Supporting lifelong learners to build personal learning ecologies in daily physical spaces

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ABSTRACT

This article presents the results from a questionnaire filled out by 147 lifelong learners with the aim to analyse learning practices of adults, and to recognize patterns of lifelong learners in order to support them with technology. These patterns capture the context in which lifelong learners are more willing to learn, that is, the day of the week, duration, location activity being performed, type of device being used, way to interact with their devices and how these aspects can affect when an adult student takes the initiative to learn. Likewise, this article examines previous publications on surveys, questionnaires and information collected with the same objective, to corroborate and contrast the findings. Moreover, we present a literature review on augmented tangibles for learning identifying potential contexts to orchestrate tangibles depending on the physical space where they are normally used. As an outcome of this work, important research questions are risen to integrate smart learning objects in learner-centred ecologies of resources.

Keywords: Mobile usage patterns, lifelong learning, personal learning ecologies, tangibles, physical spaces

1. INTRODUCTION

Lifelong learners are confronted with a broad range of activities they have to manage every day. In most cases they have to combine learning, working, and everyday life throughout the day. For the support of lifelong learners, their daily practices and learning patterns are of importance. Lifelong learning includes a variety of different educational scenarios and contexts in which learners operate. These contexts include traditional formal programs, non-formal education, on the job-training and informal, accidental learning. Fischer (2000) even values lifelong learning as a mind-set that people have to acquire including the following learning scenarios: self-directed learning, learning on demand, collaborative learning and organizational learning.

One of the most critical challenges for the implementation of lifelong learning is to integrate real world problems and learning in the same process. One promising approach to connect the worlds of working and learning is a pattern approach. According to Alexander (1977) each pattern describes a "problem, which occurs over and over again in our environment, and then describes the core of the solution to that problem". Rohse & Anderson (2006) propose design patterns that should enable the detailed formalized description of "the dynamics between learning and technologies without the potential ideological or pedagogical mask of teaching in formal education and training settings". In the setting of an adult lifelong learner this is especially difficult as in most cases interests might be highly distributed over different domains and keeping up learning needs an extra effort. Lowing the barriers for access to relevant information and support services anywhere, anytime, and anyhow is one essential component for efficient lifelong learning support.

The idea of a Personal Learning Environment (PLE) recognises that learning is on-going and seeks to provide tools to support this kind of learning. It also recognises the importance of the individual to organize his or her own learning in order to embed it in contexts of daily life (Attwell, 2007). Personal Learning has been hierarchized into learning activities, episodes and projects (Vavoula & Sharples, 2002; Tough, 1971). Vavoula & Sharples (2002) define "learning activity" as the distinct acts that the person carries out during reading, discussing, listening and making notes. Tough (1971) defines a "learning episode" as a well-defined period of time that is held together by the similarity in intent, activity or place of the thoughts and actions that occur during it; it has a definite beginning and ending in time. "Learning projects" are formed by grouping episodes together on the basis of their contingency in terms of purposes and outcomes that could happen at different locations.

Smartphones have been pinpointed as a key learning partner, not only because of their affordances supporting learning activities (camera, bigger screens, location capabilities, audio and video player and recorder, sensors etc.), but also, because they provide utilities to track users lifelong learning. Wong (2012) advocate the combination of a cloud-based "learning hub" account, a smartphone (24x7 access), and additional notebook/desktop computers as an ideal technical setting for a personalized seamless learning environment (See Figure 1).

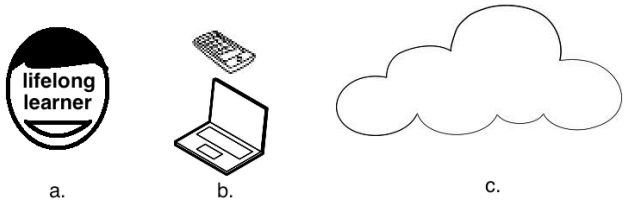

Figure 1. The "*learning hub*" as ideal technical setting for a personalized seamless learning environment (Wong, 2012). (a) lifelong learner; (b) smartphone 24x7 access and additional computer; (c) cloud-based services.

Moreover, the advent of the Internet of Things (IoT) and the capacity to integrate smaller and more sophisticated digital technology into physical objects has triggered the generation of new materials to improve and augment tangibles (e.g. SnapToTrace electronic textile (Stark, 2012), Embedded soft Material Displays (Ozsbald, 2012)). There are everyday scenarios built by lifelong learners in recognition of the places where they perform interactions with spaces, artifacts and resources through which people achieve their work. These places are more suitable to build lifelong learning ecologies supported by resources attached to concrete locations. Tangibles for learning have been reviewed to be used in the formal classroom, and according to different disciplines, subjects and ages (O'Malley & Fraser, 2004). No work was found classifying tangibles depending on where the physical space where the learning activity is performed.

