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ORIGINAL ARTICLE

# Context-aware adaptive and personalized mobile learning delivery supported by UoLmP

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Adaptation rules;
IMS Learning Design

**Abstract** Over the last decade, several research initiatives have investigated the potentials of the educational paradigm shift from the traditional one-size-fits-all teaching approaches to adaptive and personalized learning. On the other hand, mobile devices are recognized as an emerging technology to facilitate teaching and learning strategies that exploit individual learners' context. This has led to an increased interest on context-aware adaptive and personalized mobile learning systems aiming to provide learning experiences delivered via mobile devices and tailored to learner's personal characteristics and situation. To this end, in this paper we present a context-aware adaptive and personalized mobile learning system, namely the Units of Learning mobile Player (UoLmP), which aims to support semi-automatic adaptation of learning activities, that is: (a) adaptations to the interconnection of the learning activities (namely, the learning flow) and (b) adaptations to the educational resources, tools and services that support the learning activities. Initial evaluation results from the use of UoLmP provide evidence that UoLmP can successfully adapt the learning flow of an educational scenario and the delivery of educational resources, tools and services that support the learning activities. Finally, these adaptations can facilitate students to complete successfully the learning activities of an educational scenario.



## 1. Introduction

Over the last decade there is a growing interest on adaptive and personalized learning by many researchers in Technology-enhanced Learning (TeL) (Martins et al., 2008; Brusilovsky and Millán, 2007). This has led to several research initiatives world-wide that investigate the potential of the educational paradigm shift from the traditional one-size-fits-all teaching approaches to adaptive and personalized learning (Tseng et al., 2008; Brusilovsky and Henze, 2007). The key benefits of this approach are that learners are provided with adaptive

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and personalized learning experiences that are tailored to their particular educational needs and personal characteristics toward maximizing their satisfaction, learning speed and learning effectiveness.

Moreover, the widespread ownership of mobile devices and the growth of mobile communications industry has provided a number of services such as instant interpersonal and group communication, location-aware information delivery and personalized assistance based on users' preferences and needs, as well as ubiquitous communication and interaction with smart devices and objects (Mascolo, 2010; Satyanarayanan, 2010).

Mobile devices are recognized as an emerging technology with the potential to facilitate teaching and learning strategies that exploit individual learners' context (Jeng et al., 2010). More precisely, mobile devices can (a) engage students in experiential and situated learning without place, time and device restrictions, (b) enable students to continue learning activities, initiated inside the traditional classroom, outside the classroom through their constant and contextual interaction and communication with their classmates and/or their tutors, (c) support on-demand access to educational resources regardless of students' commitments, (d) allow for new skills or knowledge to be immediately applied and (e) extend traditional teacher-led classroom scenario with informal learning activities performed outside the classroom.

This has led to an increased interest on context-aware adaptive and personalized mobile learning systems that aim to provide learning experiences delivered via mobile devices and tailored to the educational needs, the personal characteristics and the particular circumstances of the individual learner or a group of interconnected learners (Liu and Hwang, 2009; Hwang et al., 2008). The key benefits of these systems are that: (a) learners are provided with personalized learning experiences in real-world situations and (b) learners' behavior is detected and recorded for providing them with adaptive feedback and support (scaffolding).

Within this context, in previous work reported in Gómez et al. (2012) we aimed to address delivering context-aware adaptive and personalized mobile learning by proposing a mobile system for delivering context-aware pedagogical strategy-enhanced educational scenarios via mobile devices.

In this paper, we present initial evaluation results from the use of this system, namely Units of Learning mobile Player (UoLmP), by delivering a context-aware and adaptive educational scenario. The evaluation results provide evidence that UoLmP can successfully adapt the learning flow of the educational scenario, as well as the educational resources and the delivery of the tools and services that support the learning activities of the educational scenario.

## 2. Background

Mobile learning has been defined as: the process of learning and teaching that occurs with the use of mobile devices providing flexible on-demand access (without time and device constraints) to educational resources, experts, peers and services from any place (Sharples and Roschelle, 2010; Traxler, 2009).

The main benefits of mobile learning for education and learning are reported as follows (Satyanarayanan, 2010; Lam et al., 2010): (a) enables on-demand access to learning resources and services, as well as instant delivery of notifications and reminders, (b) offers new opportunities for learning that extend beyond the traditional teacher-led classroom-based activities, (c) encourage learners to participate more actively in the learning process by engaging them to authentic and situated learning embedded in real-life context and (d) supports on-demand access, communication and exchange of knowledge with experts, peers and communities of practice.

Adaptivity and personalization in mobile learning systems refer to the process of enabling the system to fit its behavior and functionalities to the educational needs (such as learning goals and interests), the personal characteristics (such as learning styles and different prior knowledge) and the particular circumstances (such as the current location and movements in the environment) of the individual learner or the group of interconnected learners (Wu et al., 2008). Adaptivity deals with taking learners' situation, educational needs and personal characteristics into consideration in generating appropriately designed learning experiences, whereas personalization is a more general term and deals with the customization of the system features, including also issues which can be adapted and specified by learners themselves, such as the system interface, the preferred language, or other issues which make the system more personal (Martin and Carro, 2009). As a result, there are two main issues in the design of context-aware adaptive and personalized mobile learning systems, namely, the learner's contextual information that influence adaptations, and the type of adaptations that can be performed based on retrieved learner's contextual information (Graf and Kinshuk, 2008).

