* (i.e. the context-aware educational scenarios adaptation engine) in UoLmP, evaluates the adaptation rules (i.e. conditional structures), since they can influence on the visibility of learning activities or other entities (i.e. shown or hidden) from the very beginning.

In real time, learning situations are constantly changing and therefore captured data for contextual elements also change allowing the system to run new adaptations in each new situation. Captured data is used to evaluate context-related defined conditions and each condition is evaluated each time new data is detected as follows:

- When an execution of a UoL starts, i.e. when it is created a new running session, or
- When the value of a property have been changed.

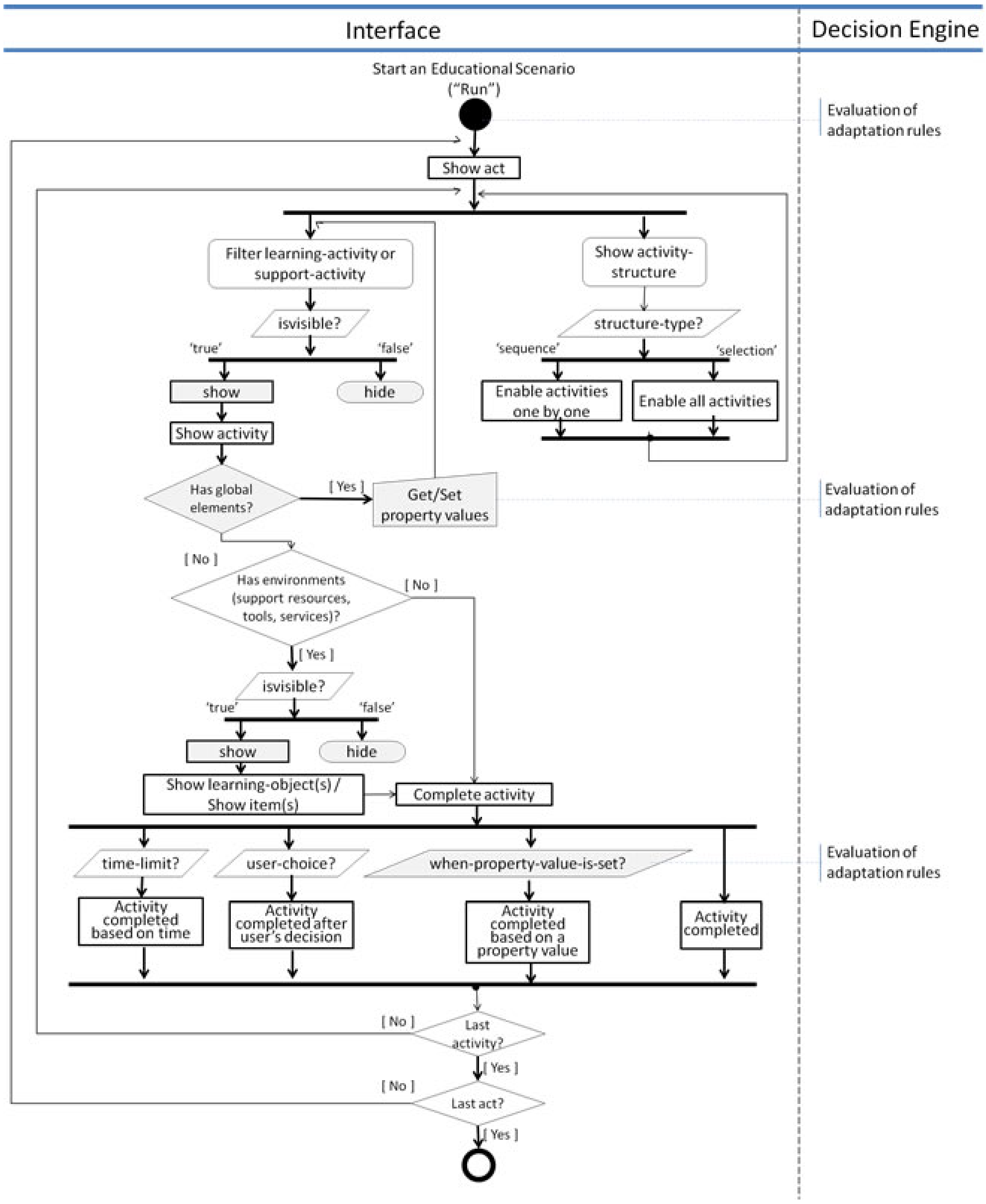


Figure 6—5 Activity diagram in UoLmP - Compliance with IMS-LD Level B

Actions to be executed in UoLmP when conditions are evaluated are:

- Show learning activities (<learning-activity>), resources (<learning-object> within <environments>), tools or services (<item> within <environments>).
- Hide learning activities (<learning-activity>), resources (<learning-object> within <environments>), tools or services (<item> within <environments>).
- Change the value of a property.

Subsequently, as depicted in Figure 6-5, in order to show learning activities flow two alternatives are presented (depending on author's learning flow design) as follows: a) show a tree structure of activities (*Show activity-structure*) or b) filter visibility and show a single activity (*Filter learning-activity or support-activity*). In the case of (a), an activity-structure may group activities in "*selection*" or "*sequence*", this means, that when it is presented to the user, all the lower level activities must be presented as some kind of menu *(enabling all activities)* for the user to *select* which activity she/he decides to carry out, or must be presented to the user in *sequence (enabling activities one by one)* respectively. In the case of (b), before each activity is showed, its attribute "isvisible" must be read so as to filter activity visibility, and thus, filter the activities flow, according to the results of adaptation rules evaluation.

After that, UoLmP validates whether a shown activity has within any "global elements" (*Has global elements?*), namely "get" or "set", so as to deliver or capture a property value respectively. According to "set" element, in UoLmP a new value for a context-aware property can be entered by the user or sensed by the mobile system. Here, it is important to declare that each context-aware property in UoLmP is represented by the <locpers-property> element (local personal property), because in m-learning environments an individual learner can run an educational scenario from her/his personal mobile device (i.e. besides the property is owned by a "run" of the educational scenario, it specifies a different value per user). In the case the activity has "global elements", the user can enter new values for properties and the adaptation engine in UoLmP again evaluates the adaptation rules, since new values for properties can influence on the visibility of learning activities or other entities. "Show" and "Hide" actions set the visibility attribute (isvisible) of different objects: activities, items, plays, etc.

Thereafter, in the case an activity has not "global elements", UoLmP validates if the activity has referenced any <environment> structure which serves as reference to a supportive items (e.g. a resource, a mobile tool, a communicative service, people information, etc.) that can help the user to complete the activity. Besides, their attribute "isvisible" must be read so as to filter the items visibility (show or hide), according to the results of adaptation rules evaluation.

Finally, an activity can be completed by the user; nevertheless, its completion can be affected by different events as follows: a) by *time-limit* which specifies that an activity is completed when a certain amount of time has passed. In level B, the *time-limit* may be specified in a property (declared by the author); b) by *user-choice* that specifies that the user may decide him or herself when the activity is completed. This means that a control is available in the user interface of UoLmP to set the activity status to 'completed'; c) when-property-value-is-set, that is, when the condition evaluates to true when a property is set to a specified property-value; and d) completion is not affected by any event.

Consistently, UoLmP can run educational scenarios compliant with IMS-LD Level B and deliver adapted learning activities, educational resources, mobile tools and communicative services in real-time as results of possible context-aware decision-making processes.

However, in order to achieve real-time context-aware decisions it is relevant to provide an adaptive system or decision support system (such as UoLmP) with contextualized data for successful adaptation. Thus, in next section it is explained how context-aware conditional structures processing is achieved by the adaptation engine in UoLmP.

6.5.1 Adaptation rules evaluation (adaptation engine)

This section presents how the adaptation engine, integrated in UoLmP, evaluates the adaptation rules so as to processes real instances from learner's context. Here, the characteristics of the dimensions of the mobile context category, namely the learner's temporal personal information, people, place, time and physical conditions, are taken into account. Regarding that this research work aimed to produce adaptive learning designs for mobile environments, real context awareness of that environments involves data influence factors from those characteristics which may affect a learning process "on the go" and, in particular, "just-in-time" adaptation and personalization.

How contextual information influences educational elements delivery?

In UoLmP retrieved contextual information can influence the delivery of educational activities and available learning materials by 3 different ways (introductory details of these three types of adaptation can be seen in section 3.4.1) (Gómez et al., 2013b):

i) *Learning flow navigation and sequencing*: real learner's context instances may alter the delivery of activities, by means of changing the activity-based designed plan (a.k.a. learning flow) by two ways (see Figure 6-6): i) *Context alters activity:* implementation of this relationship rely on changing the activity-based recommendation of activities paths depending on contextual information, thus, presentation of learning activities is conditioned (i.e. a learning activity related to a context element can be altered in presentation: hided or showed; ii) *Context as guard*: a learning activity may be influenced by learner's decision based on choosing from different options. Depending on contextual information, the selection (learner's decision based on choosing from different options) of alternative learning activities is provided. Thus, Figure 6-6 shows a case where a context object acts as the decisive element for multiple possible control flows after a decision node. For example, in this case a learner can choose between a set of activities the option (user-choice) that accommodates better to her/his situation. Figure 6-6 also shows identified contextual elements that influence delivery of adapted learning activities.

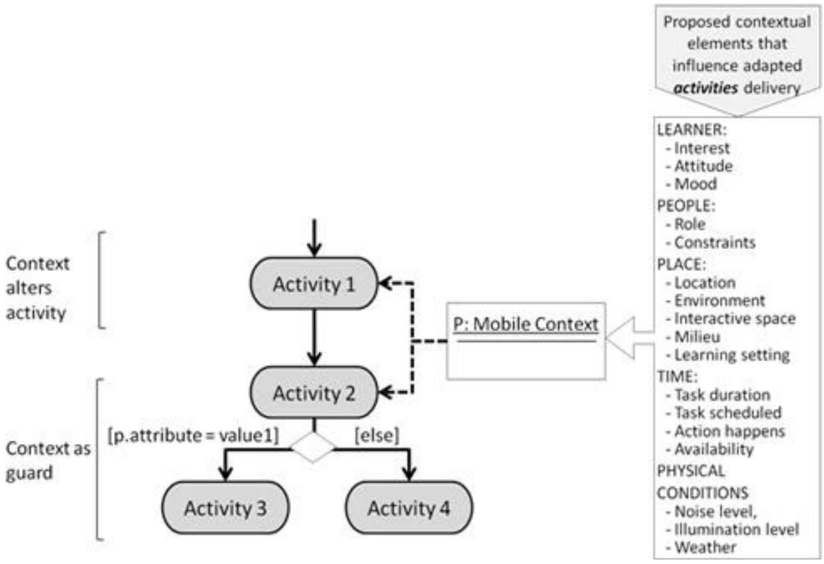


Figure 6—6 Context influences Learning flow navigation and sequencing in UoLmP

ii) *Problem solving support and feedback*: real learner's context instances may filter the presentation of supportive materials (e.g. resources, tools, services) in the moment when a problem or an activity is faced or performed respectively, by means of showing or hiding the suggestions of appropriate learning materials. Figures 6-7, 6-8 and 6-9 show identified contextual elements that influence delivery of adapted resources, tools and services respectively.

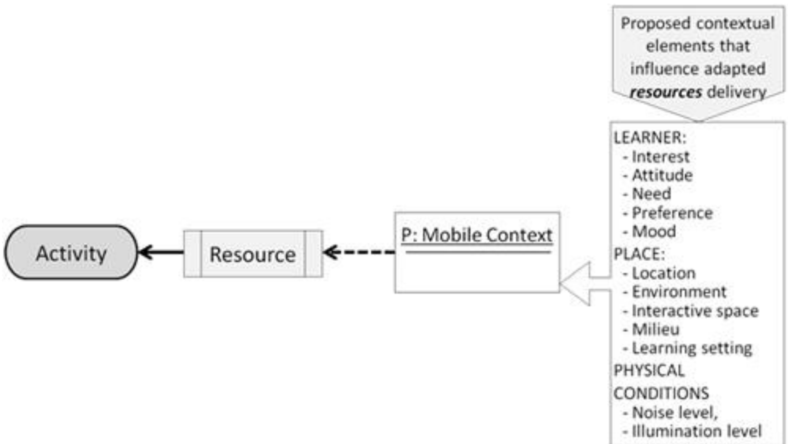


Figure 6—7 Context influences Problem solving support and feedback in UoLmP – resources delivery

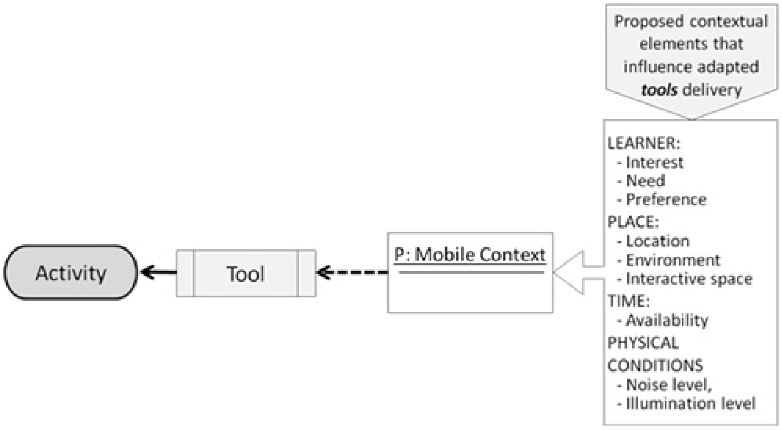


Figure 6—8 Context influences Problem solving support and feedback in UoLmP – tools delivery

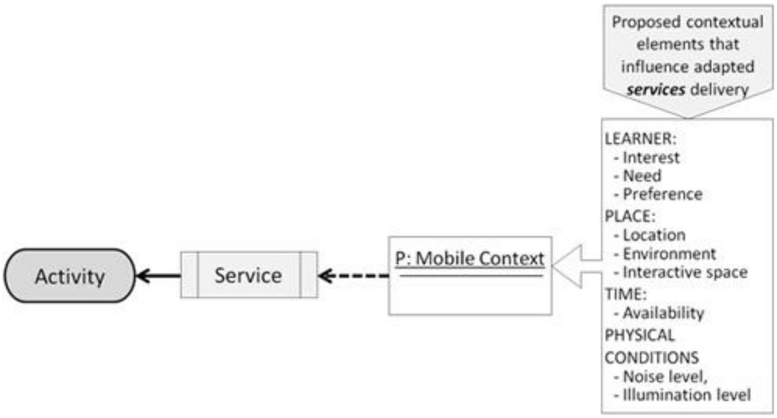


Figure 6—9 Context influences Problem solving support in UoLmP – services delivery

iii) *Interactive learners' communication*: real learner's context instances may adjust access or suggestions for collaborative interactions, by means of presenting to the learner appropriate current people's information or enabling suitable communication and collaboration tools or services. Figure 6-10 shows identified elements from "People" dimension in the mobile context category that influence delivery of adapted tools and services for interactive communication.

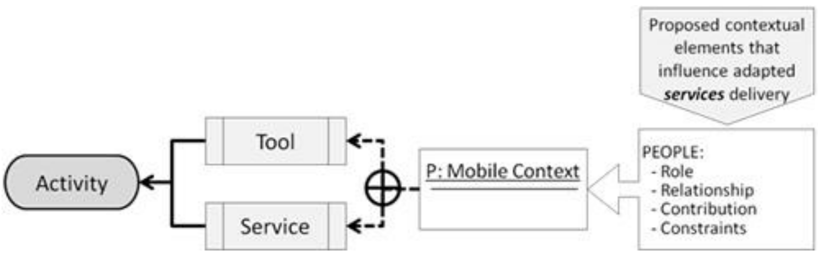


Figure 6—10Context influences Interactive learners' communication in UoLmP

Table 6-6 shows a summarized overview of the influence of proposed contextual elements to learning activities and educational materials delivery, which was presented along the Figures 6-6 to 6-10.

Table 6-6 Relationship of influences from contextual information to learning activities and educational materials delivery

Contextual Element		Learning flow navigation and sequencing	Problem solving support and feedback	Interactive learners' communication	
		Learning Activity	Resources	Mobile Tools	Communicative Services
Dimension: LEARNER					
Temporal personal information	Interest	√	√	√	√
	Attitude	√	√	√	√
	Need	√	√	√	√
	Preference	√	√	√	√
	Mood	√	√	√	√
Dimension: PEOPLE					
Role		√	-	√	√
Relationship		√	-	√	√
Contribution		√	-	√	√
Constraints		√	-	√	√
Dimension: PLACE					
Location		√	√	√	√
Environment		√	√	√	√
Interactive space		√	√	√	√
Cultural background or milieu		√	√	-	-
Learning setting		√	√	-	-
Dimension: TIME					
Task	Duration	√	-	-	-
	Scheduled	√	-	-	-
Action happens		√	√	√	√
Availability		√	√	√	√
Dimension: PHYSICAL CONDITIONS					
Illumination level		√	√	√	√
Noise level		√	√	√	√
Weather		√	-	-	-

Conditional trees evaluation

Depending on the learner's situation, outcomes of the adaptation engine in UoLmP consist in selecting and presenting, to learner's current mobile device, the learning activities and educational materials that are populating a Learning Design. More specifically, the adaptation engine, based on a *content filtering* mechanism, supports making decisions by using IMS-LD level B conditional statements to evaluate learner's mobile contextual dimensions in order to show or hide educational activities (adapting the learning flow) and available learning materials such as resources, tools and services (filtering the information).

UoLmP acquires input data and produces adaptation decision results in real time. Input data into UoLmP's adaptation engine is the learner's mobile context. Data processing is performed by the adaptation engine which consists of a set of conditional structures that implements the types of adaptation for context-aware educational scenarios, namely *Learning flow navigation and sequencing*, *Problem solving support and feedback* and *Interactive learners' communication*, so as to evaluate real instances for used contextual elements and provides adaptation outcomes. Output results of the adaptation engine are the adapted learning flow navigation and sequencing (through filtering of learning activities) and educational content (through filtering of educational resources, mobile tools and communicative services).

The approach for implementing the adaptation engine is based on processing adaptation rules, that is, when the resultant types of context-aware educational scenarios adaptation are derived from conditional structures of IF /THEN/ ELSE statements, which are based on the instances of contextual elements (Arai & Tolle, 2011; Al-Hmouz & Freeman, 2010; Bhaskar & Govindarajulu, 2009).

In design-time authors define a set of conditional structures (namely adaptation rules) that are processed in run-time. For the sake of the formal representation to describe our processing approach for processing conditional structures, the formal definitions of participating elements are introduced.

Definition 0**:** **Set of Contextual Elements (SE)** is a set of elements that influence delivering an object o, SE_o={e| e is an element of object}. Here, object may be Activity, Resource, Tool or Service (the list of contextual elements and their influence to an object delivery can be obtained from Table 6-6).

For example, for Resource object: $SE_{Resource}$={attitude, interest, interactive space, availability, …}.

Definition 1**:** **Number of Contextual Elements (m)** is the number of elements that influence delivering an object o, $m_o = |SE_o|$.

Definition 2: **Set of Contextual Instances (SI)** is a value domain for an element e of object o, $SI_{o,e}$ ={i_e| i_e must be discrete, $e \in SE_o$}. Here, examples of contextual instances may be the data (instances) presented in Appendix A.

For example, for "interest": $SI_{Activity,\ interest}$={reading, listening …}.

Definition 3**:** **Number of Contextual Instances (n)** is the number of instances for an element e of object o, $n_{o,e} = |SI_{o,e}|$.

Definition 4: **Element-Instance (e-i)** is a two tuples, e-i = <e,i>, i is an instance of the element e, $e \in SE_o$, $i \in SI_{o,e}$.

For example, when a learner is learning at home, an author may define the "environment"- instance, so e-i = <environment, home>.

Hereafter, processing conditional structures consists of evaluating a set of captured contextual property values in every possible combination between the instances in a SI for every element e and every object o. Thus, referring to the multiplication principle (rule of product) in combinatorics, if UoLmP, for example, captured values for four different contextual elements a, b ,c and d (one value per contextual element) and each contextual element has a different set of contextual instances(options) (SI_a, SI_b, SI_c, SI_d), then there are $|SI_a| \cdot |SI_b| \cdot |SI_c| \cdot |SI_d|$ possible combinations for a single object o to which the captured values can be evaluated. Then, the number of contextual conditions (C_o) that UoLmP evaluates for a single object o can be declared as follows,

$$C_o = \prod_{i=1}^{m_o} |SI_{o,e_i}|$$

Thus, captured data by UoLmP is used to evaluate a total number of context-related defined conditions for each object (activity, resource, tools or service) which are evaluated each time new data is detected. Then, the total number of contextual conditions (TC) for evaluation can be declared as follows:

$$TC = C_{Activity} + C_{Resource} + C_{Tool} + C_{Service}$$

These combinations can be seen as a conditional tree structure and its processing (evaluation of the captured set of contextual values) is handled breadth first (see Figure 6-11).

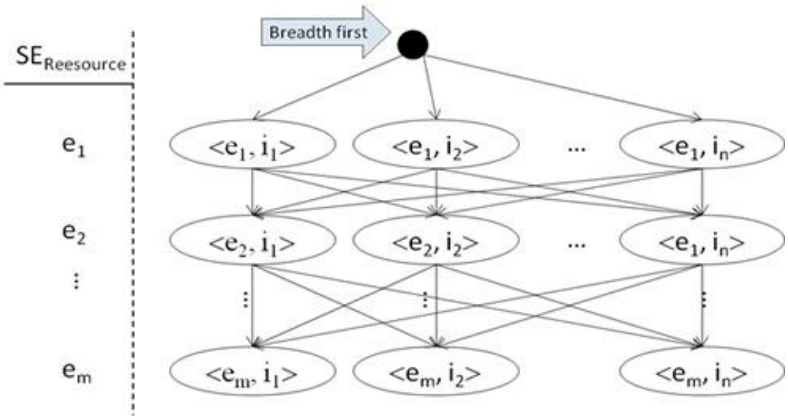


Figure 6—11 Conditional tree structure

6.5.2 Delivery example

This sections aims to use the exemplary educational scenario 2, namely Experiential Learning “setting up a business: starting a new business”, presented in section 5.3.1 so as to describe how UoLmP attempts to achieve adaptations for *learning flow sequence*, *problem solving support* and *interactive learners’ communication* (Gómez et al., 2013b). Thus, illustrations of delivering adapted learning activities, resources, tools and services through UoLmP are presented. Moreover, it is detailed how UoLmP was developed to meet the design requirements for a delivery system presented in section 4.5.2 and summarized in Table 6-7, as a client side application for smartphones and tablets with Android operating system (*meeting **Requirement 4***) as first scope of a targeted delivery device platform.

Table 6-7 Summary of requirements for a mobile Delivery System. Extracted from section 4.3

DS-Requirement 1	The tool should be able to automatically detect contextual information such as, place, time, and in some cases physical conditions according to the user situation and it should be able also to let the user input contextual information that it is not possible to be detected automatically.
DS-Requirement 2	The tool should be able to import and deliver educational scenarios compatible with IMS-LD.
DS-Requirement 3	The tool should be able to handle the adaptation rules of the delivered educational scenario and match them with the values of contextual information automatically detected or provided by the user, so as to enable the adaptation mechanisms and deliver adapted learning activities, educational resources and tools and services.
DS-Requirement 4	The tool should be client-side, so it can be installed to the mobile device and no internet connection should be required during the execution of learning activities. Internet connection should be required only during the content adaptation process, when the tool should communicate with the content adaptation mechanism located.
DS-Requirement 5	The user should be able to view the graphical structure of the learning activities that a Learning Design incorporates and navigate to these learning activities.