The contribution of this paper is twofold. First, we analyse the results of a questionnaire for lifelong learners and classify the data according to the following criteria: type of mobile device; lifelong learner's behaviour, timing, motivation, physical spaces where learning takes place, learning activity being performed, user is waiting or on-the-move, and gender. Second, we present a literature review on augmented tangibles for learning according to where does the learning activity occur. Finally we discuss findings reported in this work, that is, we highlight patterns that enable lifelong learners to design PLEs, and encourage users to make what they learn throughout the day a deliberate object of attention, reflect about the available learning channels (Tabuenca, Verpoorten, Ternier, Westera & Specht, 2012), and be aware about the learning opportunities embedded in daily activities. Moreover we describe our future research.

2. A QUESTIONNAIRE FOR LIFELONG LEARNERS

2.1 Method

This article describes the results from a questionnaire filled out by 147 lifelong learners (Tabuenca, 2012 – ANNEX I to VII). The questionnaire was distributed both in English (ANNEX I) and Spanish (ANNEX II) taking advantage of the following channels: social networks, three Dutch and Spanish universities, two high schools from Belgium and The Netherlands, two companies, one academy for skills-training and the author´s blog. The survey was stored in an on-line platform so that everybody could access and fill out the questionnaire making use of the distributed URL. Answers were collected over the course of three months. Participation was voluntary and unrewarded.

The questionnaire is composed by 21 items, these are, 5 multiple choice questions, 6 single select questions, 9 matrix selection questions, and 1 open answer question. An introduction section (60 words) was included in order to explain the aim of the questionnaire and to define frequently used concepts within the items. These concepts are: *a) Mobile device: regular phone, smartphone, tablet, multimedia player and laptop when used not always in the same place; b) Learn: taking the initiative to learn something actively. It can be related to work, current studies or self-fulfilment*.

There are 4 questions about demographics (age, genre, occupation, and professional domain), 3 questions about usage patterns with mobile devices, 2 questions about how timing and content are related, 7 questions linking activities, locations, and ways of interaction with lifelong learner's mobile devices, 1 question identifying difficulties when learning with mobile devices, 3 questions about the lifelong learner's motivation, and 1 more question to estimate how familiar is the concept of *lifelong learning* for the participants.

Variables	Levels	# of subjects	% of subjects
Gender	Male	86	59
	Female	61	41
Age	Under 25	43	29
	25-34	50	34
	35-44	27	18
	45-54	14	10
	55-65	13	9
	Older than 65	0	0
Professional domain	Computer sciences	41	27
	Engineering	24	16
	Natural sciences	16	10
	Humanities	16	10
	Business	13	9
	Law	8	5
	Medicine	3	2
	Other	34	21
Professional status	Employed	99	67
	Student	48	33
	Self employed	11	7
	Homemaker	3	2
	Unable to work	1	1
	Retired	0	0

Table 1. Questionnaire demographics

The data with the answers has been exported from the on-line survey platform to a spread-sheet (ANNEX III) file. This file has been imported with a database engine in order to create a table (ANNEX IV) for each of the questions in the survey. A database client has been used to build joining-table queries (ANNEX V), aiming to find patterns in the answers given in different questions. Chart reports (ANNEX VI) have been created from these requests to carry out the analysis (ANNEX VII).

The results of this questionnaire are presented including references to previous studies on mobile device usage patterns and mobile learning support, in order to contrast and corroborate the conclusions.

2.2 Results

The concept of "lifelong learning"

Participants where given the following definition in order for us to assess how familiar were they with the concept of "lifelong learning": "*All learning activity undertaken throughout life, with the aim of improving knowledge, skills and competences within a personal, civic, social and/or employment-related perspective*" (European comission 2011). When participants were asked whether they considered lifelong learners themshelves, 21.76% reported a negative answer. However, it is paradoxically that these same respondents answered positively to the question "*Do you have a natural motivation to learn*?"

Patterns based on type of device, lifelong learners' behaviour and timing

The presence of mobile devices in lifelong learners' daily activities is a fact and this can be gathered from the results of the questionnaire. Portable computers are used every day by 70.06% of the respondents. Smartphones are used every day by 56.46% of the respondents, while 17.68% use their tablet on a daily basis.

Trends indicate that smartphones and tablets are the cornerstone in future learning designs since they are even more portable than portable computers. The smartphone is easily carried around in a pocket and can be used in any moment of the day. A study performed by Arbitron (2011) concluded that engagement with different smartphone features is divided evenly during the day detecting a slight peak in the afternoon from 15h to 18h.

Our results show that there are two time slots of the day in which lifelong learners feel more motivated to learn, these are from 10h to 12h (55.78%) and from 16h to 20h (49,66%). This discontinuity is happening due to the pause to have lunch, in which generally people change their context, that is, using a way of transport or simply commute the place for some time. Our study (See Figure 2) shows a difference for "motivation to learn" between people that own a smartphone and those that don't own one. Individuals that own smartphone expressed to be more constantly motivated during the day when compared to non-smartphone users.