### 2.1. Learner's contextual information

There are a number of research works that attempt to model learners' contextual information during the learning process (Das et al., 2010; Economides, 2009; Hong and Cho, 2008). A commonly used definition of context in computer science is: "any information that can be used to characterize the situation of an entity" (Dey, 2001), where the term "entity" is defined as anything relevant (namely, a person, a place or an object) participating in the interaction between a user and a system, and the term "information" is defined as any particular element or detailed piece of data that allows for the description of any condition or state of the participating entities (Dey, 2001). In the field of TeL, context has been defined as: "the current situation of a person related to a learning activity" (Luckin, 2010).

In previous works as reported in Zervas et al. (2011), existing efforts have been studied for modeling learner's contextual information in mobile learning systems and a context model has been considered, which can be used in mobile learning systems for personalization and adaptation. More specifically, this context model has been developed based on previous work by Siadaty et al. (2008), who considered that context can be divided into (a) the learning context and (b) the mobile context. The learning context is defined by the learners, the educational resources, the learning activities and the specific pedagogical strategy, whereas the mobile context is defined by the learning context captured with regard to its delivery medium (i.e. the mobile devices). Christopoulou (2008) has proposed to model mobile context according to five (5) dimensions, namely user temporal information, place, artifact, time and physical conditions. Our context model combines and further elaborates the dimensions and their specific elements of both categories (i.e.,

**Table 1** Learning and mobile contextual elements (Zervas et al., 2011).

| Dimensions | Elements |
|---|---|
| *Learning context* | |
| Learning design | Learning objectives, pedagogical strategy, learning activities, participating roles, tools and learning resources |
| Learner profile | Competence profile (knowledge, skills, attitudes), role, semi-permanent personal characteristics (learning style, learning needs and interests, physical or other disabilities) |
| *Mobile context* | |
| Learner temporal information | Temporal personal information: mood, preferences, needs, interests |
| People | Role, relationship, contributions and constraints |
| Place | Location, zones, interactive space, cultural background and learning setting |
| Artifact | Technological: physical properties and digital properties, and non-technological |
| Time | Task duration, task scheduled, action happens, availability |
| Physical conditions | Illumination level, noise level, and weather conditions |

learning and mobile context). The main dimensions and the elements of this context model are presented in Table 1.

As we can notice from Table 1, learning context can be described by the elements of a particular learning design and the elements of the individual learner's profile. More precisely, a learning design is defined as: "*the description of the teaching–learning process, which follows a specific pedagogical strategy or practice that takes place in a unit of learning* (*e.g., a course, a learning activity or any other designed learning event*) *towards addressing specific learning objectives, for a specific target group in a specific context or subject domain*" (Koper and Olivier, 2004), whereas learner's profile includes elements such as: (a) learner's competence profile, which contains a set of knowledge, skills and attitudes and (b) learner's semi-permanent personal characteristics, which include learning style, learning needs and interests, as well as physical or other disabilities (Li et al., 2010; Brown et al., 2009).

Additionally, the mobile context can be described by the elements of: (a) learner's temporal information including his/her mood, interests, needs and preferences that reflect his/her temporal degree of willingness to participate in the learning process, (b) other people that influence the learning process with their role, relationships, contributions and constraints and they are related with the current circumstances, (c) current location including geospatial information, zones (small places inside bigger places e.g. a library inside a university), interactive spaces (such as public and private spaces), cultural background (such as physical and social conditions of an environment) and learning setting (such as lab-based, work-based, etc.), (d) technological artifacts (such as mobile devices, smartboards, etc.) and non-technological artifacts (such as a book or anything non-technological that can be used for learning), (e) current time conditions such as duration of a task, scheduled time of a task, history of performed learner's actions and time availability of the learner, a peer or an expert and (f) physical conditions (such as illumination level, noise level and weather conditions) where the learning process is taking place.

### 2.2. Types of adaptation

Based on relevant studies in the literature, we can identify two main categories of adaptation in context-aware adaptive and personalized mobile learning systems (Graf and Kinshuk, 2008; Economides, 2009): (a) one related to educational resources and (b) another related to learning activities. In our work, we focus on learning activities adaptation and we can identify the following types:

- **General adaptation:** This type of adaptation deals with automatic generation of individual learning activities based on different criteria derived from learners' contextual elements as described in Table 1. More precisely, automatic generation of learning activities include: (a) adaptations to the educational resources, tools and services that support the learning activities, as well as adaptations to the roles that participate to the learning activities (Gómez et al., 2012; Martin and Carro, 2009).
- **Feedback and support (scaffolding):**This type of adaptation includes personalized hints at the right time and suggestion of suitable learning activities depending on different criteria derived from learner's contextual elements. More precisely, typical criteria include: (i) learner's location (Ogata et al., 2005; Paredes et al., 2005) and (ii) the combination of current leaner's location and its physical conditions and learner's semi-permanent personal characteristics (Al-Mekhlafi et al., 2009; Liu, 2009; Yin et al., 2010).
- **Navigation to locations:** This type of adaptation includes mostly location-awareness and planning of suitable learning activities in real-world situations (for example during a museum visit or an execution of an experiment in a laboratory). More specifically, learners can be guided and perform location-dependent learning activities according to a dynamically structured navigation path, which is constructed based on: (i) current learner's location (Hwang et al., 2008; Hwang et al., 2011; Chiou et al., 2010; Chiou and Tseng, 2012; Hwang et al., 2010) and (ii) the combination of current leaner's location and learner's semi-permanent personal characteristics (Tan, 2009; Hwang et al., 2009; Wang and Wu, 2011).
- **Communication and interaction:** This type of adaptation facilitates learners during the execution of learning activities in: (i) 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 (Martin et al., 2008; El-Bishouty et al., 2007; El-Bishouty et al., 2010) and (ii) selecting appropriate communication and collaboration tools based on learners' preferences and needs (Economides, 2008).

## 3. Context-aware mobile learning systems that perform adaptations to learning activities

A system is considered as "context-aware" if it can extract, interpret and use contextual information and adapt its behavior and functionalities to the current context of use (Byun and Cheverst, 2004). In Section 2, we discussed the concept of learner's contextual information (which are considered as the input to context-aware mobile learning systems), as well as the types of adaptation (which are considered as the output of context-aware mobile learning systems). Next, we provide an overview of context-aware mobile learning systems based on the input that they process following the classification of learners' contextual information as discussed in Section 2.1, and the output that they provide to the learners following the classification of learning activities adaptation types as discussed in Section 2.2:

- **General adaptation:** In this category is included our mobile system UoLmP, which aims to support semi-automatic adaptation of learning activities that is: (a) adaptations to the interconnection of the learning activities (namely, the learning flow) and (b) adaptations to the educational resources, tools and services that support the learning activities. More details of this system are explained in next sections. One more system is CoMoLE (Martin and Carro, 2009), which 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.
- **Feedback and support (scaffolding):** (i) TANGO Ogata et al., 2005, is a context-aware mobile learning system that aims to support english language learning and provides adaptive feedback and support based on learners' location. Another similar context-aware mobile 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, (ii) CAMCLL (Al-Mekhlafi et al., 2009) is a context-aware mobile 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 mobile 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.
- **Navigation to locations:** (i) a context-aware mobile learning system has been proposed by Hwang et al. (2008), which automatically constructs a navigation path to perform certain learning activities in a university campus based on the learner's location. Another context-aware mobile 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. Two similar systems are the one presented by Chiou et al. (2010), which aims to support navigation of learning activities in a museum by proposing two navigation algorithms, and the PNSS system (Chiou and Tseng, 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, (ii) Tan (2009) describe a context-aware mobile 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. Moreover, Hwang et al. (2009) present a similar context-aware mobile learning system that automatically navigates learners to conduct learning activities within a laboratory and by exploiting learners' previous knowledge and learner's location. Other context-aware mobile learning system is presented by Wang and Wu (2011), which aims to provide context-aware navigation recommendations for learning tasks and adaptive courseware in real-world situations based on the learner's location, learning behavior and personal preferences.
- **Communication and interaction:** (i) a context-aware mobile 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. Other similar systems are the PERKAM (El-Bishouty et al., 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, (ii) a context-aware mobile learning system has been proposed by Economides (2008), which automatically selects appropriate communication and collaboration tools by exploiting learners' preferences and needs.

Table 2 compares existing context-aware mobile learning systems according to the different dimensions of the learner's contextual information that they process. Learner's contextual information is divided into two (2) main categories (namely, learning context and mobile context), in accordance with the categories and the dimensions of these categories described in Table 1.

## 4. An exemplary adaptive context-aware educational scenario

In this section, we present an exemplary educational scenario that aims to present how learner's contextual information can be used for adapting its learning flow toward implementing and demonstrating these adaptations in UoLmP. More specifically, we have adopted a learning scenario that is used in a real language learning center and involves learning activities related to a real-life task (referred to as "setting up a business"). Within the scenario, learners (namely, advanced Intermediate English level students) must achieve goals individually and collaboratively to present a project work about "starting a new business". In this work, the educational

**Table 2** Comparison of existing context-aware mobile learning systems that perform adaptations to learning activities.