UoLmP is able to capture during the run-time (*meeting* ***Requirement 1***), the contextual elements instances of which were pre-defined in design-time. Since contextual information is retrieved in run-time, the tool parses properties, global elements and conditions of the IMS-LD Level B specification (*meeting* ***Requirement 2***) in order to capture and evaluate values for the considered contextual elements. For instance, according to the exemplary educational scenario 2, Figure 6-12 shows an example of a conditional tree structure for the Resource object (i.e. adaptations for *problem solving support*) based on the considered contextual elements and instances in the educational scenario.

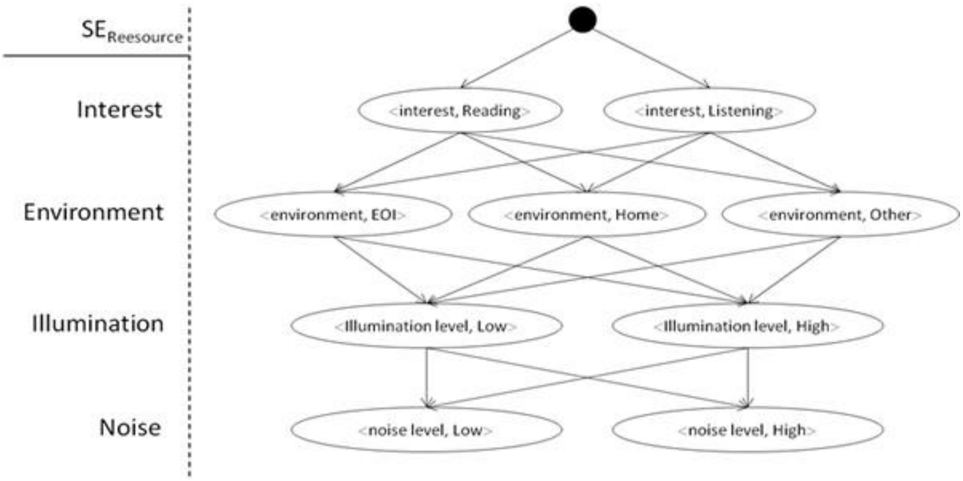


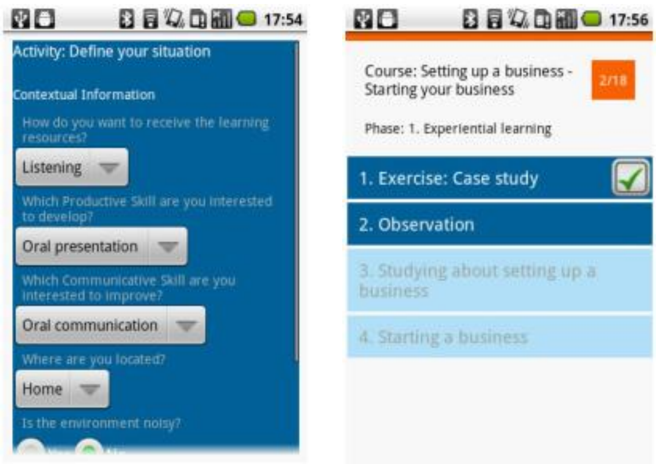
Figure 6—12 Example of conditional tree structure for Resource object delivery

Thus, the number of contextual conditions (C_o) that UoLmP evaluates for the Resource object ($C_{Resource}$) is 24 conditions, which are obtained from the conditional tree structure in Figure 6-12 and which UoLmP evaluates for processing "*problem solving support and feedback*" adaptations. That number is obtained as follows:

$$C_{Resource} = \prod_{i=1}^{4} \left| \mathrm{SI}_{\mathrm{Resource}, e_i} \right| = 2 \times 3 \times 2 \times 2 = 24$$

Figure 6-13a illustrates a particular situation of context capture where the learner is interested on improving listening (assimilative), oral presentation (productive) and oral communication (communicative) skills, she/he is located at home, the noise level is low and the illumination level is high.

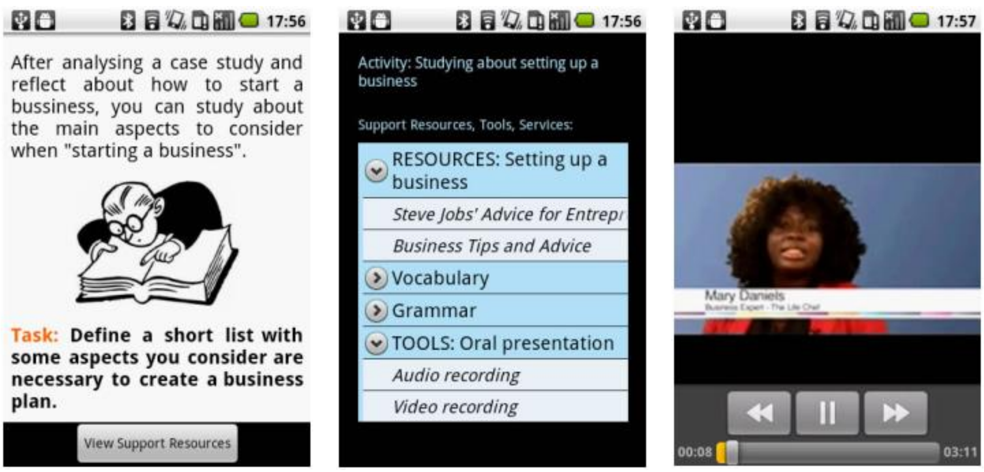
Since the learner is located at home she/he is presented with activities structures (*meeting* ***Requirement 5***) defined for that place as depicted in the learning activities flow in Figure 5-3 (see the activities structure for the activities structure “Setting up a business” in the Figure 6-13b).



(a) (b)

Figure 6—13(a) Contextual information capturing and (b) a learning activities structure

Figure 6-14 and Figure 6-15 illustrate adaptation results for educational resources, tools and services (*meeting* ***Requirement 3***) obtained from the adaptation rules evaluation process according to the captured contextual information (see Figure 6-13a).

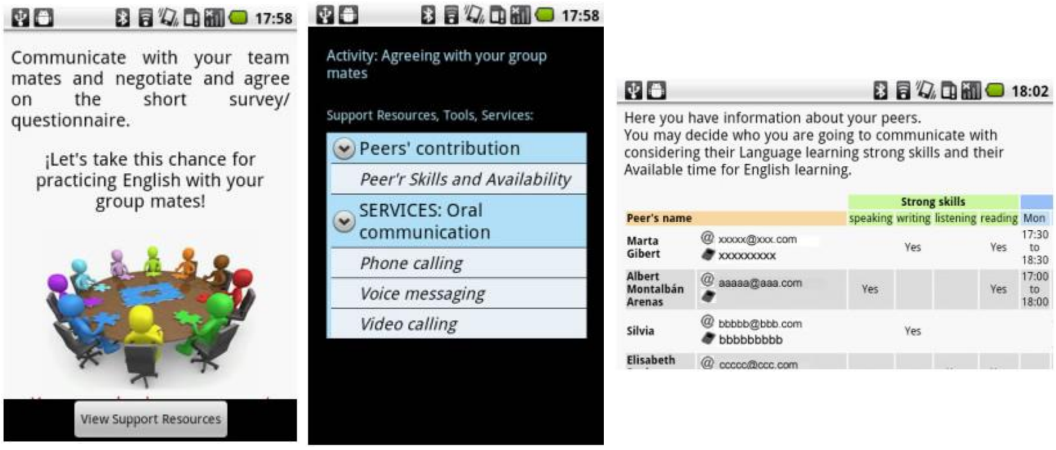


(a) (b) (c)

Figure 6—14Context-aware adaptation results for the productive activity entitled: “Studying about setting up a business”

Figure 6-14a shows the learning activity entitled "*Studying about setting up a business*" (productive activity). For this activity, adapted educational content (example educational resources) and tools are delivered to the learner (see Figure 6-14b). Audio and video resources (instead of text educational resources) demonstrate to the learner how the learning activity can be performed. Figure 6-14c illustrates a video educational resource. Additionally in Figure 6-14b, audio and video recording facility options are presented to the learner (instead of writing and typing options) letting her/him to decide how to complete the activity. Those facilities let the learner complete the activity by taking advantage of the particular conditions of the place where she/he is located and support the learner to develop the skills that she/he is interested to improve. Moreover, the learner can select to view grammar rules or vocabulary related to the topics.

Figure 6-15a depicts the learning activity entitled: "*Agreeing with your group mates on the questionnaire*" (communicative activity). In this case, the learner is presented with phone calling, voice messaging or video calling service options instead of SMS, instant messaging, email (see Figure 6-15b). Assuming that the learner decides to phone a peer (since she/he is located at home, and she/he needs immediate answers from her/his peers), she/he can decide who she/he is going to communicate with based on the peers' language skills and their availability (see Figure 6-15c).



(a) (b) (c)

Figure 6—15Context-aware adaptation results for the communicative activity entitled: "Agreeing with your group mates on the questionnaire"

6.6 Testing

In this section, results of a usability study, performed with a set of randomly selected language learning students, is presented. The results in this section presume to give a possible answer to the research question defined for this study: *Is the proposed context-aware adaptive mobile system easy to learn and to use?*

The questionnaire of mobile system usability included ten items and the Cronbach's alpha value was 0.902. That questionnaire was conducted in getting the usability data from the end users so as to analyze whether the mobile system prototype is easy to learn and use by students. The questionnaire was adopted with some criteria of the Mobile Phone Usability Questionnaire (MPUQ) (Ryu & Smith-Jackson, 2006).

The usability evaluation for UoLmP was on its "ease of learning and use", which has been used to test the capability of the mobile system as a context-aware adaptive mobile educational scenarios delivery tool for the students. The questions in the questionnaire were designed to assess the students' perceptions to aspects of its usability. Students were asked to rate statements on a five-point Likert scale for Frequency Level. Table 6-8 shows the mean and standard deviation of the responses to each item, in the range from 1 (Never) to 5 (Always). As shown in Table 6-8, the feedbacks from the usability questionnaire conducted to the participants indicated that in general they share a positively consisted point of view (Means over 4,00) about the mobile system ease of learning and use.

Particularly, the feedbacks have shown that the mobile system: (1) is fairly easy to operate (mean score 4,40), (2) it is flexible (mean score 4.40) based on the use of several operations carried out in a systematically similar way, and (3) it is practically easy to access the information delivered to students (mean score 4.35).

Table 6-8 Responses means and standard deviation in usability analysis

N=20	Questions	Mean	Std. Deviation
1	Is it easy to learn to operate UoLmP?	4,40	0,598
2	Can all operations be carried out in a systematically similar way?	4,40	0,598
3	Is it easy to access the information that you need from UoLmP?	4,35	0,671
4	Is the organization of information on UoLmP's screen clear?	4,50	0,607
5	Is the interface with UoLmP clear and understandable?	4,45	0,605
6	Are the characters on the screen easy to read?	4,45	0,759
7	Is it easy to navigate between hierarchical menus, pages, and screen?	4,15	0,587
8	Are UoLmP form's input or text entry methods easy and usable (for example: in the activity "Define your situation")?	4,40	0,681
9	Is it easy for you to remember how to perform tasks with UoLmP?	4,40	0,754
10	Is discovering new features sufficiently easy?	4,30	0,657

Besides, (4) the organization and presentation of the content and interfaces it is clear (mean score 4,50), (5) understandable (mean score 4,45), (6) easy to read (mean score 4,45), and (7) easy to navigate (mean score 4,15). (8) Input or text entry methods for contextual information as presented in the form for capturing contextual element values were also easy to use (mean score 4,40). In addition, (9) participants remarked the easiness to remember how to perform tasks (i.e. the memory load is minimal) and (10) to discover new features (i.e. it requires minimal actions to discover the system's functionalities) indicated by considerable high values 4,40 and 4,30 respectively. The results thus indicate that majority of the students agreed that the developed mobile system has met the requirement of usability.

Next, in chapter 7 evaluation results in terms of *learners' attitude*, *context-aware adaptation approach effectiveness*, and *satisfaction* of students from a real language learning center regarding their acceptance of a delivered context-aware educational scenario and UoLmP are presented.

6.7 Summary and discussion

This chapter emphasizes on the development of the proposals for the delivery approach (presented in chapter 4) as follows: i) an introduction to the developed context-aware mobile delivery system, namely UoLmP, is described. It is stated that UoLmP aims to provide a *General Adaptation* that combines the three types of context-aware educational scenarios adaptation, namely *Learning flow navigation and sequencing*, *Problem solving support and feedback (scaffolding)* and *Interactive users' communication*. UoLmP is able to support learners through every step in the learning flow of an educational scenario, providing them with learning activities that suit to the current learner's situation, as well as offering personalized learning resources, tools and services that support the activities and which are best suited to learner's current context; ii) an adaptation process, undertaken by UoLmP, to achieve delivering context-aware and adaptive educational scenarios is explained phase by phase. Outcomes of this adaptation are: a) delivery of adapted educational scenarios previously designed in design-time or new transformations to the learning resources (populating a constructed Learning Design) according to capabilities of the current mobile device at learner's hand, and b) delivery of adapted learning flow sequence (i.e. filtered learning activities), adapted problem solving support (i.e. supportive resources and mobile tools) and adapted interactive learners' communication (i.e. appropriate communicative mobile services) according to detected/captured context-related real instances (i.e. from the lived learner's situation and environment) and the evaluation of previously defined adaptation rules; and iii) an usability study made for UoLmP and its results are described.

Concerning to the adaptation process at run-time, this differs from adaptation at design-time in the moment in which the phases are executed (i.e. in run-time), as well as the adaptation level (i.e. a combination between server-side and client-side). At run-time the adaptations are carried out in client-side with only one exception that can be ran at server-side, that is, when a learner is searching for a designed educational scenario.

The presented phases of context-aware adaptive educational scenarios delivery at run-time can benefit from the results of the corresponding process at design-time level. Consequently, this can significantly reduce the time of delivering adapted mobile educational content to a learner's mobile device in run-time.

The delivery of adapted educational scenarios previously designed in design-time process, aims to adapt an existing and published authored context-aware adaptive educational scenario when the learner's device at hand is not able to run it. Within this process only the capabilities of the current learner's mobile device to transform the properties of the resources that are populating an authored educational scenario are considered.

Regarding the scope of UoLmP, this system was mainly designed to enable the learners to follow the paths in a learning flow. Moreover, it was implemented to support the delivery of adapted and personalized educational activities and materials based on processing defined context-aware adaptation rules. Thus, designers of Learning Designs can consider UoLmP as a delivery system that facilitates providing context-aware adaptations within Learning Designs in real time.

Consistently, UoLmP can run educational scenarios compliant with IMS-LD Level B and deliver adapted learning activities, educational resources, mobile tools and communicative services in real-time as results of possible context-aware decision-making processes.

Next chapter presents evidences of the validation of the developed solutions presented in chapters 5 and 6, as well as addresses the discussion about the findings from the evaluation.

CHAPTER 7

EVALUATION IN A LANGUAGE LEARNING CENTER

In this chapter, an experimental case with UoLmP and a context-aware adaptive educational scenario in a Language learning center, namely Official Language School ("EOI" in Spanish language) at Girona, Spain, is presented. More precisely, a case study aims to provide students of EOI with the adaptive educational scenario 2 described in section 5.3.1, through the developed mobile delivery system, namely UoLmP, which is the proposed context-aware mobile system in this research work. UoLmP has been implemented and it was provided to several students for evaluating the adaptation outcomes which involves: delivering adapted activities and suitable resources, tools and services considering our adaptive delivery approach based on processing contextual information. Some questionnaires were used to respond to the learning attitude, adaptation process effectiveness and students' satisfaction analysis (Gómez et al., 2013a; Gómez et al., 2013b).

As described in section 5.3.1 the educational scenario, namely "adaptive context-aware educational scenario 2 – Experiential learning", was adopted from a learning scenario that is used in EOI and delivered to participant students. In next sections, details of the study accompanied with the results and discussion are described.

7.1 Participants

The participants included a teacher of English and twenty students from two classes of advanced intermediate English level at EOI. Prior to start the case study, a short questionnaire was conducted in order to detect and recruit participant students. This questionnaire let us to detect the participants from a population of 28 students distributed in the two classes (see Table 7-1). The questionnaire consisted of seven items, that is, six questions (number 1 to 6) related to: (1) owning a mobile device, (2) willing to participate in the study, (3) providing information about their email accounts and (4) mobile numbers, (5) expressing the English learning skills they think they are strong in, (6) detailing their availability in the week for English language learning (in days and hours), and one more question (number 7) which answers were proposed to be compared with some of the results after the case study. That latter question regards to *what mobile tools and services would they like to use to complete language learning activities out of the classroom?*

Table 7-1 Short questionnaire to detect potential participants

N=28	Question	Frequency		
		Answers	Answered	Not answered
1	Do you have a mobile device (mobile phone, personal digital assistant (PDA), tablet computer, etc)?	Yes 23 No 5	28	-
	If your answer was “yes”: Which type(s)?	feature phone 5 smartphone 18 PDA 1 Tablet 0	23	-
	If your answer was “yes”: Which operating system (OS) do your mobile devices have?	Android 14 iOS (apple’s OS) 1 Windows Mobile 0 Blackberry OS 4 Other 5	23	-
2	If you have the opportunity of using language learning tools developed for mobile devices, do you think you are willing to use them?	Yes 20 No 5	25	3
3	Email	-	25	3
4	Mobile number	-	19	9
5	Which English learning skills (Reading, Listening, Writing, Speaking) you think you are strong in?	-	25	3
6	What would you think will be your availability timetable in the week for English language learning? (In hour’s intervals. For example: 9:00 to 10:00)	-	21	7
7	Which kind of “mobile” tools and services would you like to use if language learning activities were provided for doing outside of a formal classroom? Assimilative: text viewer, image viewer, audio player, video player, web content viewer (browser) Productive: notepad, camera, audio recorder, video recorder Communicative: email editor, instant message, SMSs, phone, voice message, video-call	-	24	4

Thereafter, 14 from the 28 students were selected as potential participants (they own an Android-based mobile device) plus 6 students more (who expressed to be willing to participate in the study and who did not own an Android-based mobile device). We provided those 6 students with an Android-based device. Thus, a total sample of 20 students (i.e. representing a particular group of the population: 28 students) in an age range of 16 to 51 years, in which 14 of them are female and 6 are male, and with occupations varying between student and employee (10 and 10 respectively) participated in the study. It is important to mention that 14 students out of the 28 students own and Android-based mobile device, which accordingly to (ComScore, 2012) this number can be seen as a representation slightly above of the percentage of people who own an Android-based mobile device in Spain.

On the other hand, the teacher had taught English for more than 10 years at the Language school and he had at least 4 years of experience in computer-assisted language learning. He managed on giving support and guidance over the activities development to students during the study.

7.2 Equipment

The students could use an Android-based smartphone or tablet to use UoLmP, which up to now was the initial platform selected to develop the system. UoLmP runs on versions 1.6 and later of the Android operative system. Some technical characteristics needed from the mobile devices were: 70 MB of available memory to upload the activities package (a comprised zip file) and internet connectivity through Wi-Fi or provided by a service provider to view peers' information (strong skills and availability) and/or to use some services in the case they needed to complete a collaborative activity.

The mobile system installation files and the activities package were made available one week before the study starts so as the students were able to install the files by their own and to provide technical support in case they would needed. Moreover, students were provided with an online installation guide through a link (http://bcds.udg.edu/uolmp) in Moodle, which is the learning management system they were using in the course. Additionally, students had available a forum in Moodle where they could ask or make any comment about technical issues related with the installation of the mobile system.

7.3 Research instruments

In order to evaluate the impact of the mobile system and the educational scenario, as well as the effectiveness of our context-aware adaptation approach (focusing on providing students with adapted activities, resources, tools and services according to their context), the case study evaluation was conducted through a series of online questionnaires, which were available for a period of three days, with the participants after the study were completed (see Appendix D). The purpose of these questionnaires was to evaluate a) students' attitude during their interaction with the m-learning scenario through the mobile system, b) effectiveness of the adaptive delivery approach considering contextual information, and c) students' satisfaction about the educational scenario and the mobile system functionality.

The questionnaire of (a) students' attitude consisted of twelve items which could be qualitatively analyzed. Participants from both classes were asked to complete the questionnaire after the study was completed. The questionnaires to evaluate the (b) effectiveness of the adaptive delivery approach, and (c) students' satisfaction about the educational scenario and the mobile system were created following some guidelines and survey examples from related work in (Martin & Carro, 2009; Nguyen, Pham & Ho, 2010; Hwang et al., 2009) and compiled by the authors in this work. These questionnaires were presented using a five-point Likert scale for Frequency Level, where “5” represented “Always” and “1” represented “Never”. Participants from both classes were asked also to complete these latter two questionnaires after the study was completed.

The questionnaire to evaluate the (b) adaptive delivery approach effectiveness consisted of 8 items. Its Cronbach's alpha value was 0.745. The questionnaire to evaluate (d) students' satisfaction consisted of seven items and its Cronbach's alpha value was 0.818. The Cronbach's alpha values of both questionnaires exceeded 0.7, indicating the reliability of the questionnaires used in this study, that accordingly to (Nunnaly, 1978) 0.7 is an acceptable minimum reliability coefficient.

Additionally, at the end of the questionnaire (c) participants were presented with open questions so as they can share their perceptions about the mobile system usefulness and to provide some comments and opinions based on the participation during the case study.

7.4 Case study design

Steps defined for the case study are illustrated in the flow chart shown in Figure 7-1. Three learning sessions were defined by the authors in agreement with the English teacher to be used in the study and the educational scenario activities development. These sessions were declared by the teacher as “end-of-course” sessions. This means that the educational scenario was presented to students at the end of the course. The experiment was conducted from April 18 to May 11, 2012.

As depicted in Figure 7-1, before the learning sessions started, the students had 1 week to install the mobile system and to upload the activities package to their mobile devices by their own. Moreover, before starting *Session 1* we helped few students who previously couldn’t install the files in their mobile devices. To this, these students received face-to-face support at classroom on how the mobile system should be installed.

Session 1 started after every student had the mobile system installed in their mobile device. At classroom students were split into groups of four and five students and a real case related to “setting up a business” (hard copies) was presented to each group. Students had to reflect about the main elements for setting up a business considered in the case of study. Afterward, students received a 20-minute instruction concerning about completing next activities in the learning flow out of classroom (see Figure 7-1) for the next time each group meets again at classroom in *Session 2*. Out of the classroom, students participating in the study have the opportunity to freely complete the activities by interacting with UoLmP, while those students who were not participating in the study (8 students) were provided with a hard copy on which the activities flow were described. The teacher remarked to participants that they will have this opportunity to be aware of and take control of their learning process. As stated in (Corlett et al., 2005): “in the shift from mass teaching to support of personal learning, it is also the responsibility of educators to ensure that students have the relevant skills and environments to succeed as self-directed learners”.