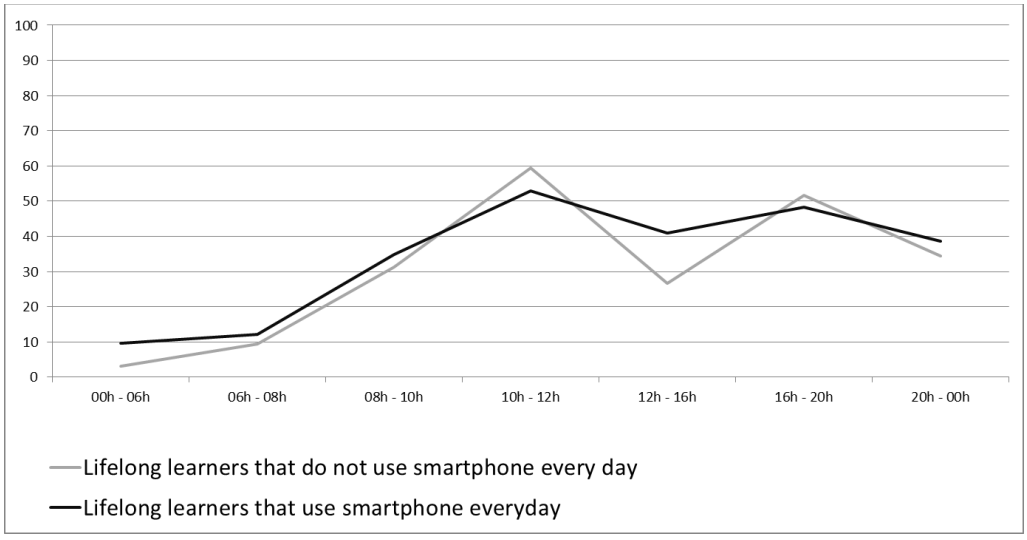

Figure 2. Motivation to learn during the day. Smartphone users vs. non-smartphone users.

A study by Eoff (2011) based on one week click data in the bitly on-line link tracking platform[1], concluded that tablets (iPads) usage during the day is not flat and drastically different when compared to other type of devices, including smartphones and portable computers. These results suggest that usage lowers after breakfast, remains low during traditional working hours and does not peak until much later in the evening (19h to 0h). The results of the questionnaire for lifelong learners suggest that there is an association between tablet users and their motivation to learn. The percentage of tablet users motivated to learn was 10% higher than with individuals that do not use tablets (See Figure 3). In relation to the peak observed late in the evening by Eoff (2011), our results show that the learning-motivation-curve in tablet users in the last hours of the day does not descend so much in comparison to non-tablet-users.

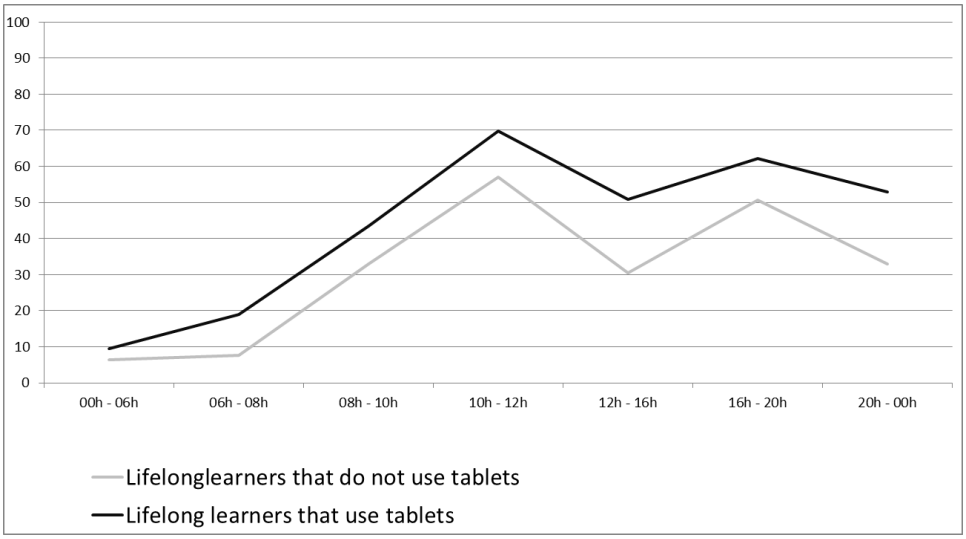

Figure 3. Motivation to learn during the day. Tablet users vs. non-smartphone users.

Eoff's results (2011) suggest that tablets are mainly used for entertainment purposes since they are less used than the rest during working times. Tablet usage is higher in comparison to the rest of the devices during leisure time. This effect can be also observed during the weekends when tablets usage between 8h and 15h is higher than it is during the week at those same hours. No other device sees a heavy increase of use during the weekends.

When asking lifelong learners on which days of the week, do they spend more time with their mobile device(s), our results show (See Figure 4) that usage for smartphone-users is flat with a slight peak on Fridays and there is always a higher percentage in comparison to non-smartphone users. There is an increase of 30% in non-smartphone-users from a working day (Thursday) to weekend day (Saturday).