| Adaptation type | Context-aware mobile learning systems | Learning context | | Mobile context | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Learning design | Learner profile | Learner temporal information | People | Place | Artifact | Time | Physical conditions |
| General adaptation | UoLmP | √ | √ | √ | √ | √ | √ | √ | √ |
| | CoMoLe (Martin and Carro, 2009) | – | √ | – | √ | √ | – | √ | – |
| Feedback and support (scaffolding) | TANGO (Ogata et al., 2005) | – | – | – | – | √ | – | – | - |
| | LOCH (Paredes et al., 2005) | – | – | – | – | √ | – | – | – |
| | CAMCLL (Al-Mekhlafi et al., 2009) | – | √ | – | – | √ | – | – | – |
| | HELLO Liu, 2009 | – | √ | – | – | √ | – | – | – |
| | JAPELAS2 (Yin et al., 2010) | – | √ | – | – | √ | – | – | – |
| Navigation to locations | Hwang et al. (2008) | – | – | – | – | √ | – | – | – |
| | CMMCUL (Hwang et al., 2011) | – | – | – | – | √ | – | – | – |
| | Chiou et al. (2010) | – | – | – | – | √ | – | – | – |
| | PNSS (Chiou and Tseng, 2012) | – | – | – | – | √ | – | – | – |
| | Hwang et al. (2010) | – | – | – | – | √ | – | – | – |
| | Tan (2009) | – | √ | – | – | √ | – | – | – |
| | Hwang et al. (2009) | – | √ | – | – | √ | – | – | – |
| | Wang and Wu (2011) | – | √ | – | – | √ | – | – | – |
| Communication and interaction | Martin et al. (2008) | – | – | – | √ | √ | – | – | – |
| | PERKAM (El-Bishouty et al., 2007) | – | – | – | √ | √ | – | – | – |
| | Social KAM (El-Bishouty et al., 2010) | – | √ | √ | √ | √ | – | – | – |
| | Economides (2008) | – | – | √ | – | – | – | – | – |

scenario was decided to build on the Second language learning discipline, which, according to related literature, is identified to be potentially set to benefit from the developments in the m-learning approaches (Kukulska-Hulme and Shield, 2008; Cui and Bull, 2005; Ogata et al., 2006). Moreover, the educational scenario is based on the "experiential learning" pedagogical model (which is an appropriate pedagogical model proposed for m-learning as recognized by the literature (Lai et al., 2007; Dyson et al., 2009). Our educational scenario is not attempting to replicate or even augment the adopted learning scenario for m-learning, but rather tried to create new learning opportunities in which, from an experiential learning perspective, learners may acquire the knowledge through the transformative experience (i.e. learners may link past experiences, related to a real-life task, with new concepts they want to learn and they utilize learning activities in tangible individual learning contexts rather than massive traditional learning settings (Kolb, 1984; Pimentel, 1999).

In the language learning center, namely Official Language School at Girona, Spain ("EOI" in Spanish language) teachers are concentrating their efforts on teaching languages "integrating language learning skills (reading, listening, writing, speaking) in real-life tasks" so as to provide different and innovative learning activities that suit students' needs and their context. According to this, students will be able to improve their skills while they are completing activities related to a real-life task such as setting up a business, sharing a flat, delivering a presentation, etc. In previous work (Gómez et al., 2012), we presented a context-aware and adaptive mobile educational scenario namely "sharing a flat" in which learners must achieve goals individually and collaboratively to present a project work about "finding a new flat mate". That scenario was based on the project based learning pedagogical model which is another appropriate pedagogical model proposed for m-learning as recognized by the literature (Ally, 2005; Kukulska-Hulme, 2009).

The presented scenario in this paper has been appropriately processed, so as to incorporate the possible adaptations that are realized based on learner's contextual information (see Fig. 1). These include: (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 Fig. 1, in the beginning, each learner, on an individual basis, provides contextual data to the system. During this act (Experiential learning), based on learner's 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). Afterward, the learner is presented with a set of adapted activities and 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, each student, individually, reflects on the main elements considered in the case study for setting up a business (Reflective observation). A set of questions 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 to understand the relationships among them.

Next, learners are presented with activities to achieve goals individually and collaboratively to present a project work (active experimentation). In these activities each group member