Students participating in the study could follow the sequence of activities of the educational scenario 2 presented in section 5.3.1 and complete each language learning activity in the moment they wanted or needed using the mobile devices. In summary, students had the opportunity to integrate English learning language skills (reading, writing, speaking, listening) in the real-life task “Setting up a business” using the support resources, tools and services the system suited delivered to them regarding the contextual information they provided. Moreover, they had the opportunity to practice and apply English grammar and vocabulary to actual situations, to communicate effectively with others expressing ideas, plans, agreements, disagreements, etc., to work collaboratively with others and develop group tasks, and to search and gather data from their contexts they could use to perform the activities and to learn and practice the English language.

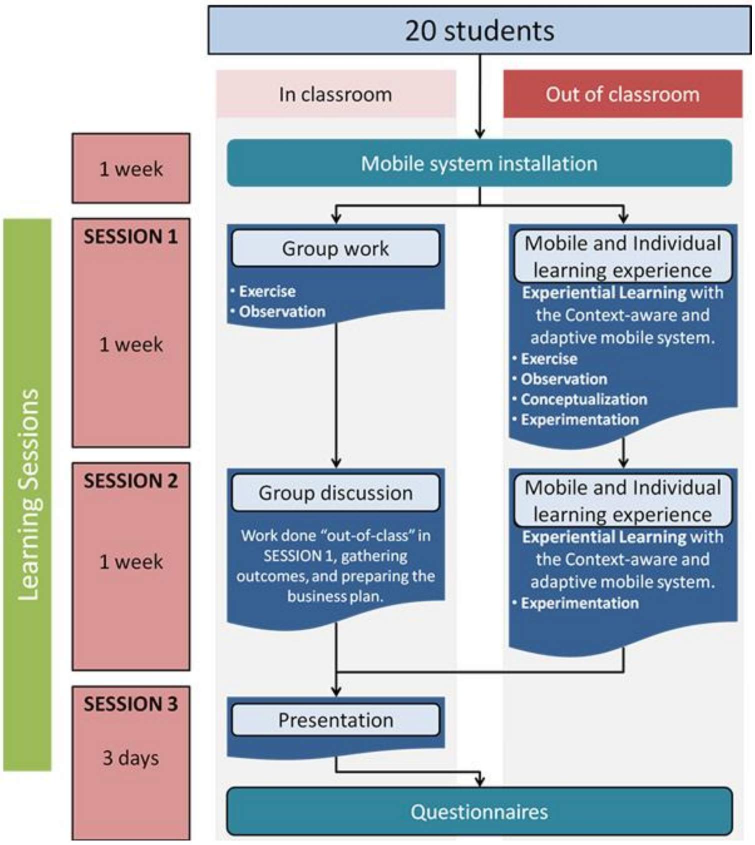


Figure 7—1 Study Procedure Flow Chart

Session 2 started when students met again with their team mates and the teacher after one week had passed. At classroom, students discussed with their team mates about the outcomes of the activities they could developed and advanced out of the classroom in Session 1 related to the business' product/services ideas, market research and marketing strategy plans. Out of the classroom, students had one more week to work on and to finish the structure activities related to "Experimentation", so as to complete the activities package and prepare the presentation with the business plan and solution.

Finally, at *Session 3*, after two weeks of interaction with UoLmP, students had to make a presentation of the work done and the business idea to other classmates, using the materials created or collected during the interaction time, so as they can vote for the best business idea. Moreover, they had to use their group blogs (previously created by them in the English course) in order to publish the materials they created or collected by using their mobile devices.

The case study lasted for 3 weeks and three days (24 days). After the learning sessions were completed, the students received the three questionnaires for measuring their a) learning attitude, b) effectiveness of the adaptive delivery approach considering contextual information, and c) students' satisfaction about the educational scenario and the mobile system functionality. Moreover, in the last day when the study was completed, students' perceptions were also received through a 20-minutes discussion guided by the author of this thesis in each of the two classes. From the results of the questionnaires, aspects related to each questionnaire could be evaluated. Moreover, through the feedback collected via the questionnaires and the discussion in classroom, students' learning attitudes, satisfaction and perceptions of the use of the mobile system could also be analyzed.

7.5 Results and discussion

The study proposes UoLmP as a mobile system for delivering adaptive educational scenarios to students considering the information detected or provided about their contexts and examines the effect of designing such scenarios based on a constructivist pedagogical model for a m-learning experience. In this section, the study results are presented and discussed in terms of the dimensions of learners' attitude, context-aware adaptation approach effectiveness and satisfaction of students regarding their acceptance of the educational scenario and the m-learning system. The results in each dimension presume to give a possible answer to the research questions defined for the study (see Table 7-2).

Table 7-2 Research questions for the case study.

Number	Question	Dimension
RQ1	Is the proposed context-aware adaptive mobile system helping to enhance students' attitude heading the use of mobile technologies for learning?	*Learners' attitude*
RQ2	Is the proposed mobile system and the context-aware adaptation approach effectively operational and suitable when delivering adapted educational activities, resources, tools and services based on processing contextual information?	*Context-aware adaptation approach effectiveness*
RQ3	Is the proposed context-aware mobile system and the adaptive educational scenario accepted by students?	*Learners' satisfaction*

7.5.1 Learners' attitude analysis

Learning experiences with the mobile system lived by the students in different situations were analyzed. English learning students were guided by the mobile system with activities related to the real-life task of "*Setting up a business*" in the places and time they freely selected to access the system for the sessions out of the classroom. Students could complete those activities using the supportive resources, tools and services that the system suited delivered to their contexts. The study analyzed the learning situations of the students in order to understand their learning attitudes towards deciding whether using the mobile system to complete the activities or not, where and when they choose to access the mobile system, what support resources they used, and what tools or services they preferred using to complete the activities during the period of the case study. Thereafter, students' attitude heading the use of mobile technologies for learning was evaluated regarding:

i) students' individual initiative and freely decisions about completing the learning activities,

ii) accessing the system in the place and moment they wanted, and

iii) using the support resources, tools and services in accordance with their learning needs and preferences.

Firstly, we thought that it is important to mention that every participant used the mobile device, and although most of the participant students (15 students) agreed to have the skills needed to use a mobile device, 5 students loaned with a mobile device expressed they have never used a smartphone or tablet. Nevertheless, before the study started, all of them expressed to be willing to use a language learning tool developed for mobile devices if they would have the opportunity to use it (see answers to question number 2 in Table 7-1). As stated by Kukulska-Hulme, Traxler & Pettit "learners who own a mobile device shows an increasingly willing to be engaged in activities motivated by their personal needs and circumstances of use" (Kukulska-Hulme, Traxler & Pettit, 2007). Hence, it was significant to provide the students who do not own a mobile device with one device so as they can feel engaged in this study too.

Table 7-3 presents the results in frequencies of attitude evaluation concerning (i) *students' individual initiative and freely decisions about completing the learning activities*. From the results, 80% of students followed all the activities flow and 20% followed part of it, that is, 80% completed all twelve activities while the remaining 20% completed only some activities. As the system showed students their progress (in percentage) of the completed activities, we could gather that value from the answers provided by the students who did not complete the activities. Thus, an average of 5 activities (41,75%) out of a total of 12 activities were completed by those students. Before we received more detailed feedback from the discussions at the end of the case study, we thought that this was because students were studying for the final exam, with not enough time to complete the activities. The 20-minutes discussion done after the case study confirmed our thoughts. The only reason for not completing all the activities given by participants was that they did not have enough time because they were preparing for the final exam which was held one week later after the end-of-course sessions.

Table 7-3 Frequencies for completed learning activities.

N=20	Questions	Frequency	Percentage	Average	Min.	Max.
	Did you complete all the activities in the lesson?	Yes = 16 No = 4	80 % 20 %			
	If not, what percentage of activities did you complete?			41,75 %	20 %	73 %

In order to explore students attitude based on their decisions to (ii) *access the system in the place and moment they wanted*, we collected students answers regarding the sessions they used to complete the activities and the times they accessed the mobile system as well as the places from where they accessed (see Table 7-4 and Figure 7-2). Moreover, we stored in the system's log the values, captured by user's input, for the place property in order to corroborate the places from where they were accessing. The results indicate that 100% of students used at least 2 sessions, which were the expected sessions they will need for completing activities in both session 1 and 2 in the case study (sessions structure can be seen in Figure 7-1). Students expressed they started a session in the system 2 times (20% of students), 3 times (65% of students), and more than 3 times (15% of students) to complete the activities (see Table 7-4). Additionally, they accessed the system from different places and different times in each place as shown in the Figure 7-2.

Table 7-4 Frequencies for sessions used by participants to complete activities.

N=20	Question	Frequency		Percentage
	How many sessions did you use to complete the activities?	One session	0	0
		Two sessions	4	20%
		Three sessions	13	65%
		More sessions	3	15%

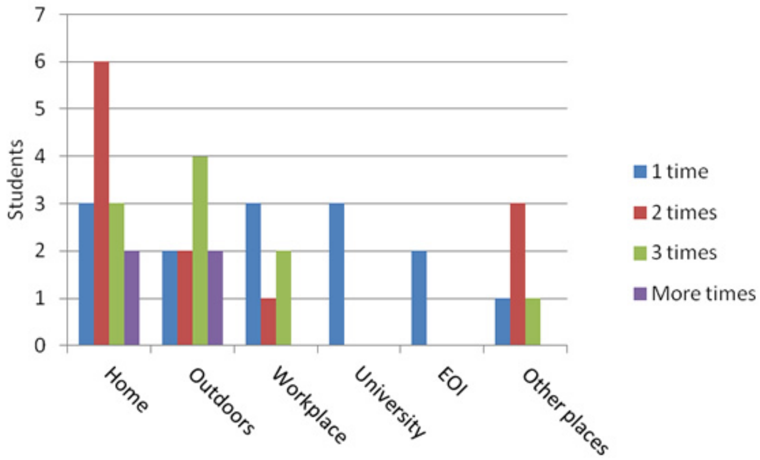


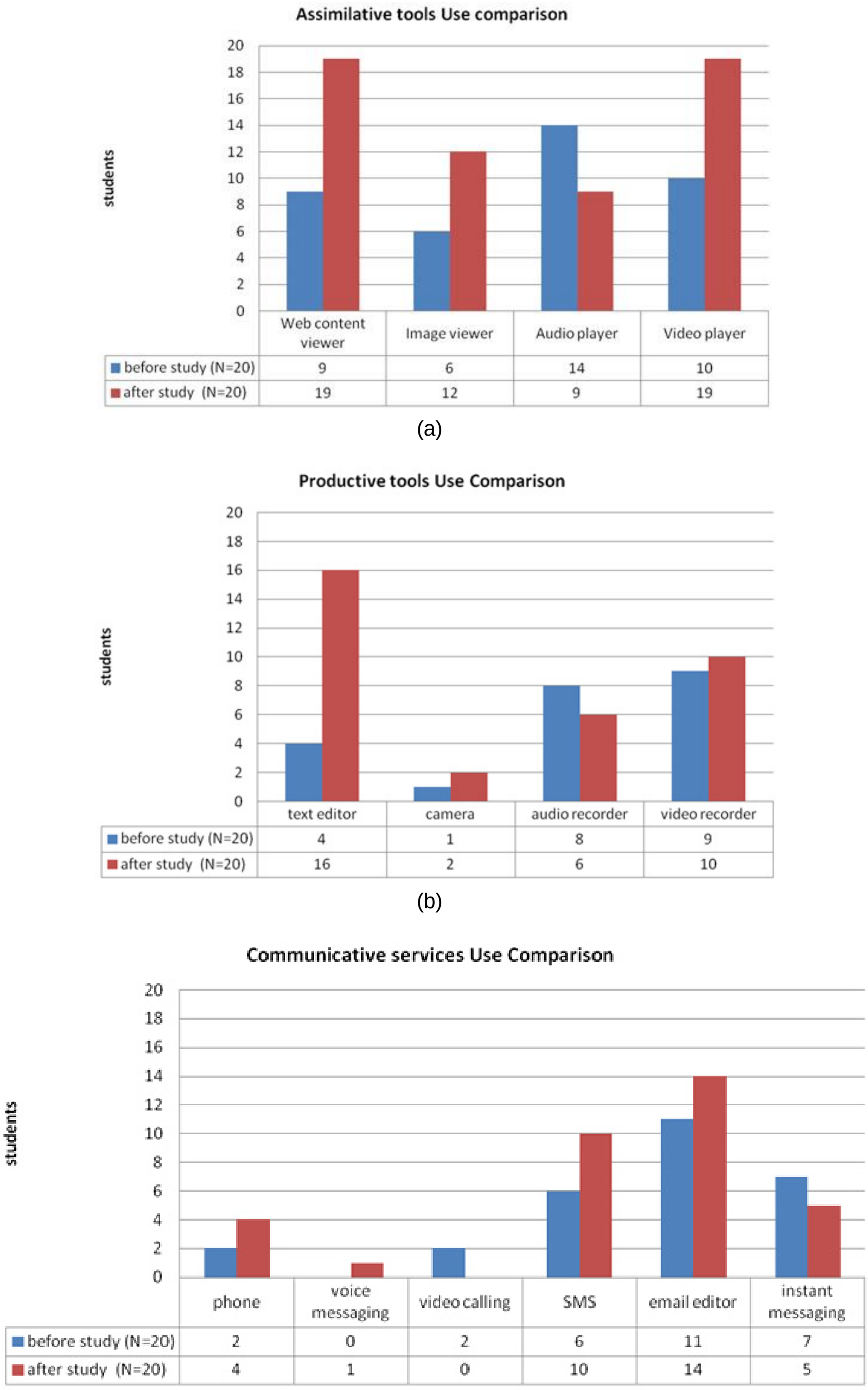
Figure 7—2 Where and How many times did you access UoLmP?

Results exposed that participants actively accessed UoLmP from places different from the Official Language School (EOI). The results additionally revealed that home and outdoors were the most common locations of use of the mobile system. This same behavior was obtained in results obtained in related work (Corlett et al., 2005; Vavuola, 2005).

Regarding the students' decisions about (iii) *using the supportive resources, tools and services in accordance with their learning needs and preferences*, the results, on the one hand, shown that all participants stated to use the grammar support presented in some activities, and almost all of them (95% of students) used the vocabulary support. On the other hand, before the case study started, students were asked to select, from a list, the mobile tools and services they would like to use if language learning activities were assigned to be completed out of the classroom (see question number 7 in Table 7-1), so as to compare those answers with the answers (regarding the tools and services they used to complete the activities) provided by them after the study finished. In Figures 6-3a, 6-3b and 6-3c it is presented that comparison between the answers provided by students before the case study and the results obtained from the questionnaire after the case study finished.

In Figure 7-3a participants' assimilative tools selections shown that during the study (real-time) the number of students who used these tools increased comparing these values with the number of students who say, before the study starts, to be willing to use them if language learning activities were assigned to be completed out of the classroom. Only an exception occurred with the audio player, nevertheless we thought that this may arise because in the educational scenario only one audio resource was included (activities and materials created for the educational scenario 2 can be seen in Table 5-5).

In Figure 7-3b, results also shown that number of students who used the productive tools during the study increased, and only the audio recorder was less used. Related to this results, participants in the 20-minutes discussion done after the case study expressed they preferred to create videos in productive activities than recording audios of themselves.



	Web content viewer	Image viewer	Audio player	Video player
before study (N=20)	9	6	14	10
after study (N=20)	19	12	9	19

(a)

	text editor	camera	audio recorder	video recorder
before study (N=20)	4	1	8	9
after study (N=20)	16	2	6	10

(b)

	phone	voice messaging	video calling	SMS	email editor	instant messaging
before study (N=20)	2	0	2	6	11	7
after study (N=20)	4	1	0	10	14	5

(c)

Figure 7—3 Comparison between tools and services willing to use by participants (answers before study) and those used during the study (answers after study)

Finally, Figure 7-3c shows that communicate services, namely phone, SMS and email editor, were the services with higher number of students who used them compared to the number of students who say, before the study, to be willing to use them. Additionally,

Figure 7-3c depicted that writing/reading-based services (namely, SMS, email editor and instant messaging) were preferred by students to complete communicative activities. One interesting point to remark here is that, although few students used speaking/listening-based services (namely, phone, voice messaging and video calling) to practice the language, they expressed, in the 20-minutes discussion after the study ends, feeling interested to exploit these services because they cannot find many opportunities to practice speaking/listening Language skills in their daily lives. Moreover, in the 20-minutes discussion some students expressed they felt more familiarized with writing/reading-based services for Language practicing.

Finally, we presume that due to the results analysis regarding the learners' attitude dimension (see **RQ1** for the case study in Table 7-2), the proposed mobile system is helping to enhance students' attitude heading the use of mobile technologies for learning. This is because the students expressed they could assume the control over their personal learning progress in different places and achieve individually the learning goals they were assigned to achieve through the activities and materials delivered by the system. Moreover, we presume that the results about accessing UoLmP from different places and using the supportive resources, tools and services in accordance with their learning needs and preferences, gave to this research work a positive perspective about designing m-learning scenarios considering aspects of the learners' context. We think, these results also suggest a slightly enhance over students' attitude, in particular Language learning students, towards using mobile technologies (such as UoLmP) for performing Language learning activities.

7.5.2 Context-aware adaptation approach effectiveness analysis

Context-aware adaptation results were analyzed from students' feedbacks about the suitability of the learning activities, materials and peers' contribution to their learning contexts. Students gave us specific feedback about the adaptation outcomes received, as well as their opinion at the end of the study. We did not asked them about the outcomes perception while they were interacting with the mobile system, as recommended by Martin & Carro (2009), because students found providing feedback at each step very tedious. Moreover, students' contextual data input was stored in logs and analyzed along with their feedback indicating the context in which the adaptation was provided.

Students' feedback related to the context-aware adaptation approach was analyzed considering:

i) adapted delivery of learning activities to the place and time where and when they interacted with the system,
ii) suitability of educational resources, grammar and vocabulary support to their needs,
iii) suitability of educational resources, mobile productive tools and communicative services to their personal interests on improving language skills, and
iv) suitability of the information of peers' contribution (i.e. peers' availability and strong language skills) to their interactions.

Regarding (i) *adapted delivery of learning activities to the place and time where and when they interacted with the system*, three activities of the educational scenario, namely "Exercise: Case study", "Observation" and "Collect marketing examples", are filtered (showed or hided) to students regarding the place from where they access the mobile system (these activities can be seen in the Learning activities flow diagram of the exemplary educational scenario 2 in Figure 5-3). The other activities are always showed regardless the place of access. According to the scenario's design, the teacher remarked that the first two activities (i.e. "Exercise: case study" and "Observation") are not mandatory to be done when students are at the Language learning school, as they work in similar activities inside the classroom (see Figure 7-1, specifically activities in classroom of "Session 1"), and referring the other activity, namely "Collect marketing examples", is better to be done outside the school and homes. Therefore, we had asked participants if they were presented with any of those three activities during the study (see Table 7-5). According to the analysis of (a) adapted delivery of learning activities to the place and time where and when they interacted with the system, the first two activities were always presented to 90% of participants pointing out they accessed the system from a different place to the training school, and sometimes presented to 10% of them indicating that these students sometimes accessed the system in the school and sometimes not. The third activity was never presented to 35% of students and always presented to 65% of them, indicating that the first group never accessed the system from outside the training school or their homes when they were at that point in the learning activities flow but the latter group did accessed. We could corroborate these results with students' opinions received through the 20-minutes discussion at the end of the study.

Table 7-5 Results of the delivery of adapted learning activities to the place and time where and when students interacted with the system.

N=20	Questions	1. never	2. almost never	3. sometimes	4. almost always	5. always	Mean	Std. Deviation
1	Did you see the activities entitled: "Exercise: case study" and "Observation" while you were interacting with the system?	0	0	2 (10%)	0	18 (90%)	4,80	0,616
2	Did you see the activity entitled: "Collecting marketing examples" while you were interacting with the system?	7 (35%)	0	0	0	13 (65%)	3,60	1,957

We presume that due to the consisted feedback of participants regarding the activities they viewed and complete through the mobile system, the learning activities were appropriately delivered to them at each step and adapted to the places they were located.

Concerning (ii) *suitability of educational resources, grammar and vocabulary support to their needs*, most of the students (80% of students) answer positively (35% said almost always and 45% said always) that they found useful the delivered educational resources so as to complete each learning activity (see Table 7-6) at the moment they needed. Moreover, 90% of students indicated that grammar support was useful (20% said almost always and 70% said always) and 65% of students (35% said almost always and 30% said always) that vocabulary support was useful at the moment they needed.

Table 7-6 Results of suitability of educational resources, grammar and vocabulary support to students' needs

N=20	Questions	1. never	2. almost never	3. sometimes	4. almost always	5. always	Mean	Std. Deviation
3	Were the resources useful and needed for you as support to complete the activities?	0	0	4 (20%)	7 (35%)	9 (45%)	4,25	0,786
4	Was the grammar support useful for you to complete the activities at the moment you did need it?	0	0	2 (10%)	4 (20%)	14 (70%)	4,60	0,681
5	Was the vocabulary support useful for you to complete the activities at the moment you did need it?	1 (5%)	0	6 (30%)	7 (35%)	6 (30%)	3,85	1,040

Results of (iii) *suitability of educational resources, mobile productive tools and communicative services to their personal interests on improving language skills* are presented in Table 7-7. For the question *6.Were the support resources suitable to your learning skills development interests (Reading or Listening)*? The results describe that 95% of participants (55% said almost always and 40% of them said always) indicated that the educational resources (audio, videos, web content and images) were suited to their interests (improving reading or listening). According to defined adaptation rules for this scenario, students' input data related to their interests (temporal personal information) is evaluated so as to deliver audio and video resources when the student wants to improve the listening skill, or deliver web content and images when the student wants to improve the reading skill.

Analysis of the participants' answers to the question *7.Were the support tools (Text editor, Camera, Audio recorder, Video recorder) suitable to your learning skills development interests (Making notes or Oral presentation)?* indicated that 70% of students found (25% always and 45% almost always) suitable the mobile tools options delivered by the system according to their interests of improving writing or speaking skills. Each tool is related with one language skill (this relationship was presented in Table 5-8). In the same question, 30% of the students indicated that sometimes they want to use a different tool from the ones presented by the tool. For instance, one of them express he had liked to use the blog editor instead of the text editor option embedded in the mobile.

Finally, results to the question *8.Were the support services (Phone calling, Voice messaging, Video calling, SMS, Email, Instant messaging) suitable to your learning skills development interests (Written communication or Oral communication)?* shown that 90% of participants found (35% always and 55% almost always) suited the services delivered by the system respectively. Each service is related with one language skill (this relationship was also presented in Table 5-8). Only 2 participants indicated that sometimes were suited. One of these two students expressed she would have liked that the system included an instant messaging tool so as she did not have to use the ones, suggested by the system which are installed in the mobile device (e.g. skype, whatsapp, etc.).

Table 7-7 Results of suitability of educational resources, mobile productive tools and communicative services to students' interest on improving language skills.