There are different ways of consuming multimedia contents with mobile devices, these are, listening, reading, writing, watching, and gaming. When lifelong learners were asked how long on average they spend on each of these ways of interaction, 21% of the individuals reported to listen more than one hour per day to their mobile devices. This preference for listening can also be inferred from the results. Media players are used at least once a week by 64.62%, of the respondents.

When lifelong learners where asked how much time do they spend on different topics per day, the outcome was that *study*, *music* and *social networking* are the activities on which they spend most of their time. In contrast to these results, the study performed by Arbitron (2011) with similar topics,

[1] An on-line link tracking platform. Bitly. https://bitly.com/

indicates that messaging, browsing, social networking and voice are the activities on which individuals spend more time.

Examining the way in which individuals check their mobile phone for a new SMS, missed call, email or any other notification, there are two different behaviours that can be gathered from the results of the questionnaire. There is a first group of individuals (37.41%) that only check incoming notifications when the device warns them with an alert. The second group's behaviour is performed by the individuals (34.68%) that check it continuously, this means, at least once per hour. Comparing behaviours between genders, it is remarkable that the option "*I only check my mobile when it alerts me*" was answered by 44% of the men and 28% of the women. Women's behaviour was more evenly distributed among the rest of the options ("once a day" and "once every four hours").

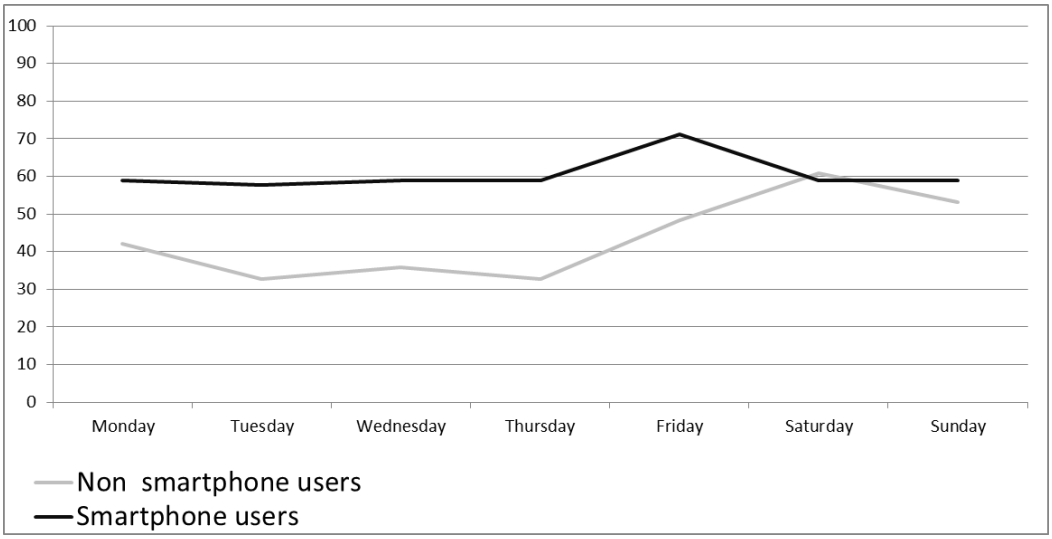

Figure 4. Mobile device(s) usage during the week. Smartphone users vs. non-smartphone users.

Linking locations, activities and ways of interaction with mobile devices

A study performed by Media (2011) on 5013 adults who identified themselves as using their smartphones to access the Internet, concluded that there are two main situations where they use smartphone. These are being at home (93%) and on-the-go (87%). Moreover, adults were requested for which activities they also use Internet on their smartphone. The highest rate was obtained (59%) for the activity "*Waiting (in the line at the market, doc, office, bus, etc.)"*. The questionnaire for lifelong learners has focused on these three main contexts including six items with the aim to identify patterns that link locations (living-room, kitchen, bathroom, working/sleeping room, on-the-move and, waiting for someone), actions normally performed in those locations (e.g. having breakfast, brushing your teeth, lying on bed, and etcetera), and ways of interaction with mobile devices (listen, watch videos, write and read), also defined as *learning activities* by Tough (1971). These results have raised some interesting differences regarding the way in which participants reported to behave depending on their gender.

Being at home

Sitting in the sofa is the most popular place to interact with mobile devices, not only compared to any activity performed being in the living-room or anywhere at home, but also outdoors and on-the-move. Exactly 62.58% of respondents reported that they normally *read* contents, 50.34 % *write* contents, 44.89% *watch videos* and 34.01% *listen* to audios while being in the sofa. The *living-room* was reported to be the most popular place to read contents, and specifying more, being *sat in the sofa* and *watching TV during advertisement time* (47.61%). There was also a high rate of respondents that reported to write contents while *watching TV during advertisement time* (32.64%).