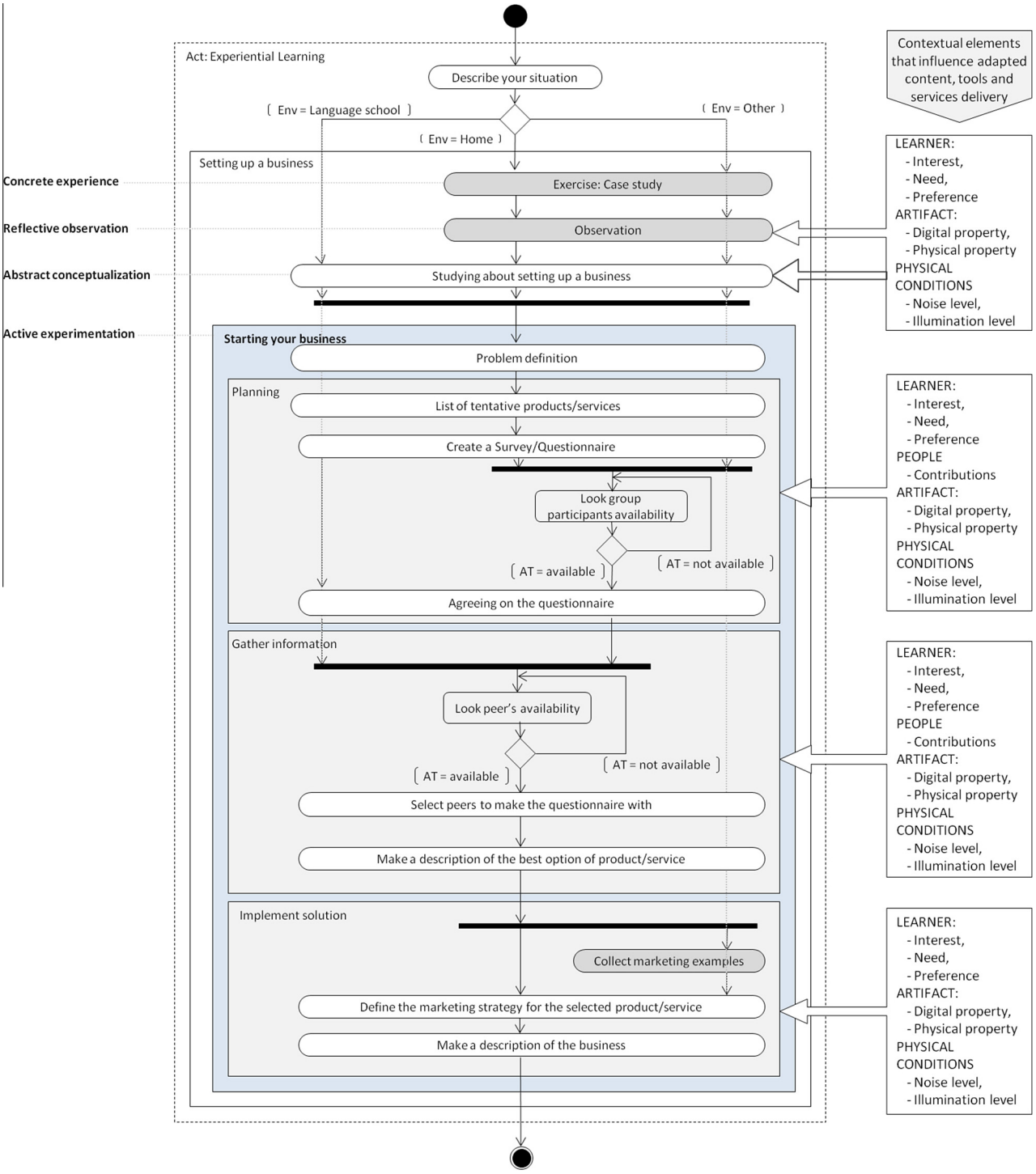


**Figure 1** Learning activities flow diagram.

collects information about his/her part of a project work. First, a problem related to the real-life task is presented which consists of 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 afterward organize some market research based on a small questionnaire or survey. 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 to 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 the 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.

The described educational scenario utilizes a subset of contextual elements from the "Mobile context" category presented in Table 1, which can be processed by UoLmP (see Table 3) and provide language learners with adapted learning activities, educational content, 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 and Ravenscroft, 2012).

Some of the considered contextual elements may have known instances (pre-defined data or set of values) as shown in Table 3, and, thus, they can be taken into account in a decision-making process held by the tool in run-time. Different values of these elements can result in different adaptation results. 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 et al., 2011).

## 5. The Units of Learning mobile Player (UoLmP)

Up to now, the system was developed aiming to provide a "General adaptation" for mobile learning, so as to support learners by delivering adapted activities and materials through every step in the learning flow of a mobile educational scenario. UoLmP's architecture focused on generating adapted individual learning activities, as well as offering adaptations to supportive educational resources, tools and services, based on processing different criteria derived from learners' contextual elements as described in Table 1.

### 5.1. Architecture

There are several approaches in the field of context-aware adaptive and personalized learning 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 mobile context dimensions (Arai and Tolle, 2011; Al-Hmouz and Freeman, 2010; Bhaskar and 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 learner's mobile context dimensions (Su et al., 2011; Madjarov and Boucelma, 2010; Zhao et al., 2008).

The context-aware and adaptive mobile delivery approach that we have developed is based on IMS Learning Design Specification (IMS-LD) (Global Learning Consortium, 2003). IMS-LD is a standard notation language for the description of educational scenarios. In IMS-LD, an educational scenario can be built at three different levels (level A, level B and level C). At level A, educational scenarios include: a series of learning activities, performed by one or more actors/roles, in an environment consisting of tools and services. Level B adds properties (storing information about a person or group), and conditions (placing constraints upon flow) and level C adds notifications based on run-time events (Koper and Burgos, 2005). Considering this, the adaptation engine implemented for UoLmP is able to process IMS-LD Level B elements so as to deliver context-aware and adaptive educational scenarios (Gómez et al., 2012). Fig. 2 shows the architecture of the developed system which is based on two adaptation mechanisms, namely:

- **Polymorphic presentation mechanism**, which is based on educational resources transformation. This process consists of a set of steps to transcode/recode the properties (format, type, size, quality, etc.) of one or more resources (that populate an IMS-LD package) considering the digital and physical capabilities of the learner's device. This mechanism has been presented in detail in previous work reported in Gómez and Fabregat (2012).
- **Filtering mechanism**, this consists of making decisions based on the evaluation of a pre-defined structured decision tree that considers contextual elements. This process is based on IMS-LD Level B properties, global elements and conditions definition. More specifically, IMS-LD conditional structures are considered for making decision processes. That is, to assess learner's contextual information in order to show or hide learning activities, educational content and tools and services. Conditional structures are predefined at design-time and consist of IF/THEN/ELSE statements that form a decision tree to select and deliver the learning activities, the educational content and tools and services that best suit to the learners' situation.