N=20	Questions	1. never	2. almost never	3. sometimes	4. almost always	5. always	Mean	Std. Deviation
6	Were the support resources suitable to your learning skills development interests (Reading or Listening)?	0	0	1 (5%)	11 (55%)	8 (40%)	4,35	0,587
7	Were the support tools (Text editor, Camera, Audio recorder, Video recorder) suitable to your learning skills development interests [Making notes(Writing) or Oral presentation(Speaking)]?	0	0	6 (30%)	9 (45%)	5 (25%)	3,95	0,759
8	Were the support services (Phone calling, Voice messaging, Video calling, SMS, Email, Instant messaging) suitable to your learning skills development interests [Written communication (Reading/Writing) or Oral communication (Listening/Speaking)]?	0	0	2 (10%)	7 (35%)	11 (55%)	4,45	0,686

In order to explore the (iv) *suitability of the information of peers' contribution (i.e. peers' availability and strong language skills) to their interactions*, participants were asked if *Did they communicate with other classmates in order to complete collaborative activities?*, and besides if *Did they use the provided peers' strong skills and availability information to communicate with their classmates?* (see Table 7-8 and Figure 7-4). On the one hand, participants' answers for the first question showed that almost half of them, 20% and 25% of students, never and almost never communicate with other peers respectively, 35% of students sometimes did, and 5% and 15% of students almost always and always did communicate respectively. On the other hand, in the second question 60% of participants indicated that always (50% of students) and almost always (10% of students) used the peers' information (i.e. the information about their peers' strong skills and availability) provided by the system for collaborative activities, 15% of students sometimes used it, and 25% of students never used it.

In order to represent better the students' answers about the peers' information contribution to their interactions presented in in Table 7-8, a cross-tabulation result between both questions are presented in a chart in Figure 7-4. Thus, 4 (20%) of participants that never communicated, did never used the peers' information, and only 1 (5%) participant who sometimes communicated with their peers never used the supportive peers' information. On the other hand, 3 (15%) participants sometimes used the peers' information, 2 (10%) participants almost always used it and 10 (50%) participants always used it, which means that 75% of students in total used the peers' information so as to complete the collaborative activities.

Table 7-8 Results of suitability of the peers' information contribution (i.e. peers' availability and strong language skills) to their interactions.

N=20		Question	Did you communicate with your classmates to complete collaborative activities?				
Question		1. never	2. almost never	3. sometimes	4. almost always	5. always	**Total**
Did you use the provided peers' strong skills and availability information to communicate with your classmates?	5. always (% of total)	0	2 (10%)	4 (20%)	1 (5%)	3 (15%)	10 (50%)
	4. almost always (% of total)	0	2 (10%)	0	0	0	2 (10%)
	3. sometimes (% of total)	0	1 (5%)	2 (10%)	0	0	3 (15%)
	2. almost never (% of total)	0	0	0	0	0	0
	1. never (% of total)	4 (20%)	0	1 (5%)	0	0	5 (25%)
	Total	4 (20%)	5 (25%)	7 (35%)	1 (5%)	3 (15%)	20 (100%)

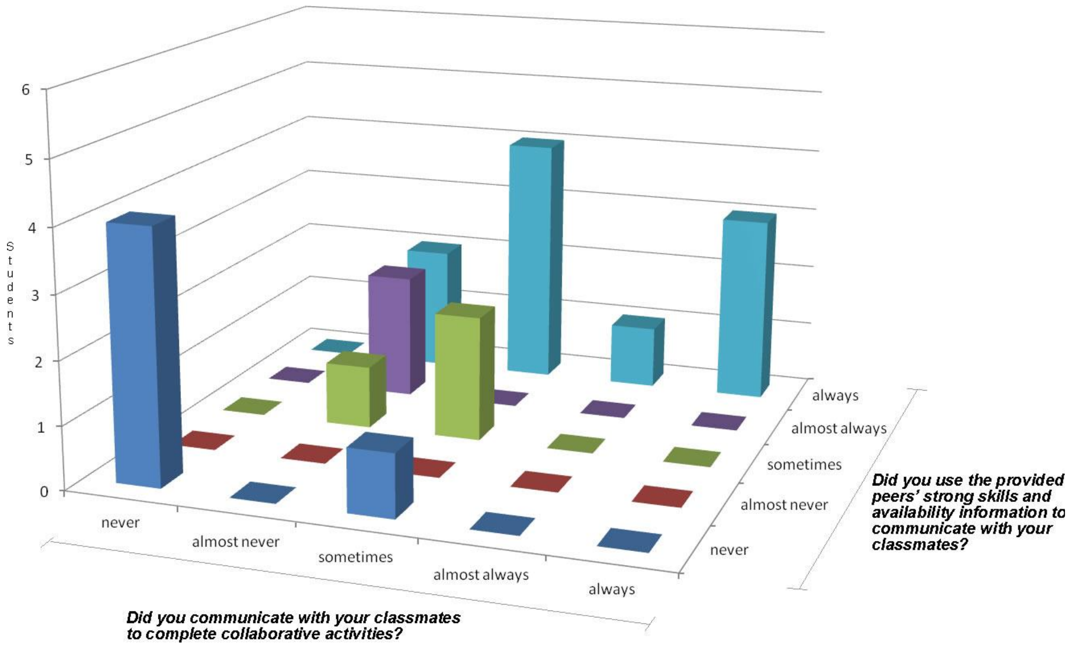


Figure 7—4 Cross-tabulation between answers to the questions a) Did students communicate with others? and b) Did students used the peers' information to communicate with others?

The results and participants' feedback for the context-aware adaptation approach effectiveness dimension (see **RQ2** for the case study in Table 7-2), give this research work positive evidence that learning activities can be assumed were appropriately and delivered to participants at each step in the learning flow and adapted to the places they were located. Moreover participants share a consisted point of view indicating that learning materials (educational resources, tools and services) were suited to their personal information, that is, contextual information such as their interests on improving language skills, as well as their needs, preferences and the physical conditions of the place from where they accessed the system. Additionally, results support that peers' information contribution (i.e. peers' availability and their strong language skills) suggested that providing students with that information contributed and would be helpful to learners interactions, even though the opportunities they had to work collaboratively during the period of the case study were limited (not all students were participating and a final exam date was closer to the case study's period).

7.5.3 Learners' satisfaction analysis

In order to explore participants' satisfaction regarding to the delivered adaptive educational scenario and the functionalities provided by UoLmP (see **RQ3** for the case study in Table 7-2), a satisfaction questionnaire was conducted as the final part of the online questionnaires. The questions were designed to assess the students' satisfaction related to aspects of the educational scenario and the mobile system functionalities for completing educational activities that the earlier questionnaires had indicated as being important. Students were asked to rate statements on a five-point Likert scale for Frequency Level, where "5" represented "Always" and "1" represented "Never". Table 7-9 shows the mean and standard deviation of the responses to each item.

Table 7-9 Results of satisfaction analysis.

N=20	Questions	1. never	2. almost never	3. sometimes	4. almost always	5. always	Mean	Std. Deviation
1	Were the support resources (texts, images, videos, audios) easy to read/view/listen to?	0	0	1 (5%)	6 (30%)	13 (65%)	4,60	0,598
2	Were the resources easy to understand?	0	0	3 (15%)	10 (50%)	7 (35%)	4,20	0,696
3	It was easy for you to complete the productive activities of the lesson using the suggested tools?	0	0	4 (20%)	13 (65%)	3 (15%)	3,95	0,605
4	It was easy for you to complete the collaborative activities of the lesson using the suggested services?	0	1 (5%)	5 (25%)	8 (40%)	6 (30%)	3,95	0,887
5	Do you find useful the peers' information (strong skills and availability) to complete collaborative activities?	0	2 (10%)	3 (15%)	13 (65%)	2 (10%)	3,75	0,786
6	Do you think that this kind of task (real-life tasks such as Setting up a business) encourages your English learning motivation much more?	0	0	2 (10%)	9 (45%)	9 (45%)	4,35	0,671
7	Do you think that completing learning activities by using UoLmP may deepen your knowledge on English much more?	0	0	7 (35%)	10 (50%)	3 (15%)	3,80	0,696

The first approximation to this analysis consisted of finding out if participants feel satisfied with the materials they used, which were provided by the educational scenario and adaptively delivered by UoLmP. Firstly, participants' satisfaction was analyzed in terms of the easiness to work with the resources and to complete the activities using the mobile tools and services (See Table 7-9, questions 1 to 4). We presume that in general, participants were satisfied with the materials that UoLmP adaptively delivered to their mobile devices, due to the majority of participants share a consisted point of view, that is, they found fairly easy (means 4,6; 4,2; 3,95 and 3,95 respectively) to work with the resources, tools and services provided by the mobile system.

Moreover, we analyzed if students find useful the peers' information (i.e. strong skills and availability) to complete collaborative activities (question 5). Here, it is important to mention that, students freely provided, before starting the case study, their personal information regarding the skills they feel are strong in and their availability during the week to train English (see Table 7-1). Nevertheless, it was find that few participants didn't feel confident using this aid during the study, and an explanation to this fact it is that they knew that not all students were participating in the case study (one participant indicated this; see "student a" comment in Table 7-11,). Moreover, few others felt they could be bothering others knowing that the final exam was coming closer as they expressed in the 20-minutes discussion after the study. However, according to students' answers for question 5 (see Table 7-9), we presume that peers' contribution is a useful support for collaborative interactions, since 65% and 10% of students found it useful a*lmost always* and *always* respectively.

In addition, we analyzed satisfaction of participants by asking them *6.if this kind of tasks (real-life tasks such as Setting up a business) do encourages their motivation for English learning?* and *7.if they do think that completing learning activities by using UoLmP may deepen their knowledge on English much more?* (see questions 6 and 7 in Table 7-9). Most of the participants affirmatively indicated (i.e. 45% of students answered almost always and 45% of them answered always) that real-life tasks such as "Setting up a business" encourages their motivation to learn English, and even more by using mobile technologies as an opportunity to complete the activities whenever and wherever they wanted, as they indicated in the 20-minutes discussion after the case study. This positively suggests that students are satisfied to complete this sort of constructivist learning activities by using mobile technologies, in this case, by using UoLmP. Participants indicated that completing learning activities through UoLmP moderately deep (mean 3,8) their knowledge on English (see this value in question 7 in Table 7-9).

Moreover, participants were able to share their feedback about whether the mobile system is a useful tool for performing learning activities, and whether they would recommend school's teachers to continue using the mobile system in their courses (see Table 7-10), as well as participants gave their comments and opinions based on their experiences during the case study (see Table 7-11).

Table 7-10 Frequencies for general perception and impact of UoLmP for learning.

N=20	Questions	Frequency		Percentage
	Do you think UoLmP is a useful tool for performing learning activities?	Yes No No answer	19 0 1	95 % 0 5 %
	Would you recommend school's teachers to continue using UoLmP in their courses?	Yes No No answer	19 0 1	95 % 0 5 %

Table 7-11 Comments and opinions from some participants gathered with the online questionnaire.

Student	Comment / Opinion
a	I think it would have been better if more people had used the application, in order to communicate with them.
b	I think that the activity was really useful for me. Start using it at the beginning of the task, after reading the case study in classroom was very interesting. It was also very useful when we were developing our business plan.
c	I use my smartphone almost all my spare time and I find this application useful to practice my English everywhere.
d	I think using the mobile phone or tablet is very interesting. It is more attractive than using a desktop computer.
e	It is a new way to support students out of the classroom. It allows us to perform self-learning in new environments.
f	I think that every activity done in class could be assisted by such aids.
g	I wanted to comment that last week I completed the activities with the tablet. It was the first experience with this device. Despite it being a new support for me, I think this method for learning English is interesting. If you have a device, must be practical to have the material at your disposal at any time and any place.
h	I like the tool and the innovation in mobil learning and languages learning. I find the application useful and well implemented. Suggestion: Maybe it would be useful to inform users how the interface changes when they edit the "actual situation settings". The students could be more aware of different resources and services for the next session. It is nice the personalization, so, you can inform the students about it.

There was only a general complaint from some participants, regarding the desire to have more time for interacting with such a system and with others. They knew that not all students were participating with the mobile device in the task and also they felt they were not totally comfortable communicating with others because of the date in which the study was carried out (i.e. close to a final exam). In this kind of activities it is essential the initiative and participation of every student (as some participants expressed) so as to build a learning community in which everybody is benefiting from others ideas and feedback and practicing according to what they have learnt (Norbrook & Scott, 2003). Nevertheless, the fact that students proposed to extend the environments to cover other Language courses and suggested to make it accessible in different periods (not close to a final exam) gives clues about the acceptance of this type of educational scenarios among students.

Finally, almost all students (95%) agreed consistently that UoLmP is a useful system for performing learning activities and that they would recommend teachers of the English learning school's to continue using UoLmP in their classes (see Table 7-10).

7.6 Summary and discussion

In this chapter definition and deployment of a case of study to evaluate the validity of the developed solutions is presented. The validation consisted in the deployment and later study of experiences with an authored context-aware adaptive educational scenario, namely Scenario 2: “Setting up a business: starting a new business” (see Appendix C for further details), jointly with the approach for delivering through UoLmP.

Three research questions were defined for this study:

RQ1: Is the proposed context-aware adaptive mobile system helping to enhance students' attitude heading the use of mobile technologies for learning?

RQ2: Is the proposed mobile system and the context-aware adaptation approach effectively operational and suitable when delivering adapted educational activities, resources, tools and services based on processing contextual information?

RQ3: Is the proposed context-aware mobile system and the adaptive educational scenario accepted by students?

Regarding (**RQ1**), we presume that due to the results analysis, the proposed mobile system is helping to enhance students' attitude heading the use of mobile technologies for learning. This is because the students expressed they could assume the control over their personal learning progress in different places and achieve individually the learning goals they were assigned to achieve through the activities and materials delivered by the system. Moreover, we presume that the results about accessing UoLmP from different places and using the supportive resources, tools and services in accordance with their learning needs and preferences, gave to this research work a positive perspective about designing m-learning scenarios considering aspects of the learners' context. We think, these results also suggest a slightly enhance over students' attitude, in particular Language learning students, towards using mobile technologies (such as UoLmP) for performing Language learning activities.

Regarding (**RQ2**), the results gave this research work positive evidence that learning activities can be assumed were appropriately and delivered to participants at each step in the learning flow and adapted to the places they were located. Moreover participants share a consisted point of view indicating that learning materials (educational resources, tools and services) were suited to their personal information, that is, contextual information such as their interests on improving language skills, as well as their needs, preferences and the physical conditions of the place from where they accessed the system. Additionally, results support that peers' information contribution (i.e. peers' availability and their strong language skills) suggested that providing students with that information contributed and would be helpful to learners interactions, even though the opportunities they had to work collaboratively during the period of the case study were limited (not all students were participating and a final exam date was closer to the case study's period).

Regarding (**RQ3**), most participant learners positively expressed that they liked this new approach of learning through mobile and adaptive educational scenarios. Besides, participants consistently confirmed that learning through the presented mobile system is more attractive. They described the experience as positive and suggested the use of the mobile system in other courses. Students wrote several comments related to the experience, stating that: learning became more attractive with such an educational scenario in which they are performing activities related to a real-life task, and they feel more motivated by using the UoLmP system in different learning settings and receiving adapted educational materials to their contexts.

Aditionally, there were some limitations identified from the case of study which needs special attention. Identified limitations from the case of study and general conclusions from the research work presented in this thesis are described in next chapter.

CHAPTER 8

CONCLUSIONS AND FUTURE WORK

In this chapter a general summary, discussion and conclusions of the research work developed in this thesis is presented. Basically, some conclusions are drawn, general results are reviewed and some limitations are addressed. As a final point, possible directions for future research are proposed.

8.1 General summary and discussion

Context-aware m-learning is an emerging and promising research field, which can benefit strongly by considering personalization and adaptivity aspects towards providing more effective, convenient, and enhanced learning experiences. In this thesis, the concepts of m-learning and context-awareness were presented and discussed in Chapter 2, as well as were examined the notions of the learning design process and the foundations for its implementation considering the characteristics of context-aware and m-learning scenarios, which was also presented in Chapter 2.

While these aspects are becoming a growing research area, aspects of adaptivity and personalization are becoming more and more important and they are playing an important role towards providing learners with adaptive and personalized learning experiences delivered via mobile devices. Chapter 3 went into aspects of adaptivity and personalization by presenting main issues to take into account for achieving a context-aware and adaptive m-learning design and delivery. Moreover in that chapter, two identified scopes for adaptation were presented, namely *educational content adaptation* and *context-aware educational scenarios adaptation.* In the former scope, content adaptation mechanisms and levels for adaptation were explained, as well as it was presented an overview of identified context-aware learning content adaptation systems. In the latter scope identified adaptation types for context-aware educational scenarios adaptation were presented and an overview of existing context-aware adaptive mobile systems.

However, in order to achieve adaptive and personalized m-learning:

- suitable educational scenarios must be re-thought and/or re-designed considering different learning situations in which heterogenous information from learners' context can used to provide enhanced learning experiences (this was addressed by the proposal presented in Chapter 4 and the implementation in chapter 5);
- adaptivity and personalization issues should be incorporated in the development of m-learning systems so as to provide learners with context-aware adaptive educational scenarios and a learning environment that is not only accessible anytime

and anywhere, but also accommodating to their context (this was addressed by the proposal presented in chapter 4 and the implementation in chapter 6).

Accordingly, the solutions presented in chapter 5 and 6 intended to present a viable solution to these two aforementioned situations and to give an answer to the first research and development question addressed in this thesis:

RQ1: *How can adaptive educational scenarios, which may benefit from learner's contextual information and m-learning dimensions, be designed and delivered?*

Additionally, in this thesis was addressed an existing overarching research challenge that consists in defining and developing optimal ways to deliver and present learning activities and educational materials (activities, resources, tools or services), which are populating educational scenarios, to learners considering the information of their lived context, as well as considering the limitations and capabilities of their mobile devices (addressed in Chapters 5 and 6). Therefore, in this research work a proposed solution to this issue consisted in to determine how explicitly to model the context (this was addressed in Chapter 5) and when to provide adapted learning activities and suited generic 'awareness' educational materials that learners, individually and together, can undertake and employ respectively (this was addressed in Chapters 5 and 6).

This situation has led to the second research and development question addressed in this thesis.

RQ2*: How can educational digital materials, used by an instructor in a procedural learning plan (i.e. learning design), be adapted and suitable delivered to the learner's mobile device at hand considering learner's contextual information?*

8.2 Conclusions

In this section, details of the review of the research work results are presented so as to explain the achieved conclusions to the solutions developed and their evaluation.

8.2.1 Review of the results

Regarding to the first research and development question addressed in this thesis: (***RQ1***) *How can adaptive educational scenarios, which may benefit from learner's contextual information and m-learning dimensions, be designed and delivered?*:

Firstly, as presented in section 5.3 there exist several ways and attempted models so as to represent some learning design components such as learning activities, participating actors, used resources, among others. Moreover, little work has been done so as to combine m-learning characteristics with existing components in a learning design template. Consistently, the author of this thesis concludes stating that in present TeL research existing learning design templates have not considered describing in the learning design process what contextual information can be useful to provide adaptive and personalized m-learning experiences.

Therefore, the author of this thesis have argued for the importance of modeling and including the information of learners' context in the learning design process and templates, considering situations of authentic learning where learner's real-life contexts and settings different from formal learning can be exploited, so as to achieve a personalized and adaptive m-learning that could be designed and delivered and shared (this was argued in chapter 5).

Additionally, it is stated that currently, there is not an existing standard model of the information of the context which support describing the elements that can be processed by a mobile system to achieve adaptation. However, there are different modeling techniques (described in chapter 2) which can be addressed to define a machine-readable data structure of contextual elements.

To this end, a context model for identifying and describing the information that can be used to characterize the situation of a particular entity (i.e. anything relevant) participating in the interaction between an individual learner and a mobile system was presented in chapter 5. With this context model, the author of this thesis aimed to present a taxonomy of contextual elements and a set of exemplary instances (pre-defined data or values) for those elements (attached as Appendix A).

In this research work, this taxonomy was used for designing two exemplary context-aware educational scenarios, namely "Adaptive context-aware educational scenario 1 – Project-based learning" (attached as Appendix B) and "Adaptive context-aware educational scenario 2 – Experiential learning" (attached as Appendix C), which were presented in chapter 5. Moreover, these scenarios can be processed by the developed mobile delivery system, namely UoLmP (presented in chapter 6), so as to provide learners with adapted learning activities and educational materials.

Along this research work has been pointed the need of developing tools for delivering adaptive and context-aware educational scenarios via mobile devices. To this end, two outcomes were presented:

i) a set of design requirements for authoring and delivering tools so as they can incorporate a context-aware adaptation engine for both the learning design and mobile delivery processes (presented in chapter 4). This was an essential step for achieving the development of UoLmP; and

ii) the development of the context-aware adaptive m-learning system, namely UoLmP, which aims delivering pedagogical-enhanced and structured adaptive and context-aware educational scenarios via mobile devices (presented in chapter 6). Through this system, educational activities, learning resources, mobile tools and communication services (considered within the structure of an educational scenario) can be adaptively delivered to the learners' device at hand by processing retrieved contextual information.

Aditionally, in this thesis was argued that, the representation of contextual information and the formal description of the learning design process (i.e. the design of context-aware adaptive educational scenarios) with a notation language can be achieved by adopting the IMS-LD specification. Thus, it is concluded that IMS-LD is a feasible specification to model in a machine readable format the learning activities flow combined with the description of learners' context properties and context-aware adaptation rules, and furthermore, to implement two proposed adaptation engines (one for each scope of adaptation), namely the *content adaptation engine* and the *context-aware educational scenarios adaptation engine* (both presented in chapters 5 and 6), which were developed and used through mobile devices in the evaluation phase of this research work (presented in chapter 7).

This decision of adopting the IMS-LD specification provided this research work to demonstrate the capability to extend the design of constructivist-oriented traditional learning strategies and the development of adaptation mechanisms for m-learning, namely *polymorphic presentation* and *content filtering*, to two approaches, namely the design approach (chapter 5) and the delivery approach (chapter 6) with clear benefits in reducing the time of delivering adapted context-aware educational scenarios to learner's mobile device at hand.

Thus, to summarize our ideas about the adoption of IMS LD, existing research works have made efforts on extending IMS-LD specification with new elements; however in this research work it was not proposed to extend the IMS-LD specification with context-related metadata, but re-using existing structures to describe contextual elements so as to design and deliver context-aware and adaptive mobile education scenarios. There still are not results that demonstrate the benefits of extending the specification, perhaps it can be feasible that additional metadata on the necessity of the components of the IMS-LD specification can be crucial to expand design, nevertheless, complexity of designing with existing structures of the IMS-LD assumes a great deal of knowledge and scenarios construction with IMS-LD compliance authoring tools requires considerable training (Rosmalen, 2006). Then, this is hard demanding for the teachers and designers who in the opinion of the author of this thesis are not agree to describe more elements than the ones the specification currently provide. Instead, considering the presented context-aware approach for re-designing existing scenarios and creating new ones, presumes to demand less effort for a learning design that benefits of the characteristics of the m-learning and contextual information. Here, it is concluded that IMS LD is an appropriate specification that answers m-learning and context-aware adaptivity needs, thanks that it claims to be pedagogically neutral, meaning it does not enforce a particular instructional strategy or model, as well as the affordances of the educational components that can be used in the three levels (A, B and C) in which it can be implemented. Some related research work also remarks the benefits that this specification brings to m-learning scenarios design and delivery (Najime & Rachida, 2008; Ryan, Kinshuk & Maiga, 2012; Mavroudi, Hadzilacos & Kalles, 2010). Moreover, Mavroudi, Hadzilacos & Kalles remark that "while m-learning is still in its infancy, avoiding the spread of technical standards for it is vital". However, there are some limitations in the specification for automatic elaboration and modeling that need further analysis. This is further described in next sub-section.