The main finding that can be gather from responses regarding the context *being in the bathroom* is that, this intimate place has a significant association with mobile device interaction when used for *listening*, that is, the individuals reported to listen while *having a shower (23.12%)*, *making-up/shaving (*18.36%*)* and *brushing their teeth (*18.36%*)*. Being *on the toilet* is the most compatible activity with the different ways of interaction, that is, 33.33% of the respondents used their mobile device to read, 21.08% to write and 11.56% to listen. The poll performed by (Media, 2011) stated that 39% of the adults had used the Internet on their smartphone while using the bathroom, and 8% while taking a shower/bathing.

The majority of the respondents (54.42%) reported that they normally read contents on their mobile devices while *being sat at the desk*, 51.69% read, 37.41% listen and 29.92% watch videos, this means, that the desk is the best place to interact with mobile devices while *being in the room*. Furthermore, the bed is suited to interact with mobile devices reading (50.33), listening (34.69), watching (34.01%) and writing (33.32%).

The kitchen is a location associated to perform learning activities while "listening" on mobile devices. The results from this questionnaire suggest the same effects than the ones observed to the context *being in the bathroom* where mobile devices are mainly used for listening. The main contexts where participants embed their listening-learning-activity are while *cooking* (30.6%) and *heating the breakfast* (25.84%). It is only remarkable that 16.32% of the respondents interact with their mobile devices to *read* contents while cooking, probably requesting cook-recipes or short messaging while boiling, frying or anything in the oven. The survey by Media (2011) indicated that 27% of the participants had used the Internet on their smartphone while cooking/and or other household chores.

Waiting

Results depict that *waiting for someone/something* is not a context in which respondents consume video contents in contrast to the rest of ways of interaction, since the rates are low varying from 15.64% (being in the airport) to 4.76% (waiting in a commercial centre). The bus stop (43.52%) and the train station (41.49%) are the most suitable places to interact with mobile devices reading contents while waiting for someone/something. When writing on mobile devices, the highest rates are evenly distributed (approximately 38%) for the following contexts: waiting at the bus stop, at the train station and anywhere in the street.

On-the-move

The results from the study performed by Kim, Jimwoo, & Yeonsoo (2005), indicate that the most common context for using mobile Internet is described as follows: *participants have a hedonic goal, their emotional state is high, their legs are stopped, visual and auditory distractions were low, few people are around them, and their interaction is low*. This is a different picture from the widely held belief that the mobile Internet would be used often while moving outdoors. However, mobile devices have improved their capabilities to access the Internet since 2005, e.g. bigger displays, touch screens and faster connections and mobile interaction with smartphones is different nowadays. Our results suggest that interaction with mobile devices on-the-go is mainly carried out *listening*, being 51.69% train, 50.33% bus, and walking 48.3%. *Reading* contents is the second most popular way of interaction when moving, being 50.33% by train, 40.82% by bus, and 36.73% accompanying the car driver. The train is the most popular place to interact with mobile devices while *listening*, *reading* and *writing*, and the plane is the most popular place to *watch* videos. The poll performed by Media (2011) stated that 43% of the individuals had used the Internet on their smartphone while commuting to work/school and 20% driving by vehicle.

Gender

Regarding the gender effects, our results show some evidence on the fact that certain learning activities were more pronounced in men than in women and vice versa (See Figure 6). On the one hand, there are a 44.18% of men that reported to use their mobile devices reading contents while being sat on the toilet, however only 18.02% of the women do so. This difference was also notable

for writing contents (29.05% men vs. 9.83% women) and watching videos (15.11% men vs. 3.27% women). However, gender did not moderate the effects of listening contents. On the other hand, differences were also found regarding to listen to contents in some particular places. Women reported to be more willing to use their mobile devices while cooking (42.60% women vs. 22.08% men), sorting groceries (26.21% women vs. 5.81% men) in the kitchen, and cleaning in the living-room (49.16% women vs. 29.05% men). Moreover, it is remarkable that for the context *waiting for someone/something in a commercial centre*, 37.24% of the men reported to read contents in their mobile devices while only 16.38% of the women reported so.

	Listen	Watch	Write	Read
In the living room				
Having breakfast	12,24	8,16	8,84	29,24
Cleaning	37,4	1,36	0,68	2,04
Sitting in the sofa	34,01	44,89	50,34	62,58
Having lunch	11,56	10,88	8,84	20,4
During cofee/time	19,72	11,56	27,2	38,77
Watching TV, during advertisement time	12,92	15,64	32,64	47,61
In my room				
Waking up in the morning in bed	18,36	2,72	7,48	25,84
Getting dressed	19,72	0,68	1,36	2,04
Sitting at my desk	37,41	29,92	51,69	54,42
Lying on bed anytime	34,69	34,01	33,32	50,33

Figure 5. Learning activities in context with mobile devices. Percentage of individuals. The higher (red) percentages represent the more preferred locations/activities.