### 5.2. Functionalities

The proposed mobile delivery tool was developed to meet the design requirements presented in previous work (Zervas et al., 2011) (summarized in Table 4), as a client side application for smartphones and tablets with Android operating system (meeting requirement 4).

UolmP is able to capture during the run-time (meeting Requirement 1), the contextual elements instances (see Table 3) of which were pre-defined in design-time. Since contextual information is retrieved in run-time, the tool parses properties,

**Table 3** Contextual elements and instances considered in the exemplary educational scenario.

| 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 and 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) Dey, 2001 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 and 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 Wide Web Consortium, 2008, WURFL (ScientiaMobile, 2008) |
| | Physical property | Hardware technical capabilities of the access mobile device | [Screen: type, colors and resolution (pixels)] | |
| | W3C-MBP Wide Web Consortium, 2008, WURFL (ScientiaMobile, 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 |

**Table 4** Requirements of a mobile delivery tool (Zervas et al., 2011).

| | |
|---|---|
| R1 | 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 |
| R2 | The tool should be able to import and deliver educational scenarios compatible with IMS-LD |
| R3 | 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 |
| R4 | 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 the content adaptation process, when the tool should communicate with the content adaptation mechanism located at the server |
| R5 | 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 |

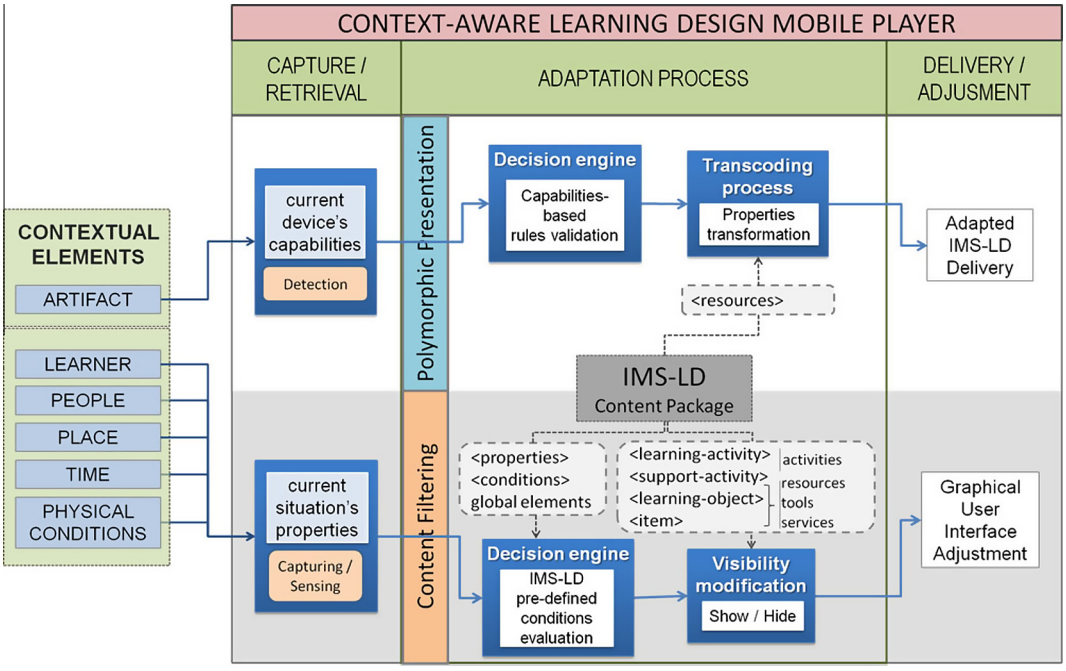


**Figure 2** Architecture of UoLmP (Gómez et al., 2012).

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, considering the exemplary educational scenario presented in Section 4, Fig. 3a presents the interface for capturing contextual information from learner's current situation, based on learner's input. Using forms or checklists can be an easy and efficient way to capture learner's inputs about their actual contexts (Cui and Bull, 2005; Lonsdale et al., 2004). More specifically, Fig. 3a illustrates a particular situation where the learner is interested in improving listening (assimilative), oral presentation (productive) and oral communication (communicative) skills, he/she 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 Fig. 1 (see the activities structure for the activities structure "Setting up a business" in the Fig. 3b).

Figs. 4 and 5 illustrate adaptation results for educational content, tools and services (meeting Requirement 3) obtained from the decision making process according to the captured contextual information (see Fig. 3a).

Fig. 4a 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 Fig. 4b). Audio and video resources (instead of text educational resources) demonstrate to the learner how the learning activity can be performed. Fig. 4c illustrates a video educational resource. Additionally in Fig. 4b, audio and video recording facility options are presented to the learner (instead of writing and typing options) letting him/her to decide how to complete the activity. Those facilities let the learner complete the activity by taking