On the other hand, the implementation of the proposed solution of an adaptation engine in design-time and run-time showed to be a possible solution for overcoming identified limitations of existing adaptations engines of m-learning activities and educational materials. That is, the proposed adaptation engines do not follow a hard-wired implementation based on defined unique instances of learners' mobile contextual information. Instead, multiple instances can be freely defined and processed by designers (such as the exemplary instances showed in Appendix A). Consequently this enables the process of (a) extending the adaptation engines with new instances of learners' mobile contextual information and (b) inter-exchanging these engines and their resultant types of content and educational scenarios adaptation with other adaptive learning systems and applications.

An additional outcome of this research work were the design of two exemplary context-aware mobile educational scenarios so as to explain and present how possible adaptations, that are realized based on learner's contextual information, can be incorporated. One of these scenarios, namely "Adaptive context-aware educational scenario 2 – Experiential learning", was delivered and evaluated in a case study and to execute it, UoLmP was provided to participant learners (presented in Chapter 7).

Concerning this evaluation by using UoLmP, it was validated that the system positively supported students to perform learning activities individually and collaboratively while they were following the procedural structure of the learning flow in the educational scenario. With UoLmP, the author of this thesis demonstrated a solution that combines parsing a designed learning script (based on the IMS-LD specification) and capturing and processing different instances for contextual elements in real-time (which normally are changing variables with different values) accordingly to a learning designer's plan.

Summarizing the evaluation results, they provided this research work evidence that UoLmP can successfully adapt the learning flow of an educational scenario, as well as the educational resources and the delivery of the tools and services that support the learning activities according to the personal learners' contextual information. The performed adaptations, through UoLmP, facilitated students to complete successfully the learning activities of an educational scenario.

The context-aware adaptation occurred in real-time in UoLmP, which processed captured data (instances) for the learners' contextual information of the *Mobile context* category (presented in Table 5-3) so as to deliver adaptively the educational materials. The case study's results and participants' feedback support that learning activities were appropriately delivered to participants at each step in the learning flow and adapted to the places they were located. Moreover, results suggested that delivering different support resources (such as examples, instructions, tips, guidelines, grammar, vocabulary, among others), assimilative educational resources types, mobile productive tools and communicative services was appropriated, considering that participants share a consisted point of view indicating that these learning materials were suited to their personal information, that is, contextual information such as their personal interests (language skills improve interests), needs, and preferences, as well as the physical conditions of the places from which they accessed. Additionally, results support that peers' information contribution (i.e. peers' availability and their strong language skills) would be helpful to collaborative interactions, even though the opportunities they had to work collaboratively during the period of the case study were limited (not all students were participating in the study and a final exam date was closer to the case study's period).

In addition, most participant learners in the case study positively expressed that they liked this new approach of learning through mobile and adaptive educational scenarios. Besides, participants consistently confirmed that learning through the presented mobile system is more attractive. They described the experience as positive and suggested the use of the mobile system in other courses. Students wrote several comments related to the experience, stating that: learning became more attractive with such an educational scenario in which they are performing activities related to a real-life task, and they feel more motivated by using the UoLmP system in different learning settings and receiving adapted educational materials to their contexts. Accordingly, we can also advise that providing such a mobile system like UoLmP, which adapts to a student's context and learning needs, based on information from a context model may create new opportunities for learning, as other authors suggested (Bull et al., 2004; Corlett et al., 2005). Participant learners were able to study individually through their mobile devices in an interactive and dynamic way, and the mobile system has promoted collaboration between classmates regarding the activities involved. The scenario encouraged discussions with other peers about the learning activities proposed and it also favored the exchange of ideas between learners in a constructivist way of learning. Then, we conclude stating that m-learning is not only about including mobile technologies in traditional learning activities; it is about how the students take advantage of mobile technologies to enhance their learning process: doing the learning activities anytime and anywhere, and allowing them to achieve, individually or collaboratively, the learning objectives defined in a core course curriculum.

Here, it is relevant to remark that the evaluation gave positive clues on attempting to design and deliver pedagogical-enhanced scenarios, considering traditional pedagogical models which have relevancy on a constructive (individual and social) and situated perspective. Then, it can be also concluded that mobile educational scenarios which are based on a constructivist pedagogical theory successes to capture the distinctiveness of context-aware m-learning. Moreover, it can be reinforced for the case of mobile environments, the conclusion made by Strobel et al. who stated that "most e-learning educational scenarios that are not based on constructivist theory fails, because they are based on theories of teaching, which predicated on the assumption that learning occurs in a classroom environment and are mediated only by a trained teacher (Strobel et al., 2009)". An educational scenario for m-learning must embrace the considerable learning that is personally initiated and occurs in settings different from a formal classroom. In addition, the delivered educational scenario can be provided as a solution to a challenge highlighted by Kukulska-Hulme, who states that: "the challenge is to develop educational scenarios that clearly identify what is best learnt in the classroom, what should be learnt outside, and the ways in which connections between these settings will be made" (Kukulska-Hulme, 2009).

Moreover, the results support positively the active participation and interest in using mobile technologies for learning. This supports related work reported in (Kukulska-Hulme & Pettit, 2009), in which evaluated students' attitude heading the use of mobile tools to learn and train indicated that mobile devices can be seem as supporting tools and not mandatory platforms for learning.

In this research work, a first approximation of using UoLmP with English language learners, who can follow the steps in a pedagogical-enhanced and structured learning flow (represented in the learning design of the educational scenario), indicated a encouraging attitude in learners heading the use of mobile devices for learning and an individual self-control over a constructivist learning process. To achieve this learners' engagement: alongside social interaction, intensely personal uses of mobile devices were provided through UoLmP, and the element of free choice of place, time, resources, tools, services, supportive peers, etc. was particularly appealing for participant learners.

Finally, the mobile system has initially been tested and evaluated with the delivery of context-aware educational scenarios constructed for language learning environments; however, its implementation aims to be used in any field of learning. Hence, UoLmP can support the individual learner in different contexts, by providing context-aware and adapted learning activities and educational materials, as well as by creating learning and work spaces for collaborative interaction in settings different from traditional ones.

Concerning to the second research and development question addressed in this thesis: (***RQ2***) *How can educational digital materials, used by an instructor in a procedural learning plan (i.e. learning design), be adapted and suitable delivered to the learner's mobile device at hand considering learner's contextual information?*:

In this research work, the issue of mobile educational content adaptation by exploiting contextual information, from the *Mobile context* category, was also discussed and an adaptation process for context-aware educational content adaptation that can be incorporated in both the design and the delivery approach was presented (chapter 5 and

6). An important factor for achieving meaningful learning experiences with m-learning is the capability of delivering adapted content without restrictions of the capabilities of the delivery end. This is also an emerging issue since most existing digital educational resources have been mainly, and continue, be designed assuming access and delivery through desktop computers.

To implement this adaptation process, technological capabilities of the access device are detected. As first approach, four default delivery device profiles, were defined to facilitate construction of four adapted versions of a designed educational scenario in design-time that can be published for delivery. In run-time detection of the capabilities of the learner´s device enables rapid delivering of constructed educational scenarios. Although developing a transcoding mechanism to adapt educational digital content, which are populating an educational scenario, on server side enhance the adaptation process, this mechanism is still computer and time consuming. Accordingly, this process is still best performed on server side than running through client side. That is, the adjustment can be applied more efficiently from the server-side approach because not all clients (ie mobile devices) can perform automatic content adaptation, due to their limitations such as reduced memory for processing and storing, limited bandwidth, among others. Then, this consistently benefits in reducing the time of delivering adapted educational scenarios to learner's mobile device at hand.

Aditionally, in this research work some performance tests of the transcoding process were undertook. Transcoding of digital content (such as audio, image, video and text) in terms of format conversions and scaling, is an optimal mechanism of adaptation that can be incorporated in authoring systems and educational scenarios repositories. Results of the tests done demonstrate that educational scenarios can be provided for different delivered ends. Moreover, it can be concluded that this process enhance the satisfaction of learners since it facilitates accessing the educational scenarios using other means different from a desktop computer.

It is concluded then, that the presented content adaptation process can be executed before publishing an educational scenario or in the moment when the user wants to download it into her/his mobile device. This avoids the transcoding process to run in real time, and thus, to make the learners to wait until this process is performed, which in the cases when an educational scenario is big in bytes size, can affect their satisfaction.

8.2.2 Limitations to address

In this research work, it was clearly confirmed that the IMS-LD specification is a feasible notation language, for modeling adaptation strategies that accommodates to the identified types of adaptation for context-aware m-learning, namely, *learning flow navigation and sequencing*, *problem solving support and feedback (scaffolding)*, and *interactive learners' communication*. Thus, to achieve these adaptations it was presented a context-aware adaptive m-learning delivery system that is compliant with IMS-LD level B, namely UoLmP, which aims to support the delivery of adapted learning activities and educational materials (i.e. resources, tools and services).

Specifically to achieve aforementioned aspects, properties, conditions and global elements structures of IMS-LD were modeled so as to capture single context-aware data entries and evaluate a set of Adaptation rules (IF-THEN-ELSE conditional structures). Moreover, in this research work it was defined that the scope of the context-aware properties should be local and personal because it was intended to capture personal context of learners, through their individual owned mobile devices, so as to provide them, in the instance of a specific run of a delivered educational scenario, with adapted and personalized learning elements. Positively to this matter, IMS LD specification denotes that local and personal properties can be used for personalization (IMS-LD, 2003). Nevertheless, according to (IMS-LD, 2003) properties can contain only single values, i.e. properties may not contain arrays (lists) of data or data sets, but can only contain a single value. For the scope of this research work this was not a problem. However, it must be advice for stakeholders that work, or are willing to work, in on-coming research with IMS-LD, that a limitation is presented in the specification for modeling other kind of educational scenarios that not includes aforementioned adaptation types, such as context-sensitive scenarios [for example mixed-reality or augmented learning, ambient learning, game-based learning, etc. (Pachler, Bachmair & Cook, 2010)] and/or for defining smart indicators (Glahn, 2009), which are characterized on providing adaptations or analytics respectively, based on evaluating considerable amounts of sensor-based data (i.e. data sets) and rules that need applying intelligent algorithms (Su et. al. 2011, Madjarov & Boucelma, 2010; Zhao et al., 2010) or patterns analysis.

Of course, this open issue matters to the continuity of this research work, so as to provide different scenarios that benefit from the affordances of the lived learners context such as surrounding objects, people, systems, etc., which can support the learning process in mobile environments. Here, it can be suggested that to achieve those adaptations, further proposals for extending the IMS-LD properties declaration to support data sets and define some operations that work with data sets, perhaps facilitates other kind of adaptations for context-aware adaptive m-learning. Similarly, this was recommended for e-learning environments by Burgos (Burgos, 2008) and by Glahn (Glahn, 2007). Aditionally, another possible solution could be to work on a different layer (with global properties) from the one in which the IMS-LD is described and can be parsed (i.e. the XML structure), aiming to capture/sense/detect contextual data and store it externally in data sets repositories, so as to achieve desired adaptations on the layer through which, the IMS-LD is delivered (i.e. player/delivery system) without modifying the IMS-LD structure.

On the other hand, obtained results from the evaluation also were analyzed to pinpoint limitations with regards to the developed delivery system. Although the students who participated in the experiment have addressed several benefits of completing learning activities by means of using the UoLmP system, there were several limitations in applying this system that is important to address so as to point issues that can be taken into account for enhancing the design of context-aware m-learning systems:

i) The mobile system was designed to provide adapted educational materials in different situations and learning contexts, and to guide the students when they are learning and practicing what they have learnt. In case that the learners do not complete some activities in the learning flow of an educational scenario delivered through the system, the effects of the system will be reduced.

ii) The learners can perform collaborative activities with the mobile system: sharing and communicating ideas and making decisions together using communication services provided by the mobile device and installed messaging applications. However, two limitations have to be faced: up to now, the system was only able to be used by students with Android-based mobile devices and some services and applications rely on rented internet services and wireless network; therefore, it can only be used by students with Android-based mobile devices and be able for users who paid to a service provider for the internet service or in environments with wireless communications.

iii) Up to now, the mobile system make decisions based on processing the contextual data captured by students input; therefore, if the learners' inputs are not consistent with the actual and real context, the system will not be able to provide suitable adaptations and useful educational content.

In addition, the students who participated in the experiment also offered some suggestions for improvement of the mobile system. For example, a participant (see "student h" comment in Table 7-10,) mentioned that when entering or editing the "actual situation settings" (i.e. contextual information) perhaps it would be useful to inform students how the interface of the system changes. According to this student, students could be more aware of different available resources, tools and services regarding their contextual information. Other participant (see "student a" comment in Table 7-10,) expressed that it would have been better if more people had used the application, in order to communicate with them. In other words, it would more attractive and fruitful in terms of learning collaboratively if the application were developed for other mobile operating systems. Fortunately, as this system was an initial prototype, hence such a problem can eventually be resolved by developing it for other mobile operating systems. Another problem that prevents the mobile system to be a fully support mobile system for delivering adaptive educational scenarios is the limitation of free space in the memory. An instructional designer has to be aware of the size of a package with the educational materials, so as to prevent delivering big sized educational resources that can be loaded by users who are limited by free space in memory in their mobile devices.

8.3 Future work

Future research includes the execution of additional experiments with UoLmP, so as to evaluate the learning effectiveness of the context-aware adaptation approach compared with the traditional learning approach. Moreover, design, creation and evaluation of new context-aware adaptive educational scenarios in different learning fields and with different leaners considering different elements of the context model is proposed, so as to provide new evidence of the effectiveness of our adaptation approaches for m-learning.

Future work includes, the implementation of automatically retrieval mechanisms for contextual information in run-time (i.e. sensing mechanisms), in which user intervention is not necessary, so as to reduce number of inputs from user and to accelerate adaptive engine processing of contextual data and adaptation outcomes delivery. We are planning to enhance developed mobile system`s functionalities including some of the suggestions given by the students, and create new ones. Moreover, it is worth mentioning that another interesting issue would be, analyzing all user actions in UoLmP so as to extract conclusions about what is going on within the mobile system on run-time, and update automatically data of the context model and refine the adaptation decisions based on that information. We are doing research on user model acquisition, trying to obtain information about student' contextual information instances without asking them to fill in the corresponding form.

Moreover, it should be mentioned that the adaptation approach of our proposed mechanism based on context-aware adaptation rules (despite the fact that it is flexible enough for defining new adaptation rules) might need an important number of adaptation rules to be created and processed, so as to cover a bigger amount of possible instances of learner's contextual information of the mobile context category. This could be a possible limitation of the proposed adaptation approach, which could be overcome by considering the use of planning techniques (Hernandez et al., 2009, Baldiris et al., 2012) and/or decision-based adaptation algorithms respectively (Sampson & Karampiperis, 2012).

Besides, regarding the adaptation rules it is important providing a set of guidelines for learning designers about the definition of these rules, considering the educational context to which a Learning Design can be targeted.

In addition, as future work, the author propose a prototype implementation of an IMS-LD level B compatible authoring tool for semi-automatically designing of adaptive and context-aware educational scenarios that can be delivered through the presented mobile delivery system. This authoring tool should be developed according with the designed requirements presented in chapter 4, and the integration with the content transformation approach for design-time developed in this research work and presented in chapter 5. An adaptive engine on such as an authoring tool, that can automatically handles conditional statements and adaptation rules creation, according to a selected subset of defined contextual elements and a set of possible defined values/instances for those elements, may facilitate authoring and reduce authors' workload and time for designing adaptive educational scenarios. An initial development of the prototype is in progress by customizing an existing IMS-LD authoring tool, namely the ASK-Learning Designer Toolkit (ASK-LDT) (Sampson, Karampiperis and Zervas 2005).

Moreover, further work includes a prototype implementation of a Learning Design repository which incorporates the content transformation approach for run-time developed in this research work and presented in chapter 6.

Finally, regarding the content transformation, further enhancements to the adaptation approach includes creating a content recommendation process based on history data (collected from interactions) of the capabilities of the mobile devices. This would let to identify new delivery profiles of mobile devices and, furthermore to refine the delivery of transformed content aiming to have generic adaptation rules, that facilitates delivering the adapted educational scenarios to a large number of devices.

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APPENDIX A

TAXONOMY OF CONTEXTUAL ELEMENTS FOR M-LEARNING DESIGN

In this appendix description of the contextual elements taxonomy is detailed in the following table. In our work, we adopt the dimensions and elements presented in this table, as the key dimensions and elements for modeling learner's context towards constructing our adaptation mechanism which can be used in m-learning design authoring tools (design approach) and m-learning delivery systems (delivery approach) for personalization and adaptation. Moreover, exemplary data is presented so as to provide instances for the development of the work presented in this thesis and for learning-design authors who can use them to describe contextual information in new context-aware adaptive mobile educational scenarios that can be processed by the tools presented in this research work.

Contextual element		Description	Exemplary data (instances)	Exemplary data source
Dimension: LEARNER				
Temporal personal information	Interest	Learner's self evaluated capacity to describe her/his attention in different learning situations. This information reflects the learner's willingness of assuming the control of her/his learning process.	e.g. Skills to improve. [Creativity, Critical analysis, Critical reading, Group/team work, IT Literacy, Numeracy, Oral communication, Practical Problem solving, Research, Written communication, Ability to learn, Commercial awareness, Computer literacy, Criticism, Data modeling, Decision making, Foreign languages, Information handling, Information literacy, Interpersonal competence, Management of change, Negotiating, Planning and organizing, Self management, Self reflection, Synthesis, Study skills, Critical analysis and logical argument, Writing style, Library, E-literacy, Listening, Making notes, Oral presentation, Reading, Referencing, Research reading, Inference and synthesis of information, Selecting and prioritizing, information, Summary skill, Time management and organization]	(Conole & Fill, 2005)
	Attitude	Learner's self evaluated capacity to describe her/his position or thoughts in different learning situations.	e.g. Concentration level [low, high]	(Bomsdorf, 2005).
	Need	Learner's self evaluated capacity to describe her/his desires or requests in different learning situations and act according to them.	e.g. Support content [vocabulary, grammar, self-assessment, examples, etc.]	Proposed by the author of this thesis
	Preference	Learner's self evaluated capacity to describe her/his inclinations for something in different	e.g. Learner's choice for a learning action, resource, etc. Preferable Input & Output Means [speech, text, keyboard, mouse, pen, handwriting,	(Economides, 2009)

Contextual element		Description	Exemplary data (instances)	Exemplary data source
		learning situations. Can be provided by the learner at the moment that the learner is presented with choice options.	graphics, animation, video, etc.]; Preferable Media [Audio, Text, Photos, Graphics, Animation, Video, 3D, etc.]; Preferable Educational Activities, Educational tools [video player, audio player, text editor, etc.]; Assessment Types; Preferable Communication Mode: 1. Synchronous [face-to-face, phone, chat, videoconference] – 2. Asynchronous [email, SMS, MMS, IM, Podcast, forums, social networks], People to communicate and/or collaborate, etc.	
	Mood	Learner's self evaluated capacity to describe her/his emotions in different learning situations.	e.g. Level of Enthusiasm (Fascination, Excitement, Passion, Involvement) – Boredom (Apathy); Happiness (Joy, Delight, Pleasure, Amusement) – Sadness (Melancholy, Sorrow and Depression); Satisfaction (Fulfillment); Calmness (Tranquility, Serenity, Peacefulness, Comfort, Relaxation); Anger (Irritation, Indignation and Upset); Anxiety (Stress and Nervousness); Frustration (Despair, Hopelessness and Panic); Fear (Concern, Worry and Doubt); Confusion; Hope (Optimism) – Pessimism (Defeatism and Self-pity); Expectancy (Anticipation, Certainty, Assurance, Acceptance) – Astonishment (Amazement and Negative Surprise); Sympathy (Love) – Disgust (Aversion); Hate; Pride (Honor) – Shame (Guilt, Humiliation, Embarrassment and Dishonor).	(Economides, 2006)
Dimension: PEOPLE				
Role		Function assumed or part played by people in a particular situation.	e.g. [Teacher, Peers, Parents, Subject expert, etc.] e.g. [Individual learner, Group leader, Coach, Group participant, Mentor, Supervisor, Rapporteur, Facilitator, Deliverer, Pair person, Presenter, Peer assessor, Moderator.]	(Luckin, 2010) (Conole & Fill, 2005)
Relationship		The nature of the More Able Partners' (MAP) (Luckin, 2010) relationships with the learner.	e.g. [Frequent, Infrequent]; [Formal or Informal]	(Luckin, 2010)
Contribution		The information that the learner's MAP may bring to their interactions with the learner that are of particular relevance for the individual learning process.	e.g. Peer's learning skills, English language learning skills [Reading, Writing, Listening, Speaking], social skills, knowledge in a subject, support doing an activity, etc.	(Luckin, 2010), (Conole & Fill, 2005)
Constraints		Known constraints on people`s interactions with the learner.	e.g. Interactions only out of the school time, constrained by others, etc.	(Luckin, 2010)
Dimension: ARTIFACT				
Technological	Digital property	Software technical capabilities of the access mobile device.	e.g. [Audio support, Image support, Video support, Text support, Dynamic content support, Markup language support]	(W3C-MBP, 2008;(WURFL, 2008)
	Physical property	Hardware technical capabilities of the access mobile device.	e.g. [Display: type, colors and resolution (pixels)]	(W3C-MBP, 2008; WURFL, 2008)

Contextual element		Description	Exemplary data (instances)	Exemplary data source
Dimension: PLACE				
Location		Spatial coordinates or point in a map.	e.g. [latitude, longitude]	Geospatial info from embedded GPS in mobile device.
Environment		One-word physical description of where the learner stands.	e.g. [workplace, home, outdoors, university, school, etc.]	Proposed by the author of this thesis
Interactive space		Aim or intention of the place.	e.g. [public, private, transient, social, informative]	(Luckin, 2010), (Economides, 2009)
Cultural background or milieu		The people, physical and social conditions, circumstances and events which provide the environment in which someone acts or lives.	e.g. [political, sportive, scholar, familiar]	(Luckin, 2010), (Economides, 2009)
Learning setting		Purpose of the place in terms of learning.	e.g. [computer-based, lab-based, field-based, work-based, lecture-based, seminar-based]	(Conole & Fill, 2005)
Dimension: TIME				
Task	Duration	The time span it takes to perform a learning task	e.g. [days(dd), months(mm), years(yy), hours(hh), etc]	Proposed by the author of this thesis.
	Scheduled	The planned time when the learner should complete a task or when a task ends. It can take a time span.	e.g. a date [dd-mm-yyyy] [hh:mm]	Proposed by the author of this thesis.
Action happens		Time when an event/action/activity can happens.	e.g. [dd-mm-yyyy] [hh:mm]	(Christopoulou, 2008)
Availability		The time interval that a, person, resource, tool, service is active/enabled to be used or considers has spare time available.	e.g. [dd-mm-yyyy] [hh:mm]	Proposed by the author of this thesis.
Dimension: PHYSICAL CONDITIONS				
Illumination level		State of the illumination level in the place where the learner is located.	e.g. [low, mild, high]	(Christopoulou, 2008)
Noise level		State of the noise level in the place where the learner is located.	e.g. [low, mild, high]	(Christopoulou, 2008)
Weather		State of the weather in the place where the learner is located.	e.g. [sun, rain, wind, hail, snow]	(Christopoulou, 2008)

TABLE LEGEND

- *Dimension*: Classification of the contextual characteristics within six categories: Learner, People, Place, Artifact, Time and Physical conditions.
- *Contextual element*. Every piece of contextual information identified, defined and considered that can be used to characterize the situation of an entity, considered

relevant to the interaction between a user and an application, including the user and applications themselves.