	Listen	Watch	Write	Read
In the living room				
Having breakfast	-7.08	-5.65	9.5	5.16
Cleaning	-20.1	-0.47	-1.63	-2.11
Sitting in the sofa	-0.72	9.5	-0.82	3.28
In the bathroom				
Having shower	-2.49	1.16	0	1.16
Sitting on the toilet	2.95	11.83	19.22	26.15
In my room				
Waking up in the morning in	6.17	4.64	9.98	4.95
Getting dressed	-5.5	1.16	-3.27	0.68
Lying on bed anytime	11.67	16.11	9.33	13.2
In the kitchen				
Preparing breakfast	-11.85	2.05	-2.38	-0.32
Sorting groceries	-20.4	0	0.68	-5.39
Cooking	-20.52	1.58	-1.9	-8.51
Waiting for someone/something				
Anywhere in the street	-4.24	0.89	9.6	6.26
At the bus stop	-6.84	4.38	7.48	9.08
In a commercial center	-9.52	2.53	14.3	20.85

Figure 6. Learning activities in context with mobile devices. Difference in percentages between men and women. Positive (blue) numbers represent higher male percentage. Negative (red) numbers represent higher female percentage.

Missing learning activities

Participants were asked whether they had missed in the questionnaire any other activity where they usually get along some learning episode with or without their mobile devices. They reported sport activities like "running", "cycling" or "at the gym", on-the-go activities like "taking a walk" or "walking the dog", and some other miscellaneous ones like "having lunch/dinner alone in a bar", "feeding the infant", "taking care of infant" and "while doing some do-it-yourself labour at home (carpentry, plumbing…)". The poll performed by Media (2011) concluded that 48% of the adults had been eating while using the internet on their smartphone, 17% walking their dog and 13% playing sports. Another respondent reminded us that there are no patterns for every situation and he/she reported "*I just learn something when I find the time*".

Difficulties when learning with mobile devices

Wong (2010) identified ten seams by which learning experiences are disrupted today and for which Mobile-assisted Seamless Learning (MSL) technology has to find new solutions. The identified ten gaps (MSL1-10) in seamless learning support are of high relevance for lifelong learners. Participants were asked about seven of these ten gaps in two items of the survey. The remaining three gaps

(MSL5, 9, 10) were too complex concepts to deal in this poll and will be treated in suitable future studies.

The above paragraphs "*On-the-move*" and "Patterns based on type of device, lifelong learners' behaviour" provide evidences to confirm the existence of both "across location" (MSL4) and "across time" (MSL3) gaps in the participants. Some cues are also exposed on how to resume these gaps supported with mobile technology. Participants were requested to report how often do they encounter these difficulties (MSL1-3 and MSL6-8) when learning and assisted with their mobile devices. The results from the questionnaire indicate that participants, varying from 12% to 17% in the different MSLs "usually" find these difficulties. Nevertheless, approx. 34% of the respondents reported "not a difficulty" in all these difficulties. The most remarkable difficulty is "find suitable slots of time during the day" with a 21.08% of the respondents that reported to have it "usually" and a 4.76% that find it "always". Slightly higher rates to the three resting difficulties, and with similar rates between them were "Combined use of multiple device types (laptop, mobile phone and/or tablet)" and "Linking real world to what I learned digitally" with approximately 17% of the respondents that "usually" found these difficulties.

An extended study performed by Eurostat (2011) concluded that the two most commonly cited obstacles to participation in education and training among those who wanted to participate but did not do so were: lack of time due to family responsibilities (36.6 % of those not participating); conflict with work schedules (35.0 %).

3. A REVIEW ON SMART OBJECTS FOR LEARNING

In 2009 smart objects have been named in the Horizon report, as one of the relevant technology trends with a time-to-adoption between four to five years (Johnson, 2009). In principle the report defines smart objects as "*objects that know about themselves and link the real world with digital information*". Smart objects in that sense use embedded technology to track state changes in the environment and their context without altering objects original aspect. Relevant technologies are QR codes and barcodes, RFID and NFC technologies, all 'other kind of embedded sensor technologies that can track changes of objects' state as the accelerometer, magnetometer, gyroscope, and others.

In our work we focus on the use of smart objects for learning and therefore we propose the concept of Smart Learning Object (SLO). We define SLO as: "Any augmented tangible resource that can be used to learn or support learning activities".

This section presents a review on tangibles for learning since early years (1997) to nowadays (2012). The first subsection gives an overview on related work based on a literature review. Next, Smart Learning Objects (SLOs) are presented as the evolution of tangibles for learning, providing a workable definition. This section concludes with a review of the conference series on Tangible, Embedded and Embodied Interaction (TEI) from 2007 to 2012 pursuing identify potential contexts to orchestrate tangibles with learning purposes.

3.1 SLOs attached to home

Our own **home** seems to be a suitable place to learn intimate and closely acquainted issues since we all spend many hours and pursue many activities at home. In the review, we have found smart objects that make us aware of our energy consumption patterns and support us on the way to learn about sustainability and improve our usage habits. The *thrifty faucet* (Togler, Hemmert and Wettach; 2009) is a pervasive home appliance that takes a different position depending on the water consumption during the last period of time, so whenever you use more water, it adopts a curled position and it is more difficult to get water from it.