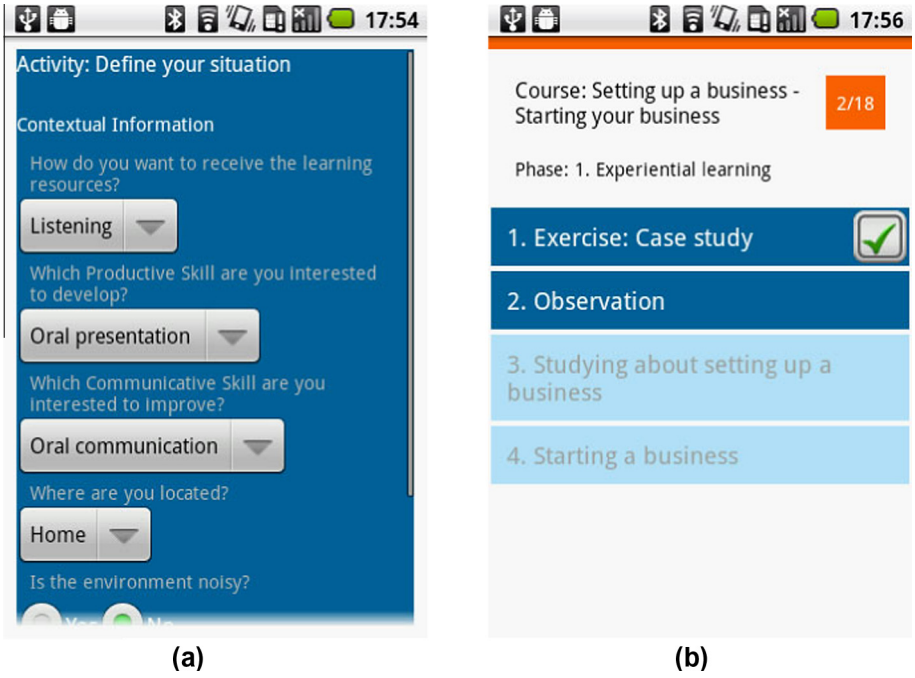


**Figure 3** (a) Contextual information capturing and (b) adapted flow of learning activities based on contextual information.


**Figure 4** Context-aware adaptation results for the productive activity entitled: ''Studying about setting up a business''.

advantage of the particular conditions of the place that he/she 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.

Fig. 5a 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 Fig. 5b). Assuming that the learner decides to phone a peer (since he/she is located at home, and he/she needs immediate answers from his/her peers), he/she can decide who he/she is going to communicate with based on the peers' language skills and their availability (see Fig. 5c).

## 6. Experiment design

In this section, we present an experiment of using UoLmP for the delivery of context-aware and adaptive learning activities. The main objective that we aim to address through this experiment is to measure students' perception of the context-aware adaptation process.

### *6.1. Participants*

The study was conducted with twenty students (20) from two classes of intermediate English level, as well as with


**Figure 5** Context-aware adaptation results for the communicative activity entitled: "Agreeing with your group mates on the questionnaire".

an English Language Teacher from the Official Language School in Girona, Spain. Fourteen (14) out of twenty (20) students owned an Android-based mobile device, whereas the other six (6) students did not own an Android-based mobile device and they were provided with a device for the purpose of the study. The students had an age range from 16 to 51 years old. Fourteen (14) of them were female, whereas six (6) were male. On the other hand, the teacher had 10 years of experience in English language teaching, as well as 4 years of experience in computer-assisted language learning. As a result he was able to provide support and guidance to the students during the experiment.

### 6.2. Experiment procedure

Fig. 6 presents the flow chart of our experiment and the procedure that was followed.

As we can notice from Fig. 3, three (3) learning sessions were designed by the authors in collaboration with the English teacher, so as to evaluate UoLmP. The experiment was conducted from April 18 to May 11, 2012 and it lasted for 3 weeks and three days (24 days in total). Prior to the beginning of the learning sessions, the students had one week to install UoLmP and to install an educational scenario package to their mobile devices. The educational scenario package included the learning activities from the exemplary context-aware educational scenario presented in Section 4. The activities are related to the real-life task referred to as "setting up a business", in which students (namely, advanced Intermediate English level students) should be able to achieve goals individually and collaboratively to present a project work about "starting a new business".

The first learning session lasted for one week and included classroom and out of classroom activities, which were presented to the students based on the environment in which each student is located. More precisely, during classroom activities students were split into groups of five students and a case study of "setting up a business" was presented to each group. Students of each group had to reflect on the main elements of "setting up a business". On the other hand, during out of the classroom activities the students had