- *Description*: Description of the contextual element.
- *Exemplary Data (instances)*: Examples of contextual data or instances that let characterize the situation of an entity, and that will be processed by the adaptation engines proposed in this research thesis.
- *Exemplary Data source*: Source of the data (instances). This will be useful for learning design authors when authoring new educational scenarios.

APPENDIX B

LEARNING DESIGN OF THE ADAPTIVE CONTEXT-AWARE EDUCATIONAL SCENARIO 1 – PROJECT BASED LEARNING

Based on the efforts in teaching the English language by the proposal of Integrating second language learning skills in real-life tasks, which was discussed with Joaquim Vidal (teacher from EOI School), and considering the learning pedagogical approaches which can benefit from m-learning characteristics and the contextual information, namely constructivist and situated learning, details of the characteristics of the educational scenario "Sharing a flat: finding a new flat mate" are described in the next template. This template was proposed in (Sampson, Zervas & Sotiriou, 2011). Considered contextual information is proposed to be described in this template.

1) Narrative description

Description of the Context-aware adaptive educational scenario considering language learning activities based on the real-life task: "Sharing a flat: Finding a new flat mate"	
Title of the Educational Scenario	Sharing a flat: finding a new flat mate
Educational Problem	Main problems a. Lack in lessons attendance. b. Students are failing in pass the final exam of the Intermediate English level. c. Lack of motivating learning experiences related to the tasks and challenges of the real world where students may be engaged. d. No mobile technologies support is available. e. No context information is considered to provide appropriately and adapted learning activities to the learners.
Educational Scenario Objectives	**Knowledge** The students should learn grammar rules and related vocabulary in order to: • be able to describe qualities in people, things, places such as houses, inside a house, in a city, etc. • be able to make an interview (making questions and answer questions). • be able to express agreements and disagreements. • be able to write emails (formal and informal). • be able to write short reports. **Skills** The students should be able to: • integrate English learning language skills (reading, writing, speaking, listening) in real-life tasks like sharing a flat. • practice and apply English vocabulary to actual situations. • explore the ICT-based learning opportunities that the teacher propose. • perform language learning activities on their own in the moment and place they may want or need. • search and gather data from their contexts they could use to perform the activities to learn the English language.

<table>
<tr><th colspan="2">Description of the Context-aware adaptive educational scenario considering language learning activities based on the real-life task: “Sharing a flat: Finding a new flat mate”</th></tr>
<tr><td></td><td>Attitudes
The students should be able to:
show willingness to learn the English language even if they cannot attend all the lessons.
be aware of and take control of their learning process.
be aware of any information on their context that can be useful to practice English language.
show willingness to practice English language outside of a formal classroom.</td></tr>
<tr><td>Characteristics and Needs of Learners</td><td>Cognitive
Students that are in the Intermediate English Level have acquired the pre-intermediate English level knowledge which is a pre-requisite.

Psychosocial
More of the half total number of the students not attend to classes but are interested in participating actively in the learning process because they search for learning activities that fit and improve their acquired competences. According to teacher’s experience some of the reasons related with the lack of attending the classroom sessions of some students are because: job time overlaps with lesson’s timetable, students do not plan the time to go, students prefer to practice English outside than taking lessons, students prefer to spent time doing homework activities, students prefer to use available learning resources in Moodle and internet that suit their needs, etc.)

According to the teacher’s teaching experience the students are willing to test new tools (such as mobile devices, Moodle tools, etc.) to enhance acquisition of English language learning objectives.

Physiological
Students’ age is between 15 and 60 years old. They are living in Girona’s province (including Girona city and nearby towns). Other physiological characteristics are:
Students are mobile, their work or studies require a certain degree of mobility.
Students are adaptable to the use of new technology developments. All of them use a mobile device (such as smartphones, PDA or tablets).
Some students use their free time to use the allowable tools that EOI School provides (Moodle activities, computer labs, library, internet searching, etc.)
Needs
Learners need tools that they can use anytime and anywhere in order to follow and complete the activities planned by the teacher in the core course curriculum. Learners need to learn and practice English language in different situations from a formal classroom setting.</td></tr>
<tr><td>Educational Approach of the Educational Scenario

(a) Description of the Educational Approach rationale
(b) Parameters that guarantee the implementation of the Educational Approach</td><td>(a) Project-based learning aims at giving learners a highly motivating learning experience, which is closely related to the tasks and challenges of the real world. Students that learn the English language as a second language explore by themselves new opportunities to integrate what they have learn with the world experiences and practicing. English learning can be applied to new contexts and can be related with developing different skills in real-life tasks.

Project-based learning also supports learning so called “adult skills”, which include skills such as working in teams, working in self-guided manner, and assessing of own actions. Project-based learning is also connected to the idea of attaining transferable skills such as problem solving (Helle et al., 2006).

The projects in Project-based learning are challenging and complex tasks that are based on some topics, questions, or problems that are driving the working in projects. Challenging and complex tasks means here that the tasks must be such that they cannot be accomplished successfully without new learning taking place. The projects at hand usually involve elements from various subjects, which make them multidisciplinary and not bound to any particular subject domain.</td></tr>
</table>

<table>
<tr><th colspan="2">Description of the Context-aware adaptive educational scenario considering language learning activities based on the real-life task: “Sharing a flat: Finding a new flat mate”</th></tr>
<tr><td></td><td>The nature of the tasks have to be such that it involves learners in various kinds of activities that support the learning, such as designing, problem-solving, decision making, and active investigation. In projects, the learners work autonomously and collaboratively in small groups, whereas the teacher is more in a role of the tutor facilitating the learning process (Henry, 2005).

(b) The parameters that guarantee the implementation of the educational approach are the following:
• It must be ensured that the required time for the project to be completed exists.
• It must be ensured that the appropriate cognitive background for the learners exists.
• The teacher must prepare the topics for the learners’ projects beforehand.
• The teacher, who supports the learning process, should understand his role as a facilitator of the learning process.
• The teacher should not be in the experts' role trying to impose his knowledge over the topic or directing the activities of the learners, but let the learners to do their learning and decisions in projects.
• Each learner must have a smartphone or tablet device that it might need to have access to the Internet.
• Each lesson must consist of m-learning activities populated with learning resources that address the training needs of the above described learners.</td></tr>
<tr><td>Learning Activities:</td><td></td></tr>
<tr><td>Phase 1: Definition of the Project Goal</td><td>Organize into Groups
The teacher divides the class into groups of learners and ensures that these groups consist of learners with different capacities.

Presentation of the New Question/Problem
The teacher introduces the new question/problem to the learners related to the real-life task called sharing a flat: finding a new flat mate. Moreover, the teacher remarks the grammar and vocabulary related with the task that involve a) describing people, things and places, b) to be able to make an interview (making questions and answer questions, expressing agreements and disagreements, writing emails (formal or informal).

Discussion
Learners discuss about the new question/problem and contribute with opinions and ideas, and the teacher may provide feedback on the learners’ opinions.</td></tr>
<tr><td>Phase 2: Planning the Project</td><td>Discussion among the Group Participants
Learners discuss into the context of their groups about the project to be created and the responsibilities of each group member. The teacher facilitates support to avoid possible misunderstandings.</td></tr>
<tr><td>Phase 3: Doing the Project Work</td><td>Collection of Information
Each group member collects information about the topics related to their project work. The teacher can support the learners by pointing out with questions some topics that the learners might have given little or no attention or he/she may have prepared some material for learners that serves as a starting point for further inquiries on those topics.

Appropriate guidelines to provide learner with a working methodology are described for information collection. The learner is presented with a working methodology based on completing a sequenced activity structure. The following associated sub-activities are defined within the activity structure:
<table>
<tr><th>Related Subject</th><th>Sub-activities</th><th>Support</th></tr>
<tr><td>describing people, things and places</td><td>- Make a general description of your flat (how many rooms/bathrooms are?, services, rules, etc.).
- Make a specific description of the zones inside your flat (kitchen, room</td><td>- Text, Audios, Images, and videos, web content about people who</td></tr>
</table>
</td></tr>
</table>

Description of the Context-aware adaptive educational scenario considering language learning activities based on the real-life task: "Sharing a flat: Finding a new flat mate"

	for rent, bathrooms, living-room, etc.). - Describe the characteristics of the place where your flat is located (places nearby, location, services nearby, etc.). - List which are the necessary qualities in a flat mate.	introduce themselves trying to find a flat to share. - Text, Audios, Images, and videos, web content about people's descriptions that are looking for a flat to share. - Related vocabulary - Related Grammar

Support resources are presented to the learner in order to help her/him on completing the activities.

The learner can use the functionalities provided by her/his mobile device (Internet service, camera, voice recorder, multimedia player, notepad, standard docs viewer, etc.) in order to collect appropriate information that will help her/him to complete the activities.

Synthesis of Information
After the learners have collected the information, they synthesize together the collected pieces of information. The teacher can support the synthesis process by asking questions about various concepts and topics and their relations to each other.

Appropriate guidelines to provide learner with a working methodology are described for synthesizing. The learner is presented with a working methodology based on completing a sequenced activity structure. The following associated sub-activities are defined within the activity structure:

Related Subject	Sub-activities	Support
participating in interviews (asking and answering questions, expressing agreements and disagreements, and writing emails)	- Negotiate the flat mate qualities with the other group participants. - Agreeing on a common list of flat mate qualities.	- Related vocabulary - Related Grammar

The learner can use the functionalities provided by her/his mobile device (Internet service, SMS and MMS services, multimedia player, phone service, notepad, etc.) in order to complete the activities.

Create Project
Learners work collaboratively in order to create their project, while the teacher acts as a facilitator to their efforts.

Appropriate guidelines to provide learner with a working methodology are described for creating the project. The learner is presented with a working methodology based on completing an activity structure. The following associated sub-activities are defined within the activity structure:

Related Subject	Sub-activities	Support
- describing people, things and	- Write a questionnaire to measure the flat mate qualities. - Agreeing on the questionnaire.	- Related vocabulary - Related Grammar

<table>
<tr><th colspan="2">Description of the Context-aware adaptive educational scenario considering language learning activities based on the real-life task: “Sharing a flat: Finding a new flat mate”</th></tr>
<tr><td></td><td><table><tr><td>places
- participating in interviews (asking and answering questions, and writing emails)</td><td>- Select different peers (minimum 5 peers) to ask the questions in the questionnaire.
- Measure the selected peers according to their answers.</td><td></td></tr></table>
The learner can use the functionalities provided by her/his mobile device (notepad, standard docs viewer, SMS and MMS services, phone service etc.) in order to complete the activities.</td></tr>
<tr><td>Phase 4: Presentation of the Outcomes</td><td>Project Outcomes Presentation
Each group of learners presents the outcomes of the project to others and the teacher.

Students participate collaboratively in preparing a short report based on the obtained results and the decision made: selection of the new flat mate.

Discussion/Feedback
Learners answer to questions/comments of other learners and the teacher.</td></tr>
<tr><td>Phase 5: Assessing the Project Work</td><td>Summative Assessment
The teacher assesses the projects created by learner groups</td></tr>
<tr><td>Participating Roles:</td><td>Student
• Actively participate in the learning process by expressing his/her ideas, experiences and opinions.
• Complete learning activities using a mobile device to improve her/his English language learning skills.
• Describe and input contextual information.
• Gather contextual information to complete activities.

Group Participant
• Works collaboratively in small groups to create their project.
• Communicates and debates with other group participants.
• Searches, selects and synthesizes information
• Creates the final project
• Presents the final project
• Assesses the other groups

Peers
• Share their English language strong learning skills.
• Help between them to complete activities.
• Provides feedback.

Teacher
• Prepare the project topics for the learners
• Collect resources for the related subjects (videos, audios, texts, images, etc.).
• Design and create learning objects for the related subjects.
• Design the Learning activities flow using the ASK LD authoring tool.
• Poses questions.
• Coordinates, mediates, communicates and guides students in order to overcome any difficulties.
• Evaluates the final project outcomes and the cooperation between the learners.</td></tr>
<tr><td>Tools, Services and Resources</td><td>Tools:
Hardware
• Smartphone
• Tablet
• Computer</td></tr>
</table>

<table>
<tr><th colspan="2">Description of the Context-aware adaptive educational scenario considering language learning activities based on the real-life task: “Sharing a flat: Finding a new flat mate”</th></tr>
<tr><td></td><td>Software
UoLmP.
Mobile device assimilative tools: text viewer, image viewer, audio player, video player, web content viewer.
Mobile device productive tools: notepad, word processor, camera, audio recorder.
Moodle
Services:
Internet.
Mobile device communicative services: email, voice messaging, phone calling, video calling, SMS
Resources:
Narrative text, lecture, figure, problem statement, questionnaire.</td></tr>
<tr><td>Contextual Information for adaptation</td><td>Learner:
Temporal personal information: Interest:
Language learning skills to improve.
Temporal personal information: Preference:
Student’s choice for an action (selecting a learning tool or service).
Temporal personal information: Need:
Language support (vocabulary, grammar, examples).

People:
Contributions:
Peer’s Language learning strong skills.

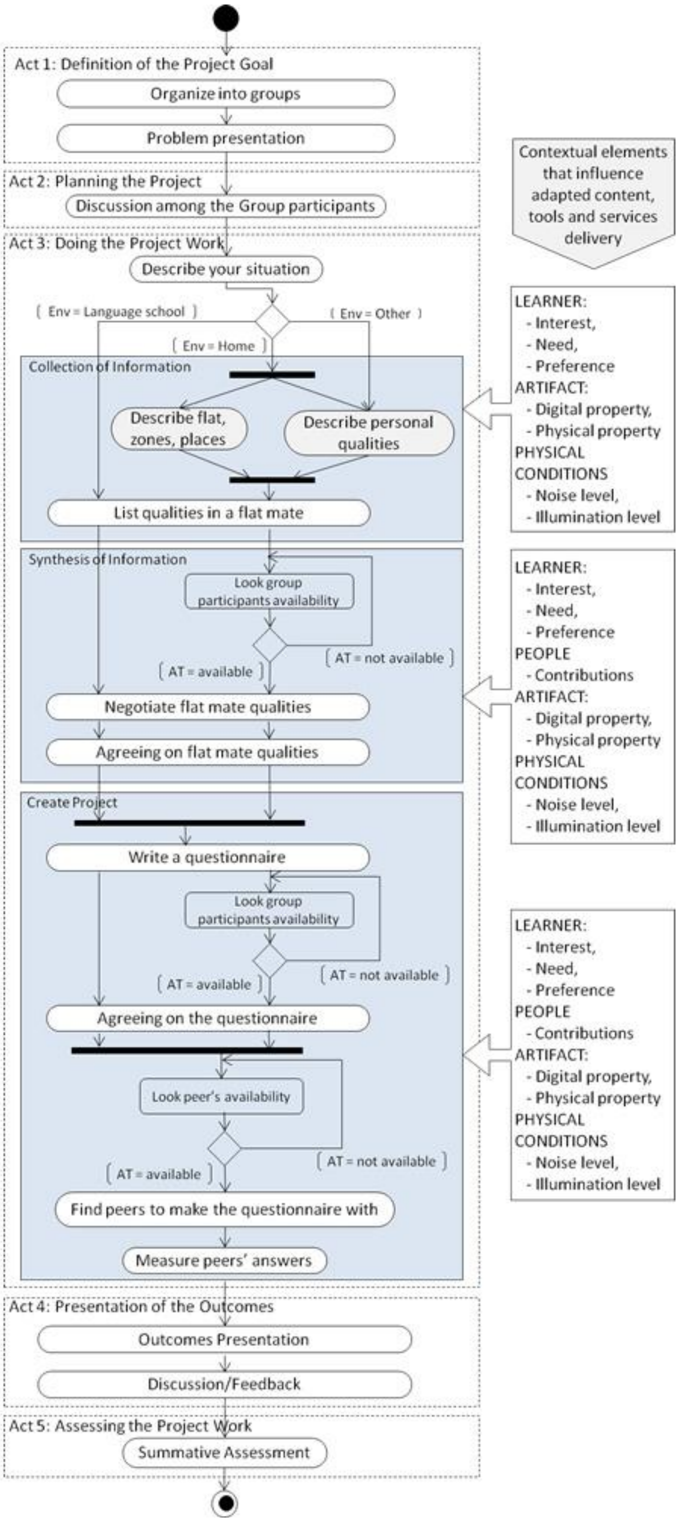
Place:
Location:
Spatial coordinates of the place where the student stands.
Environment:
One-word physical description of the place where the student stands.

Time:
Availability:
Student available time in the week for English learning.

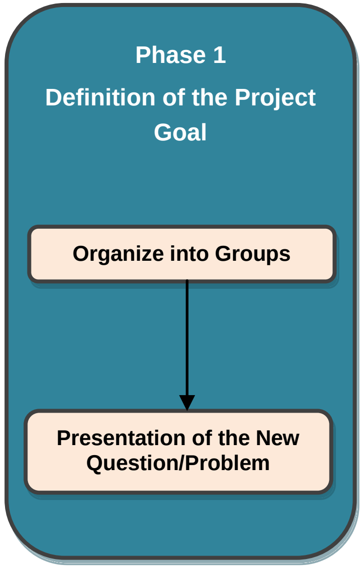
Physical conditions:
Noise level:
State of the noise level condition in the place where the student stands.
Illumination level:
State of the illumination level condition in the place where the student stands.</td></tr>
</table>

2) Graphical Representation of the Flow of Learning Activities

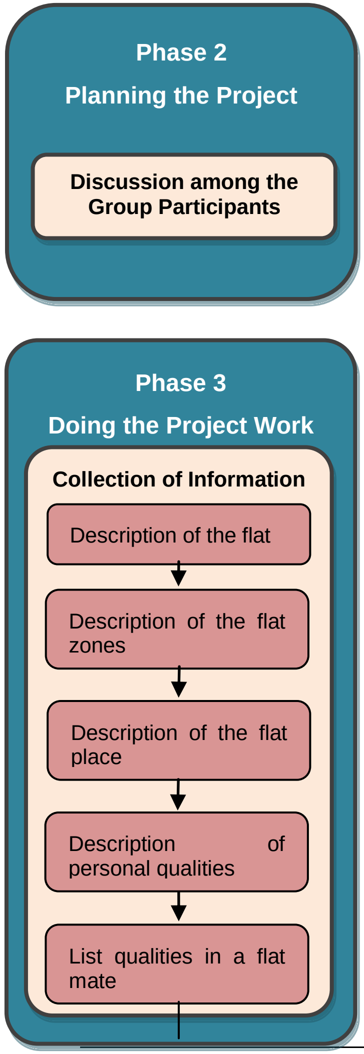
The order in which the steps are taken here is only a suggested order, not a mandatory one. Also contextual elements are considered here to suggest how they can participate in the learning flow.



3) Description of the Educational Scenario Template in Common Terms

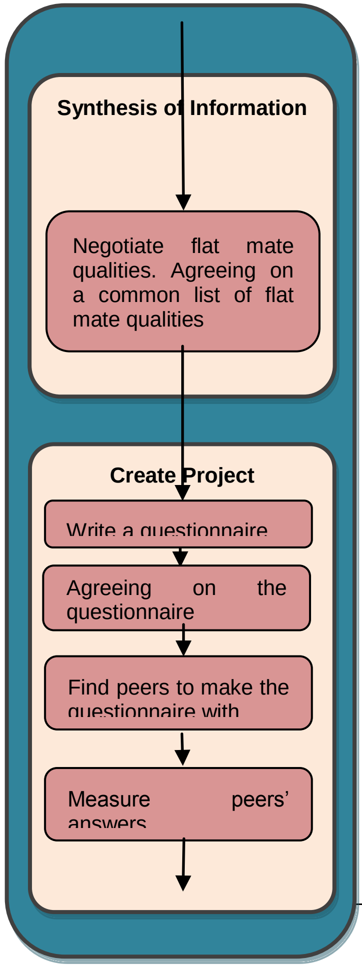


Type	Technique	Interaction	Roles	Tools/Services	Resources
Communicative – Presenting	Communicative – Negotiation	Who – Class based Medium – Face-to-face Timing – Synchronous	– Facilitator – Individual Learner	Hardware – Computer Software – Moodle – UoLmP Services – None	– Narrative text
Assimilative – Listening – Reading	Assimilative – Skim reading – Listening	Who – Class based – Individual Medium – Face-to-face – Learning object Timing – Asynchronous	– Facilitator – Individual Learner	Hardware – Smartphone – Tablet Software – Moodle – UoLmP Services – None	– Problem statement

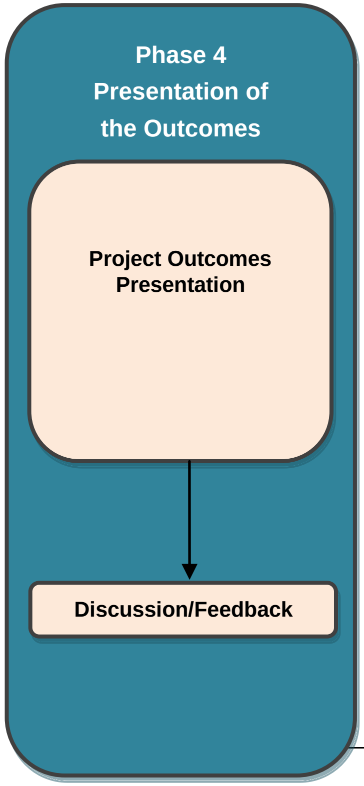


Type	Technique	Interaction	Roles	Tools/Services	Resources
Communicative – Discussing	Communicative – Debate	Who – Group based Medium – Face-to-face – Online Timing – Asynchronous	– Individual Learner – Group participant	Hardware – Smartphone – Tablet Software – UoLmP Services – Mobile device communicative services.	- Narrative text

Type	Technique	Interaction	Roles	Tools/Services	Resources
Productive – Writing – Producing	Productive – Assignment	Who – Individual Medium – Online – Learning object Timing – Asynchronous	– Group participant	Hardware – Smartphone – Tablet Software – UoLmP – Mobile device assimilative tools. – Mobile device information handling tools. – Mobile device productive tools. Services – None	– Narrative text – Slide – Figure – Lecture
Productive – Writing – Producing	Productive – Assignment				
Productive – Writing – Producing	Productive – Assignment				
Productive – Writing – Producing	Productive – Assignment				
Productive – Writing Information handling – Selecting	Productive – Assignment				



Type	Technique	Interaction	Roles	Tools/Services	Resources
Communicative − Discussing	Communicative − Negotiation − Discussion	Who − Group based Medium − Face-to-face − Online Timing − Asynchronous	− Group participant	Hardware − Smartphone − Tablet Software − UoLmP − Mobile device communicative tools. Services − Mobile device communicative services.	− Narrative text − Slide − Figure − Lecture
Productive − Writing	Productive − Assignment	Who − Group based Medium − Face-to-face − Online Timing − Asynchronous	− Group participant	Hardware − Smartphone − Tablet Software − UoLmP − Mobile device productive tools. − Mobile device communicative tools. Services − Mobile device communicative services.	− Narrative text − Slide − Figure − Lecture
Communicative Discussing	Communicative − Discussion				
Communicative Presenting	Communicative − Question and answer				
Information handling − Classifying	Productive − Assignment				



Type	Technique	Interaction	Roles	Tools/Services	Resources
Productive – Producing	Productive – Report/paper	Who – Group based – Class based Medium – Face-to-face – Online Timing – Asynchronous	– Group participant – Facilitator	Hardware – Smartphone – Tablet Software – UoLmP – Mobile device productive tools. Services – Mobile device communicative services.	- Narrative text
Productive – Presenting	Productive – Presentation				
Communicative – Critiquing	Communicative – Articulate reasoning	Who – Class based Medium – Face-to-face Timing – Asynchronous	– Group participant – Facilitator	Hardware – Smartphone – Tablet Software – UoLmP Services – None	- Narrative text

Phase 5

Planning the Project

Summative Assessment

Type	Technique	Interaction	Roles	Tools/Services	Resources
Communicative – Critiquing	Communicative – Arguing	Who – Class based Medium – Face-to-face Timing – Synchronous	– Group participant – Facilitator	Hardware – Smartphone – Tablet Software – UoLmP Services – None	- Exercise

4) Description of educational elements

Description of educational elements		
Dimension	**Type and Value**	**Description**
Type	Assimilative: Reading	Read given material
	Assimilative: Listening	Listening to given material
	Communicative: Presenting	Presentation of a specific subject/work
	Communicative: Discussing	Discussion among the participating roles
	Communicative: Critiquing	Critique on a specific subject
	Information Handling: Classifying	Classify information by certain given measured values.
	Information Handling: Selecting	From a big amount of information select the most appropriated data
	Productive: Writing	Write about something
	Productive: Producing	Produce something from previous collected information.
Technique	Assimilative: Skim Reading	Reading the content in order to understand its detailed meaning
	Assimilative: Listening	Listening to the content in order to understand its detailed meaning
	Communicative: Negotiation	A structured discussion of opposing points of view
	Communicative: Coaching	The teacher guides learners
	Communicative: Debate	A structured discussion of opposing points of view
	Communicative: Discussion	Expressing points of view
	Communicative: Question and answer	Ask something to receive an immediate answer.
	Communicative: Articulate reasoning	Learners explain their reasoning via speaking
	Communicative: Arguing	A verbal dispute
	Information Handling: Web search	Searching the world wide web for information about a specified topic using for example a search engine
	Productive: Assignment	Structured steps or tasks for doing an activity
	Productive: Presentation	Presentation of a specific subject/work
	Productive: Report/paper	Production of a report describing the process and the findings

Description of educational elements		
Interaction	Who: Class based	In the context of the classroom
	Who: Group based	In the context of the groups
	Who: Individual	The individual learned engaged in the learning process
	Medium: Face to Face	Face to face interaction of the participating role with others or content
	Medium: Online	Interaction via the use of Internet
	Medium: Learning object	Interaction with a learning object
	Timing: Synchronous	Synchronous interaction of the participating role with others or content
	Timing: Asynchronous	Learning activities can take place in different times
Roles	Individual Learner	The individual learner
	Group participant	A student participating in a group of students
	Facilitator	The teacher in a role of facilitator of the learning process
Tools/ Services	Hardware: Smartphone	An electronic, digital mobile device that stores and processes information
	Hardware: Tablet	An electronic, digital mobile device that stores and processes information
	Hardware: Computer	An electronic, digital device that stores and processes information
	Software: UoLmP	Software used to follow the learning activities flow based on the IMS-LD specification
	Software: Mobile device assimilative tools: text viewer, image viewer, audio player, video player	Typical mobile device embedded tools for doing assimilative activities such as: PDF or text viewer, image viewer, player for listening to audio files, player for viewing video files
	Software: Mobile device information handling tools: web viewer	Typical mobile device embedded tool for browsing.
	Software: Mobile device productive tools: notepad, word processor, camera, audio recorder	Typical mobile device embedded tools for doing productive activities such as: Text editor, Software that let performing word processing functions (i.e. insert, print, delete text, etc.), Software that enables to record video or take pictures, Software that enables to record audio
	Software: Mobile device communicative tools: email, instant messaging	Typical mobile device embedded tools for doing communicative activities such as: email editor and software that let sending and receiving instant messages
	Software: Moodle	Learning Management System to provide additional supporting information to learners
	Service: Mobile device communicative services: voice messaging, phone calling, SMS, MMS	Typical mobile device paid services for doing communicative activities such as: send voice messages, make phone calls, send short messages, send short messages with embedded media

Description of educational elements		
Resources	Narrative text	Description or explanation of something made by text
	Problem Statement	Document, audio or video for defining a problem
	Slide	Hypermedia document
	Figure	A figure is any graphic, text, table or other representation that is unaligned from the main flow of text
	Lecture	Presentation of a given subject or a document, audio, video explaining concept in detail
	Questionnaire	A list of questions by which information is sought from a selected group
	Exercise	Document, audio, video for practicing a skill or understanding
Contextual information	Learner: Temporal personal information: Interest	Language learning skills to develop. [Oral communication, Written communication, Writing style, Oral presentation, Listening and comprehension, Reading]
	Learner: Temporal personal information: Preference	Student's choice for a learning action (selecting a learning tool or service, resource, etc.)
	Learner: Temporal personal information: Need	Language support [vocabulary, grammar, examples]
	People: Contributions	English language learning skills in which a peer is strong [Oral communication, Written communication, Writing style, Oral presentation, Listening and comprehension, Reading]
	Place: Location	Spatial coordinates of the place where the student stands [latitude, longitude]
	Place: Environment	One-word physical description of the place where the student stands [workplace, home, university, EOI school, outdoors]
	Time: Availability	Available or spare time planned for English learning [Day, Hour]
	Physical conditions: Noise level:	State of the noise level condition in the place where the student stands [low, high]
	Physical conditions: Illumination level:	State of the illumination level condition in the place where the student stands [low, high]

APPENDIX C

Learning design of the Adaptive Context-Aware Educational Scenario 2 – Experiential Learning

Based on the efforts in teaching the English language by the proposal of Integrating second language learning skills in real-life tasks, which was discussed with Joaquim Vidal (teacher from EOI School), and considering the learning pedagogical approaches which can benefit from m-learning characteristics and the contextual information, namely constructivist and situated learning, details of the characteristics of the educational scenario "Setting up a business: Starting a new business" are described in the next template. The template was proposed in (Sampson, Zervas & Sotiriou, 2011). Considered contextual information is proposed to be described in this template.

1) Narrative description

Description of the Context-aware adaptive educational scenario considering language learning activities based on the real-life task: "Setting up a business: Starting a new business"	
Title of the Educational Scenario	Setting up a business: Starting a new business
Educational Problem	Main problems a. Learners need opportunities for real-world experiences in order to apply direct knowledge, create new understandings and extend their skills in practical ways. b. No mobile technologies support is available. c. No contextual information is considered to provide appropriately and personalized learning activities to the learners.
Educational Scenario Objectives	**Knowledge** The students should learn grammar rules and related vocabulary in order to: • be able to express hopes and wishes. • be able to express intentions and plans. • be able to define purposes and objectives. • be able to use English second conditional for imaginary and hypothetical situations. • be able to make an interview (making questions and answer questions). **Skills** The students should be able to: • understand the effect of an action • integrate English learning language skills (reading, writing, speaking, listening) in real-life tasks like setting up a business. • practice and apply English vocabulary to actual situations. • explore the ICT-based learning opportunities that the teacher propose. • complete language learning activities on their own in the moment and place they may want or need. • communicate effectively with others expressing ideas, plans, agreements, disagreements.

<table>
<tr><th colspan="2">Description of the Context-aware adaptive educational scenario considering language learning activities based on the real-life task: "Setting up a business: Starting a new business"</th></tr>
<tr><td></td><td>

work collaboratively with others and develop group tasks.
search and gather data from their contexts they could use to perform the activities to learn the English language.

Attitudes
The students should be able to:

show willingness to learn the English language even if they cannot attend all the lessons.
be aware of and take control of their learning process.
be aware of any information on their context that can be useful to practice English language.
show willingness to practice English language outside of a formal classroom.

</td></tr>
<tr><td>Characteristics and Needs of Learners</td><td>
Cognitive
Students that are in the Advanced English 4th Level have acquired the intermediate English level knowledge which is a pre-requisite.

Psychosocial
Students feel motivated when they are participating actively in the learning process because they like to search for learning activities that fit and improve their acquired competences. According to teacher's experience some of the reasons related with motivation in the classroom sessions of some students are because: they participate collaboratively with other peers, students are presented with learning activities that involve engagement with technologies, students practice English inside and outside the classroom, students enjoy doing technology-oriented homework activities, students are willing to use available learning resources in moodle and internet that suit their needs, etc.)

According to the teacher's teaching experience the students are willing to test new tools (such as mobile devices, moodle tools, etc.) to enhance acquisition of English language learning objectives.

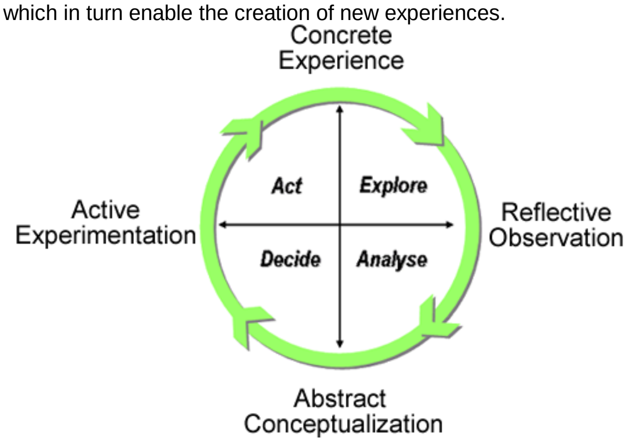
Physiological
Students' age is between 15 and 60 years old. They are living in Girona's province (including Girona city and nearby towns). Other physiological characteristics are:

Students are mobile, their work or studies require a certain degree of mobility.
Students are adaptable to the use of new technology developments. All of them use a mobile device (such as smartphones, PDA or tablets).
Some students use their free time to use the allowable tools that EOI School provides (moodle activities, computer labs, library, internet searching, etc.)

Needs
Learners need tools that they can use anytime and anywhere in order to follow and complete the activities planned by the teacher in the core course curriculum. Learners need to learn and practice English language in different situations from a formal classroom setting.
</td></tr>
<tr><td>Educational Approach of the Educational Scenario

(a) Description of the Educational Approach rationale
(b) Parameters that guarantee the implementation of the Educational Approach</td><td>
(a) Experiential Learning provides opportunities for real world experiences in which the learner can apply prior knowledge, create new understandings and extend his/her skills in practical ways. Learners may expand upon their prior knowledge and apply what they already know. Students that learn the English language as a second language explore by themselves new opportunities to integrate what they have learn with the world experiences and practicing. English learning can be applied to new contexts and can be related with developing different skills in real-life tasks.

Examples of experiential learning include service projects, case studies, field trips, work study programs, role playing, simulations, drama, and laboratory experiments. Although performances may serve as a culminating event (such as exhibitions for senior requirements) frequently they are shorter
</td></tr>
</table>

Description of the Context-aware adaptive educational scenario considering language learning activities based on the real-life task: "Setting up a business: Starting a new business"	
	assignments which serve as both learning and assessment. Kolb's learning theory (Kolb, 1984; Kolb & Kolb, 2005) sets out four distinct learning styles (or preferences), which are based on a four-stage learning cycle (which might also be interpreted as a 'training cycle'). In this respect Kolb's model is particularly elegant, since it offers both a way to understand individual people's different learning styles, and also an explanation of a cycle of experiential learning that applies to us all. Kolb includes this 'cycle of learning' as a central principle his experiential learning theory, typically expressed as four-stage cycle of learning, in which 'immediate or concrete experiences' provide a basis for 'observations and reflections'. These 'observations and reflections' are assimilated and distilled into 'abstract concepts' producing new implications for action which can be 'actively tested' in turn creating new experiences. Kolb says that ideally (and by inference not always) this process represents a learning cycle or spiral where the learner 'touches all the bases', i.e., a cycle of experiencing, reflecting, thinking, and acting. Immediate or concrete experiences lead to observations and reflections. These reflections are then assimilated (absorbed and translated) into abstract concepts with implications for action, which the person can actively test and experiment with, which in turn enable the creation of new experiences.  Figure 1. Kolb's learning cycle. Extracted from (Kolb, 2005) Moreover, we will use in *Active Experimentation* phase the Problem Solving Model, where learners have the opportunity to develop skills and apply their prior knowledge related with the experience presented. The *Problem Solving model* is a *Problem Based Learning* Model that combines four phases (Eggen & Kauchak, 2001). In Phase 1 (Problem Definition) the problem is defined. The problem must be well defined, while its solution must be based on background knowledge. In Phase 2 (Planning) the learner plans what do she/he has to know and do to solve the problem; how to rank these possibilities, and how do these relate to the list of solutions. In Phase 3 (Gather information) the learners must gather appropriate information (i.e. facts, data, interviews) that will help them solve the problem and look at the problem from different perspectives and consider alternative solutions. In the final phase (Implement Solution) the learners must choose the best alternative and implement their decision.

Description of the Context-aware adaptive educational scenario considering language learning activities based on the real-life task: "Setting up a business: Starting a new business"

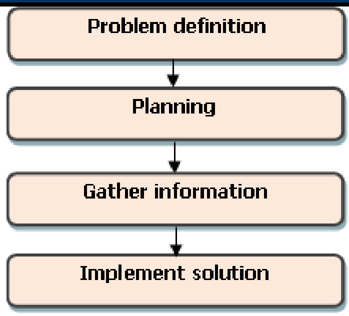


Figure 2. Problem solving model

(b) The parameters that guarantee the implementation of the educational approach are the following:

- The goal of experience-based learning involves something personally significant or meaningful to the students.
- Students should be personally engaged.
- Reflective thought and opportunities for students to discuss their experiences should be ongoing throughout the process.
- The whole person is involved, meaning not just their intellect but also their senses, their feelings and their personalities.
- Students should be recognized for prior learning they bring into the process.
- Teachers need to establish a sense of trust, respect, openness, and concern for the well-being of the students.

Experiential Learning:

- Recognizes that people learn best from their own experiences and their own reviews.
- Subscribes to the notion that what people do is more important than what they know.
  ("I hear, I know. I see, I remember. I do, I understand." *Confucius*)
- Moves beyond knowledge and into skill by generating a learning experience.
- Understands that to be remembered over a long period of time the learning process should be enjoyable, motivating and rewarding.
- Respects the individuals' ideas and choices.
- Provides opportunity to take on challenge in an atmosphere of support.
- Generates space and time to stand back and reflect when pressures or doubts become too strong.
- Cultivates a realization that the attempt at doing something new or different is more significant than the result.
- Produces awareness that effective learning requires small controlled steps outside comfort zones.

Learning Activities:

Phase 1: Concrete experience

The learner carries out a particular action and then observes the effect of the action in this situation.

Experiencing or immersing oneself in the "doing" of a task is the stage in which the learner simply carries out the task assigned. The engaged person is usually not reflecting on the task at this time but rather just carrying it out with intention.

Activities which help learners in this phase include ice breakers & energisers, team games, case study, problem solving, discussion, practical exercises, debates, etc.

Teaching activities that support different aspects of the Learning Cycle:

<table>
<tr><th colspan="2">Description of the Context-aware adaptive educational scenario considering language learning activities based on the real-life task: “Setting up a business: Starting a new business”</th></tr>
<tr><td></td><td>readings, examples, fieldwork, laboratories, problem sets, trigger films, observations, simulations/games, text reading, etc.

Excercise

<u>The teacher:</u>

Divides the class into groups of students and ensures that these groups consist of students with different capacities.

The teacher introduces a case study to the students related to the real-life task called setting up a business: starting your business. Moreover, the teacher remarks the grammar and vocabulary related with the task that involve a) expressing hopes and wishes, b) expressing intentions and plans, c) defining purposes and objectives and d) using English second conditional for imaginary and hypothetical situations.

<u>The student:</u>

Carries out the tasks assigned to the case study which consist in:

- Analyze the case identifying the product or service offered, the business plan (people involved, target audience, etc.) and the description of the marketing strategy.

- Identify the related grammar used in the case study description.</td></tr>
<tr><td>Phase 2: Reflective observation</td><td>Reflection involves stepping back from task involvement and reviewing what has been done and experienced. The skills of attending, noticing differences, and applying terms helps identify subtle events. One's paradigm (values, attitudes, values, beliefs) influences whether one can differentiate certain events. Understanding of the effects of an action in the particular instance is required in order to anticipate what would follow from the action if it was to be taken again under the same circumstances.

Activities which help learners in this phase include ask for observation, write a short report on what took place, give feedback to other participants, quiet thinking time, tea & coffee breaks, completing learning logs or diaries, etc.

Teaching activities that support different aspects of the Learning Cycle include logs, journals, discussion, brainstorming, thought questions, rhetorical questions, etc.

Observation

The student reflects about the main elements for setting up a business considered in the case study. The student is presented with a set of questions that would help her/him to extract the main steps for starting a business. Some examples of the questions presented are:

- How did you feel with the case study?
- What might you have done differently from the person in the case study?
- How would you organize some market research?
- Who might be your target audience?
- What would you need to carry out to start a business?
- Would you employ any people? How many? What profile?
- What would be a good marketing strategy for the product/service?
- Are there any other points that you may consider are relevant in the case study description?
- Are there any other points (related to starting a business) that you</td></tr>
</table>

<table>
<tr><th colspan="2">Description of the Context-aware adaptive educational scenario considering language learning activities based on the real-life task: “Setting up a business: Starting a new business”</th></tr>
<tr><td></td><td>think the case study description is missing?

The student can discuss his answers and ideas with her/his group peers in order to identify differences and understand other’s point of view. Students can identify some steps to set up a business that are relevant for doing a collaborative project work based on previous reflection and analysis.</td></tr>
<tr><td>Phase 3: Abstract conceptualization</td><td>Conceptualization involves interpreting the events that have been noticed and understanding the relationships among them. It is at this stage that theory may be particularly helpful as a template for framing and explaining events. One's paradigm again influences the interpretive range a person is willing to entertain. Understanding the general principle under which the particular instance falls does not imply ability to express the principle in a symbolic medium.

Activities which help learners in this phase include models, theories, facts, etc.

Teaching activities that support different aspects of the Learning Cycle include lectures, papers, projects, analogies, etc.

Theory presentation

The student is presented with assimilative learning materials to provide her/him with instructions/steps/tips on how to start a business. Moreover, information related to the topics (expressing hopes and plans, and defining objectives) will be delivered to the student which can be used as support resources. The teacher prepares some material for students that serves as a starting point for further inquiries on those topics. Moreover, the assimilative learning materials and support resources will be also presented to the student in the next phase “Active experimentation” in order to help her/him on completing the activities.

Appropriate guidelines to provide student with a working methodology are described for theory presentation. The student is presented with a methodology based on completing a sequenced activity structure.

The student can use the functionalities provided by her/his mobile device (Internet service, audio player, video player, text viewer, standard docs viewer, etc.) in order to study appropriate information that will help her/him to complete the activities in next phase “Active experimentation”.</td></tr>
<tr><td>Phase 4: Active experimentation</td><td>Application through action in a new circumstance within the range of generalization. Within this context planning enables taking the new understanding and translates it into predictions about what is likely to happen next or what actions should be taken to refine the way the task is handled.

Teaching activities that support different aspects of the Learning Cycle include projects, problem solving, fieldwork, homework, laboratory, case study, simulations, etc.

Problem Definition
The teacher introduces a new problem to the students related to the real-life task called setting up a business: starting your business. Appropriate guidelines related to a problem based on “starting a small business with the group members” will provide the student with a working methodology for a problem based learning.

Planning
The student may look at the problem from different perspectives and based on reflection of the case study and theory studied she/he will consider alternative solutions for a small business where the following initial tasks have to be completed:
- Define what is going to be offered, product or service?</td></tr>
</table>

Description of the Context-aware adaptive educational scenario considering language learning activities based on the real-life task: "Setting up a business: Starting a new business"

- What is the product or service?
- Organize some market research based on a small questionnaire or survey.

Learners will discuss into the context of their groups about the outcomes to be produced and the responsibilities of each group member in order to make a plan for a solution to the problem. The teacher may facilitate support to avoid possible misunderstandings.

Appropriate guidelines to provide learner with a working methodology are described for planning. The learner is presented with a working methodology based on completing a sequenced activity structure. The following associated sub-activities are defined within the activity structure:

Related Subject	Sub-activities	Support
- expressing intentions and plans - defining purposes and objectives - using English second conditional for imaginary and hypothetical situations	- Make a list with tentative products/services you want to sell/offer. - Negotiate and agree on one product/service with the other group participants. - Make a brief description of the agreed selection of the product/service.	- Audios and videos presenting people who introduce a product/service. - Text with people's descriptions of a product/service. - Related vocabulary - Related Grammar

Support resources are presented to the learner in order to help her/him on completing the activities.

The learner can use the functionalities provided by her/his mobile device (Internet service, camera, voice recorder, multimedia player, notepad, standard docs viewer, etc.) in order to collect appropriate information that will help her/him to complete the activities.

Gather information

The learner gathers appropriate information (i.e. facts, data, interviews) that will help them in solving the problem.

Each group member collects information about the topics related to their problem solution.

Appropriate guidelines to provide learner with a working methodology are described for information collection. The learner is presented with a working methodology based on completing a sequenced activity structure. The following associated sub-activities are defined within the activity structure:

Related Subject	Sub-activities	Support
- expressing intentions and plans	- Make a survey/questionnaire to measure if the product/service is feasible and likely to succeed. (*Using English second conditional for the questions*) - Agreeing on the survey/questionnaire. - Select different peers (minimum 5 peers) to ask the questions in the	- Related vocabulary - Related Grammar

Description of the Context-aware adaptive educational scenario considering language learning activities based on the real-life task: "Setting up a business: Starting a new business"

	questionnaire and measure the selected peers' answers according to the proposal of product/service. - Gather together the answers collected with your group peers. - Collect examples of different marketing means and advertisements in your environment. (*student's location different from EOI and home*).	

Support resources are presented to the learner in order to help her/him on completing the activities.

The learner can use the functionalities provided by her/his mobile device (Internet service, multimedia player, phone, instant messaging, SMS, email, etc.) in order to collect appropriate information that will help her/him to complete the activities.

Implement Solution

The learner decides in the context of the work group the strategy/points-to-consider/alternatives in order to implement a solution for the problem. Learners work collaboratively in order to create their project, while the teacher acts as a facilitator to their efforts.