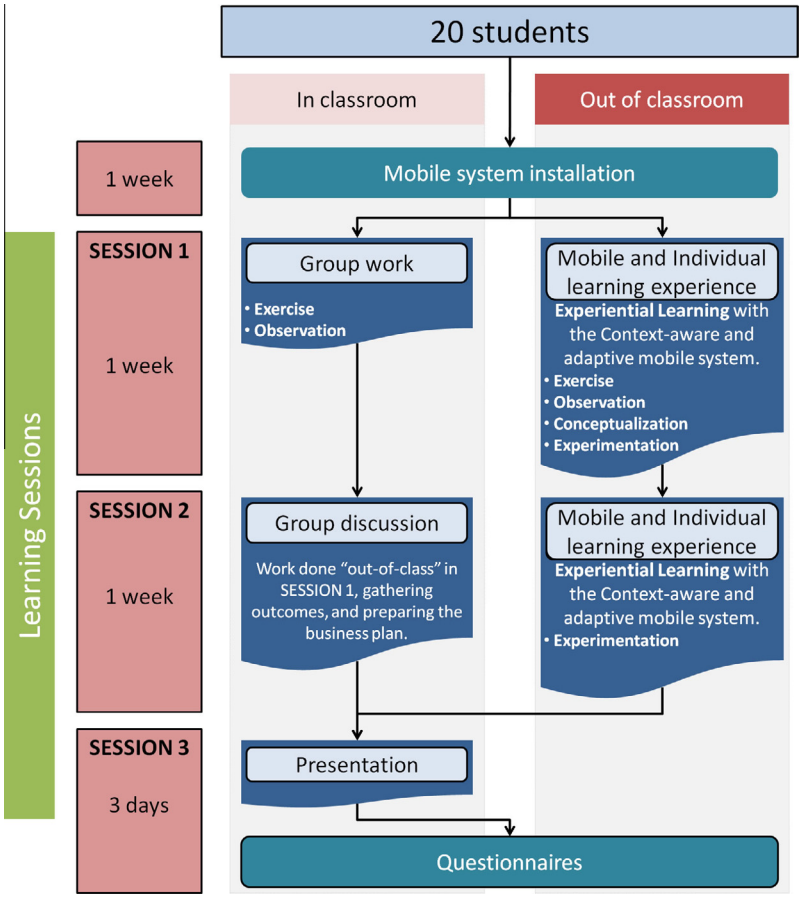


**Figure 6** Experiment procedure flow chart.

the opportunity to complete learning activities by interacting only with UoLmP and was based on their available time. In summary, students had the opportunity to integrate English language skills (namely, reading, writing, speaking, and listening) in the real-life task "setting up a business" using the educational resources, tools and services that UoLmP was able to deliver them based on their contextual information.

The second learning session lasted for one week and it also included classroom and out of classroom activities. During classroom activities students discussed with their teammates about the outcomes of the learning activities they executed out of the classroom in learning session 1. On the other hand, during out of the classroom activities, students worked on the preparation of the business plan in response to the real-life task "setting up a business".

Finally, during the third learning session (after two weeks of interaction with UoLmP), which lasted for three days, students had to make a presentation on their business idea to other classmates, using the materials created or collected during the first and the second learning session, so as they can vote for the best business idea. Moreover, they were able to use their group blogs in order to publish the materials they created or collected by using their mobile devices.

### *6.3. Instruments*

After the completion of the experiment, participants were asked to fill out a post-task questionnaire. The purpose of the questionnaire was to evaluate the effectiveness of our context-aware adaptation approach, which focused on providing students with adaptive learning activities and supportive materials according to their contextual information. For each one of the questions presented in the questionnaire, a five-point Likert scale was used where 5 denotes "strongly agree" and 1 denotes "strongly disagree". The questionnaire consisted of eight questions and its Cronbach's alpha value was 0.745. This value provided us with evidence about the reliability of the questionnaire used in our study, since according to Nunnaly (1978) 0.7 is an acceptable minimum reliability coefficient.

## 7. Results and discussion

This section presents quantitative data analysis results from students' responses on the post-task questionnaire. More specifically, students provided their feedback about the outcomes of the context-aware adaptation approach. Moreover, students' contextual data was stored in log files and they were analyzed along with their feedback, so as to identify the context in which the adaptation was performed.

Students' feedback was analyzed according to the following three (3) dimensions:

1. Adaptive delivery of learning activities according to learners' contextual information (adaptation to the learning flow).

**Table 5** Results (Mean and Standard Deviation) of the Questionnaire.

| Nr. | Questions | Mean ($N = 20$) | Standard deviation ($N = 20$) |
|---|---|---|---|
| *1. Adaptation to the learning flow* | | | |
| 1 | Was the learning flow of the educational scenario adapted based on your contextual information? | 4.80 | 0.116 |
| 2 | Did the adapted learning flow assist you on the completion of the educational scenario according to your contextual information? | 3.60 | 0.681 |
| *2. Adaptation to the educational resources* | | | |
| 3 | Were the educational resources adapted based on your contextual information? | 4.35 | 0.587 |
| 4 | Did the adapted educational resources assist you on the completion of the learning activities according to your contextual information? | 4.25 | 0.786 |
| *3. Adaptation to the tools and services* | | | |
| 5 | Were the support tools (namely, text editor, camera, audio recorder and video recorder) adaptively delivered based on your contextual information? | 3.95 | 0.759 |
| 6 | Did the adapted delivery of support tools assist you on the completion of the learning activities according to your contextual information? | 3.95 | 0.605 |
| 7 | Were the support services (namely phone calling, voice messaging, video calling, SMS, email, instant messaging) adapted based on your contextual information? | 4.45 | 0.586 |
| 8 | Did the adapted delivery of support services assist you on the completion of the learning activities according to your contextual information? | 3.95 | 0.887 |

2. Adaptive delivery of educational resources that support learning activities according to learners' contextual information.
3. Adaptive delivery of tools and services that support learning activities according to learners' contextual information.

Table 5 presents the mean and the standard deviation for each question of the questionnaire that was filled by the students who participated in our study ($N = 20$). The standard deviation indicates that the individual students' responses are close to the students' responses mean proving its validity for each question of the questionnaire.

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