After the learners have collected the information, they synthesize together the collected pieces of information.

Appropriate guidelines to provide learner with a working methodology are described for implementing a solution. The learner is presented with a working methodology based on completing a sequenced activity structure. The following associated sub-activities are defined within the activity structure:

Related Subject	Sub-activities	Support
- expressing hopes and wishes - expressing intentions and plans - defining purposes and objectives - using English second conditional for imaginary and hypothetical situations	- Define a list of aspects you consider are necessary to make a business plan. - Define the marketing strategy for the selected product/service (remarking the idea behind, image or slogan, and the medium). - Negotiate the aspects list and the marketing strategy with the other group participants and agree on common solutions for the aspects and marketing strategy. - Make a brief description of the business considering the negotiated solutions (e.g. target audience, needed people, etc.).	- Audios and videos presenting steps to set up a business. - Text with steps/tips to consider when starting a business. - Related vocabulary - Related Grammar

The learner can use the functionalities provided by her/his mobile device (Internet service, SMS services, multimedia player, phone service, notepad, etc.) in order to complete the activities.

After implementing the solution each group of learners presents the outcomes to others and the teacher.

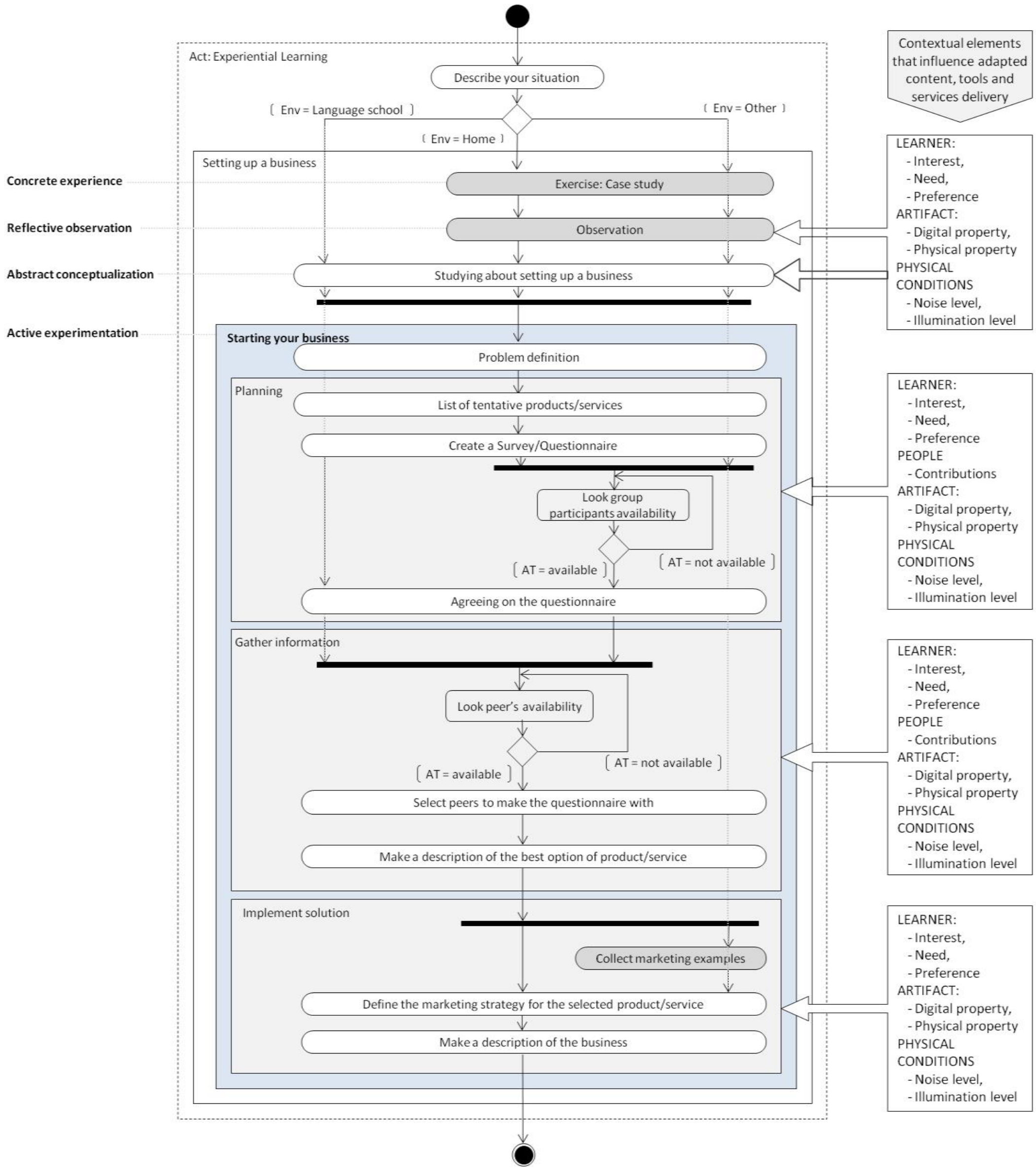
Students participate collaboratively in preparing a short report based on the obtained results and the solution proposed.

<table>
<tr><th colspan="2">Description of the Context-aware adaptive educational scenario considering language learning activities based on the real-life task: “Setting up a business: Starting a new business”</th></tr>
<tr><td></td><td></td></tr>
<tr><td>Participating Roles:</td><td>Student
Acts as an active problem-solver:
- Participating actively in the learning process,
- Investigating problems,
- Gathering and synthesising data,
- Implementing solutions
Actively participate in the learning process by expressing his/her ideas, experiences and opinions.
Complete learning activities using a mobile device to improve her/his English language learning skills.
Describe and input contextual information.
Gather contextual information to complete activities.
Group Participant
Works collaboratively in small groups to create their project.
Works collaboratively in small groups to solve problems.
Communicates and debates with other group participants.
Searches, selects and synthesizes information
Assesses the other groups
Peers
Share their English language strong learning skills.
Help between them to complete activities.
Provides feedback.
Teacher
Prepare the project topics for the learners
Prepare the experience case, problem to solve and topics for the learners
Collect resources for the related subjects (videos, audios, texts, images, etc.).
Design learning objects for the related subjects.
Design the Learning activities flow.
Poses questions.
Coordinates, mediates, communicates and guides students in order to overcome any difficulties.</td></tr>
<tr><td>Tools, Services and Resources</td><td>Tools:
Hardware
Smartphone
Tablet
Computer
Software
UoLmP.
Mobile device assimilative tools: text viewer, image viewer, audio player, video player, web content viewer.
Mobile device productive tools: notepad, word processor, camera, audio recorder.
Moodle
Services:
Internet.
Mobile device communicative services: email, voice messaging, phone calling, video calling, SMS
Resources:
Narrative text, lecture, figure, problem statement, questionnaire.</td></tr>
<tr><td>Contextual Information for</td><td>Learner:
Temporal personal information: Interest:
Language learning skills to improve.</td></tr>
</table>

Description of the Context-aware adaptive educational scenario considering language learning activities based on the real-life task: "Setting up a business: Starting a new business"	
adaptation	Temporal personal information: Preference: Student's choice for an action (selecting a learning tool or service). Temporal personal information: Need: Language support (vocabulary, grammar, examples). **People:** Contributions: Peer's Language learning strong skills. **Place:** Location: Spatial coordinates of the place where the student stands. Environment: One-word physical description of the place where the student stands. **Time:** Availability: Student available time in the week for English learning. **Physical conditions:** Noise level: State of the noise level condition in the place where the student stands. Illumination level: State of the illumination level condition in the place where the student stands.

2) Graphical Representation of the Flow of Learning Activities

The order in which the steps are taken here is only a suggested order, not a mandatory one. Also contextual elements are considered here to suggest how they can participate in the learning flow.



3) Description of the Educational Scenario Template in Common Terms

Phase 1

Concrete experience

Excercise

Type	Technique	Interaction	Roles	Tools/Services	Resources
Experiential – Experiencing	Experiential – Case study	Who – Class based – Individual Medium – Face-to-face – Learning object Timing – Synchronous – Asynchronous	– Facilitator – Individual Learner	Hardware – Smartphone – Tablet Software – UoLmP Services – None	– Problem statement

Phase 2

Reflective observation

Observation

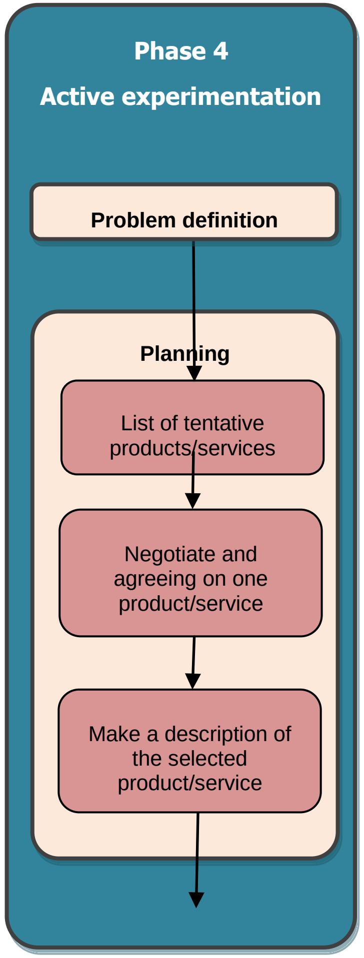
Type	Technique	Interaction	Roles	Tools/Services	Resources
Information handling – Analyzing	Information handling – Articulate reasoning	Who – Group based Medium – Face-to-face – Online Timing – Asynchronous	– Group participant – Facilitator	Hardware – Smartphone – Tablet Software – UoLmP Services – Mobile device communicative services.	- Narrative text – Exercise

Phase 3

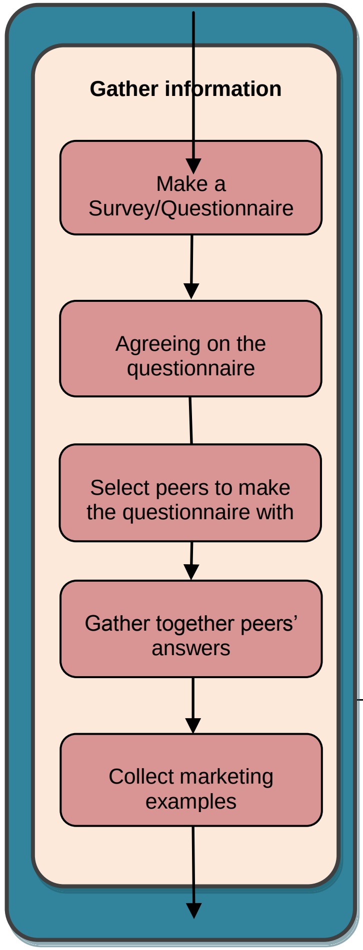
Abstract conceptualization

Theory presentation

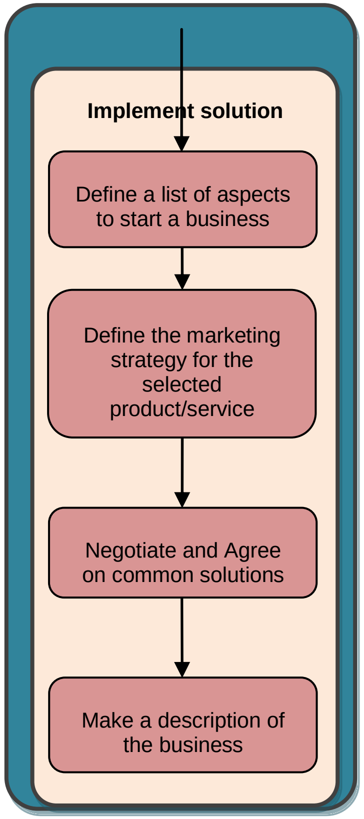
Type	Technique	Interaction	Roles	Tools/Services	Resources
Assimilative – Viewing	Assimilative – Skim reading	Who – Individual Medium – Learning object Timing – Asynchronous	– Individual Learner	Hardware – Smartphone – Tablet Software – UoLmP Services – Mobile device communicative services.	– Narrative text



Type	Technique	Interaction	Roles	Tools/Services	Resources
Assimilative – Reading – Listening	Assimilative – Skim reading – Listening	Who – Individual Medium – Learning object Timing – Asynchronous	– Individual Learner	Hardware – Smartphone – Tablet Software – LD m-Player Services – None	– Problem statement
Productive – Writing Information handling - Selecting	Productive Assignment	Who – Individual – Group based Medium – Online – Learning object Timing – Synchronous – Asynchronous	– Individual Learner – Group participant	Hardware – Smartphone – Tablet Software – UoLmP – Mobile device assimilative tools. – Mobile device information handling tools. – Mobile device productive tools. Services – Mobile device communicative services.	– Narrative text – Slide – Figure – Lecture
Communicative – Discussing	Communicative – Negotiation				
Productive – Writing Producing	Productive Assignment				



Type	Technique	Interaction	Roles	Tools/Services	Resources
Productive – Writing – Producing	Productive – Assignment	Who – Individual – Group based Medium – Online – Learning object Timing – Synchronous – Asynchronous	– Individual Learner – Group participant	Hardware – Smartphone – Tablet Software – UoLmP – Mobile device assimilative tools. – Mobile device information handling tools. – Mobile device productive tools. Services Mobile device communicative services.	– Narrative text – Slide – Figure – Lecture
Communicative – Discussing	Communicative - Discussing				
Communicative – Presenting	Communicative – Questiong and answer				
Information handling – Gathering – Classifying	Productive – Assignment				
Information handling – Gathering	Productive – Assignment				



Type	Technique	Interaction	Roles	Tools/Services	Resources
Productive – Producing Information handling – Selecting	Productive – Assignment	Who – Individual – Group based Medium – Online – Learning object Timing – Synchronous – Asynchronous	– Individual Learner – Group participant	Hardware – Smartphone – Tablet Software – UoLmP – Mobile device assimilative tools. – Mobile device information handling tools. – Mobile device productive tools. Services Mobile device communicative services.	– Narrative text – Slide – Figure – Lecture
Productive – Producing	Information handling – Defining				
Communicative – Discussing	Communicative – Negotiation				
Productive – Writing – Producing	Productive – Assignment				

4) Description of educational elements

Description of educational elements		
Dimension	**Type and Value**	**Description**
Type	Experiential: Experiencing	The learner experiments to gain insight into a specific problem
	Assimilative: Viewing	The learner views information related to a specific problem
	Assimilative: Reading	Read given material
	Assimilative: Listening	Listening to given material
	Communicative: Presenting	Presentation of a specific subject/work
	Communicative: Discussing	Discussion among the participating roles
	Information Handling: Analysing	The learner analyses the information that is required for solving a specific problem
	Information Handling: Classifying	Classify information by certain given measured values.
	Information Handling: Selecting	From a big amount of information select the most appropriated data
	Productive: Writing	Write about something
	Productive: Producing	Produce something from previous collected information.
Technique	Experiential: Case Study	The learner experiments with a case study to get insight into a specific problem
	Assimilative: Skim Reading	Reading the content in order to understand its detailed meaning
	Assimilative: Listening	Listening to the content in order to understand its detailed meaning
	Communicative: Negotiation	A structured discussion of opposing points of view
	Communicative: Discussion	Expressing points of view
	Communicative: Question and answer	Ask something to receive an immediate answer.
	Information Handling: Articulate Reasoning	The learner reasons about the knowledge, steps, etc, required for solving a specific problem
	Information Handling: Defining	Describing the meaning of a concept or term or problem
	Productive: Assignment	Structured steps or tasks for doing an activity
Interaction	Who: Class based	In the context of the classroom

Description of educational elements		
	Who: Group based	In the context of the groups
	Who: Individual	The individual learned engaged in the learning process
	Medium: Face to Face	Face to face interaction of the participating role with others or content
	Medium: Online	Interaction via the use of Internet
	Medium: Learning object	Interaction with a learning object
	Timing: Synchronous	Synchronous interaction of the participating role with others or content
	Timing: Asynchronous	Learning activities can take place in different times
Roles	Individual Learner	The individual learner
	Group participant	A student participating in a group of students
	Facilitator	The teacher in a role of facilitator of the learning process
Tools/ Services	Hardware: Smartphone	An electronic, digital mobile device that stores and processes information
	Hardware: Tablet	An electronic, digital mobile device that stores and processes information
	Hardware: Computer	An electronic, digital device that stores and processes information
	Software: UoLmP	Software used to follow the learning activities flow based on the IMS-LD specification
	Software: Mobile device assimilative tools: text viewer, image viewer, audio player, video player	Typical mobile device embedded tools for doing assimilative activities such as: PDF or text viewer, image viewer, player for listening to audio files, player for viewing video files
	Software: Mobile device information handling tools: web viewer	Typical mobile device embedded tool for browsing.
	Software: Mobile device productive tools: notepad, word processor, camera, audio recorder	Typical mobile device embedded tools for doing productive activities such as: Text editor, Software that let performing word processing functions (i.e. insert, print, delete text, etc.), Software that enables to record video or take pictures, Software that enables to record audio
	Software: Mobile device communicative tools: email, instant messaging	Typical mobile device embedded tools for doing communicative activities such as: email editor and software that let sending and receiving instant messages
	Software: Moodle	Learning Management System to provide additional supporting information to learners
	Service: Mobile device communicative services: voice messaging, phone calling, SMS, MMS	Typical mobile device paid services for doing communicative activities such as: send voice messages, make phone calls, send short messages, send short messages with embedded media
Resources	Narrative text	Description or explanation of something made by text

Description of educational elements		
	Problem Statement	Document, audio or video for defining a problem
	Slide	Hypermedia document
	Figure	A figure is any graphic, text, table or other representation that is unaligned from the main flow of text
	Lecture	Presentation of a given subject or a document, audio, video explaining concept in detail
	Questionnaire	A list of questions by which information is sought from a selected group
	Exercise	Document, audio, video for practicing a skill or understanding
Contextual information	Learner: Temporal personal information: Interest	Language learning skills to develop. [Oral communication, Written communication, Writing style, Oral presentation, Listening and comprehension, Reading]
	Learner: Temporal personal information: Preference	Student's choice for a learning action (selecting a learning tool or service, resource, etc.)
	Learner: Temporal personal information: Need	Language support [vocabulary, grammar, examples]
	People: Contributions	English language learning skills in which a peer is strong [Oral communication, Written communication, Writing style, Oral presentation, Listening and comprehension, Reading]
	Place: Location	Spatial coordinates of the place where the student stands [latitude, longitude]
	Place: Environment	One-word physical description of the place where the student stands [workplace, home, university, EOI school, outdoors]
	Time: Availability	Available or spare time planned for English learning [Day, Hour]
	Physical conditions: Noise level:	State of the noise level condition in the place where the student stands [low, high]
	Physical conditions: Illumination level:	State of the illumination level condition in the place where the student stands [low, high]

APPENDIX D

QUESTIONNAIRE FOR THE EVALUATION OF THE EXPERIENCE WITH A CONTEXT-AWARE AND ADAPTIVE MOBILE EDUCATIONAL SCENARIO AND UOLMP

The questionnaire offered to the students in the experience described in chapter 7, section 7.2 is presented in this appendix.

Name: Gender: Male...... Female...... Gender: Male...... Female...... Current activity: a) student, b) employee c) unemployed, d) retired, d) housework, e) other? ....

Contextual information may be used to design student-centered and mobile learning scenarios where students can benefit from their situations (every learning experience out of a formal classroom) and surrounding resources to practice and learn a second language like English.

Your engagement in mobile English learning is important for us!

Attitude (Interest in Mobile learning)

Please mark with an X the answer of your choice or fill in the gaps on the following questions:

1.	Did you complete all the activities in the lesson?	____Yes, ____No
	If not, what percentage of activities did you complete?	______%
2.	How many sessions did you use to complete the activities (i.e. how many times did you use UoLmP to complete the activities)?	____ 1, ____ 2, ____ 3, ____ More sessions
3.	Where and How many times did you access UoLmP?	EOI 0, 1, 2, 3, more Home 0, 1, 2, 3, more Workplace 0, 1, 2, 3, more University 0, 1, 2, 3, more Outdoors 0, 1, 2, 3, more Others 0, 1, 2, 3, more
4.	Which kind of resources provided by UoLmP did you use? (Check any that apply)	____ Web content (Texts), ____ Images, ____ Audios, ____ Videos
5.	Which of the suggested tools by UoLmP did you use to complete the activities? (Check any that apply)	____ Text editor, ____ Camera, ____ Audio recorder, ____ Video recorder
6.	Which of the suggested services by UoLmP did you use to complete the activities?	____ Phone calling, ____ Voice messaging, ____ Video calling, ____ SMS, ____ Email, ____ Instant messaging

Context-aware adaptation approach effectiveness

Please mark with an X the answer of your choice on the following questions:

		Never		Sometimes		Always
1.	Did you see the activities entitled: "Exercise: case study" and "Observation" while you were interacting with the system?	1	2	3	4	5
2.	Did you see the activity entitled: "Collecting marketing examples" while you were interacting with the system?	1	2	3	4	5
3.	Were the resources useful and needed for you as support to complete the activities?	1	2	3	4	5
4.	Was the grammar support useful for you to complete the activities at the moment you did need it?	1	2	3	4	5
5.	Was the vocabulary support useful for you to complete the activities at the moment you did need it?	1	2	3	4	5
6.	Were the support resources suitable to your learning skills development interests (Reading or Listening)?	1	2	3	4	5
7.	Were the support tools (Text editor, Camera, Audio recorder, Video recorder) suitable to your learning skills development interests [Making notes(Writing) or Oral presentation(Speaking)]?	1	2	3	4	5
8.	Were the support services (Phone calling, Voice messaging, Video calling, SMS, Email, Instant messaging) suitable to your learning skills development interests [Written communication (Reading/Writing) or Oral communication (Listening/Speaking)]?	1	2	3	4	5
9.	Did you communicate with your classmates to complete collaborative activities?	1	2	3	4	5
10.	Did you use the provided peers' strong skills and availability information to communicate with your classmates?	1	2	3	4	5

Satisfaction

Please mark with an X the answer of your choice on the following questions:

		Never		Sometimes		Always
1.	Were the support resources (texts, images, videos, audios) easy to read/view/listen to?	1	2	3	4	5
2.	Were the resources easy to understand?	1	2	3	4	5
3.	It was easy for you to complete the productive activities of the lesson using the suggested tools?	1	2	3	4	5
4.	It was easy for you to complete the collaborative activities of the lesson using the suggested services?	1	2	3	4	5
5.	Do you find useful the peers' information (skills and availability) to complete collaborative activities?	1	2	3	4	5
6.	Do you think that this kind of task (real-life tasks such as Setting up a business) encourages your English learning motivation much more?	1	2	3	4	5
7.	Do you think that completing learning activities by using UoLmP may deepen	1	2	3	4	5

	your knowledge on English much more?	
8.	Do you think UoLmP is a useful tool for performing English learning activities?	____Yes, ____No, ____No answer. Comments:________________________________
9.	Would you recommend EOI's teachers to continue using UoLmP in their courses?	____Yes, ____No, ____No answer. Comments:________________________________

We appreciate your comments or suggestions about your experience with UoLmP. Please write them below:

____

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Thank you for your cooperation.