One more example of an embedded smart object giving feedback about habits in daily life has been brought to practice by Nakajima, Lehdonvirta, Tokunaga and Kimura (2008) and takes place in the **bathroom**. An augmented toothbrush recognizes toothbrushing patterns by analysing the

acceleration data. The *virtual aquarium* displays animations giving positive or negative feedback depending on how effective the toothbrushing is. Both the toothbrush and the phone are augmented can be combined to teach hygiene habits. Mirrors, located in the bathroom, have been augmented with different purposes (Schmeer & Baffi, 2011; Roy, Hemmert, & Wettach, 2009) and seem to be potential SLOs to take part in future LLL ecologies.

SLOs track our behavior while we rest in the **bedroom**. The *PillowTalk* (Schiphorst, Nack, Kauwatjoe, Bakker, Stock, Arroyo, Rosilio, Schut and Jaffe, 2007) is an augmented pillow that gives feedback on the correct position to sleep with a serious game. Furthermore, there is a variety of commercial products around body scale, sleep behavior, healthcare, and others.

The **kitchen** is usually one of the rooms equipped with more appliances. Nowadays, it is not difficult to find fridges with a computer integrated in the market. They provide different kinds of facilities from counting the number of calories you take by reading the barcode of the consumed products, until a warning system alerting the owner when any product is going out of date. The *impatient toaster* (Burneleit, Hemmert and Wettach; 2009) is an augmented toaster designed to motivate its owners to eat more often and in regular intervals: after not using it for a while, it signals hunger through nervous movements. The *augmented cutting board* and the *sensor-enriched knife* (Kranz, Schmidt, Maldonado, Rusu, Beetz, Benedikt and Rigoll; 2007) enable the environment to determine the type of food handled during the preparation of meals.

Some other activities normally practiced out of home in specialized places like a clinic or gymnasium are embedded in daily life with the support of smart objects and brought to the **living room**. The *Yoga-Tablet* touch screen and the augmented mat (Nagargoje, 2012) enable any room to become a place to practice yoga. The *ReWall* (augmented decorative textile) and the *ReSwing* (augmented swing) (Bagalkot & Sokoler, 2012) represent smart objects in the field of rehabilitation technology that support an integration of physiotherapy with the everyday life.

3.2 SLOs attached to the classroom & workplace

Apart from our own home, the **workplace** or the classroom are places where we all invest a big percentage of our lives. Within the same embodied interaction paradigm as the previous paragraph, *Limber* (Leung, Reilly, Hartman, Stein & Westecott; 2008) is an interconnected system of wearables (augmented wrist band and neck sensor) designed to reduce repetitive stress injury among knowledge workers. Furthermore, smart objects tend to play an important role in order to support trainings in the working environment. These are some of the examples found in the review: *DressUp* (Erato, 2012) is a computerized system for designing dresses with 3D input using an augmented mannequin as a guide. The *tangible video editor* (Zigelbaum, 2007) is a multi-user tangible interface for sequencing digital video by using multiple handheld computers embedded in plastic tokens.

There is extensive use of tangible objects in teaching ***mathematics*** especially in children's education (e.g.: Dienes, 1964; Montessri; 1917). Manipulation of concrete objects helps in to learn abstract mathematics concepts. Nowadays, algebra or geometry are the main target topics when building SLOs to learn mathematics. In the branch of algebra, we identified the *wooden beam* (Leong, 2011) a significant example of a SLO designed with formal learning purposes The results obtained in this experimenting with this tangible suggest that students can better understand equations concepts when equations are constructed on a tangible wooden beam with plastic tokens, and the graphical user interface is displayed on a connected laptop.

The Smart Blocks (Girouard et al., 2007) is group of tangibles equipped with RFID tags, used to support learning geometry skills. These blocks are augmented mathematical manipulatives that allow users to explore the concepts of volume and surface area of 3-dimensional objects (Figure 7).

Figure 7. The *smart blocks,* a Smart Learning Object to learn geometry

4. CONCLUSIONS

The aim of the questionnaire for lifelong learners is to analyse learning daily activities in adults, and recognize patterns in lifelong learners, in order to shed light on new ways to support them with mobile technologies. The analysis of the results arises the 10 following findings:

1. Portable computers are the most used type of device. Recent studies (Wesel, 2011; 2012) have found similar results arguing ergonomic reasons. Furthermore, students preferred bigger screen compared to smartphones or tablets. Moreover, we think that portable computers are supplanting the heavy desktops because the drop in the prices (Tapellini, 2011; Kharif, 2009) in the last years.
2. Individuals that own a smartphone reported to be more constantly motivated to learn during the day than non-smartphone users.
3. Individuals that own smartphone use them constantly during the whole week. The rest of the individuals reported lower usage during working days and an increase during the weekends.
4. Listening is the most compatible learning activity when performing other tasks at the same time. It is also the one where adults spend more time and in longer time-slots. These results suggest that audio is very suitable for distributing learning materials. Audio contents can be consumed from any media player, which are very affordable since they can be found independently or embedded in most of the phones.
5. There are two different behaviours when adults check their mobile phone for a new SMS, missed call, email or any other notification. There is a group that only checks incoming notifications when the device warns them with an alert. There is another group that check it continuously. These results suggest that two behaviours must be taken into account when building mobile applications for learning. Users attend to notification coming from his/her mobile device: continuously polling; check based on warning event (vibration, sound, icon on the screen desktop…).
6. There is an association between the learning activity being performed (reading, listening, writing, or watching) and the concrete location where it takes place. Some patterns were found in the way to interact with mobile devices while being at home and depending on the room where the individuals were located. Participants were more willing to perform any kind of activity with their mobile device(s) while being *in the living room* or *in the sleeping/working room*. Nevertheless, participants reported that *the kitchen* and *the bathroom* were places where they use to perform the "listening" learning activity.
7. Learning activities are mainly performed when adults are with their legs stopped. The "reading" and "writing" learning activities mostly take place being sat (sofa, desk, train, bus and toilet) or lying on somewhere (bed). *Sitting in the sofa* is the concrete place where adults reported the higher acceptance when carrying out any learning activity. However, the "listening" learning activity that takes part more evenly in the different locations and embedded in different activities.
8. Men and women behave in a differently when making use of their mobile devices. These results suggest that man and women seem to behave differently, not only in the way to perform learning activities depending on the context, but also in the way to attend to an

incoming notification on their mobile phones. Furthermore, the study performed by (Ofcom, 2010) stated that men spend nearly an hour more per day using media than women.

9. Lifelong learners reported that their learning experiences are disrupted. Finding a suitable time slot to learn during the day is the most frequent difficulty reported by participants. These results and the ones by Eurostat (2011) suggest that there is a need to integrate learning activities in daily life.
10. There is a high rate of individuals that are not familiarized with the concept of "lifelong learning".

The review of SLOs attached to physical spaces has revealed the following findings:

1. Nowadays, physical spaces like classroom, workplaces, homes, or ways of transport are enriched with ambient displays, smart boards, multi-touch screens, WI-FI connection and smart objects. Nevertheless, these artifacts mostly work in standalone mode and are rarely interconnected. There is a need to orchestrate technologies augmenting physical spaces so they can be integrated and seamlessly managed in a learning flow. Hernández-Leo et al. (2011) present an example on how to orchestrate SLOs in physical spaces. Same conclusion can be derived for the orchestration of SLOs in subject-oriented contexts and learner's abilities-oriented contexts.
2. SLOs can be found in formal and informal learning environments and a variety of application domains. Reviewed SLOs related to healthcare, diet, wellness, and exercising are placed at home. SLOs related to formal education are placed in the classroom. This means, SLOs with a common learning goal might be naturally grouped by lifelong learners and associated to concrete physical spaces.
3. SLOs are often perceived in an isolated manner. This review has revealed that the majority of the artifacts were not equipped with capabilities, namely, RIFD, NFC or application interfaces that let them extend their interactions (Figure 8). This paradigm is described (Vasseur & Dunkels, 2010) and prototyped in recently proposed middlewares (Bernardos et al. 2011; Gama et al. 2012; Kawsar & Fujinami 2008). Nevertheless, these models are lacking links to educational instruction design and orchestration.
4. Most of the SLOs reviewed implement a simple behavior change model or neo-behavioristic approach by giving feedback based on data-collection or real-time data feedback. Very few examples found in the review have an underpinning didactical model used for the design of the SLO.
5. There is no didactical meta-data attached to SLOs with the aim to define its educational purpose. The learning aim of many of the enumerated SLOs was not explicit and sometimes it was difficult to determine "what is not learning for lifelong learners?". There is a need to embed this data so lifelong learners can be aware what the SLOs is offering to learn.
6. SLOs (reviewed in this work) are not aligned with the "*ideal technical setting for a personalized seamless learning environment*" (Wong, 2012). SLOs should implement interfaces to interact both with smart devices (Figure 8 d.) and cloud-based services or content repositories (Tabuenca, 2012a) (see Figure 8 e.). In this scenario, smartphones will act not only as a hub 24x7 hours aware of the learning opportunities supplied by the SLOs surrounding the lifelong learner, but also tracking his/her learning embedded in daily activities. SLOs should take advantage of cloud-based containers facilities (e.g. COSM[2]) to track and store sensor information. This fact would imply the transformation of SLOs in Holmquist's categorization (Holmquist et al. 1999) from information "*containers*" to "*tools*" that are used to manipulate digital information. An interface (Figure 8 e.) between SLOs and Learning Objects repositories might facilitate reusability of learning contents.

[2] COSM. https://cosm.com/

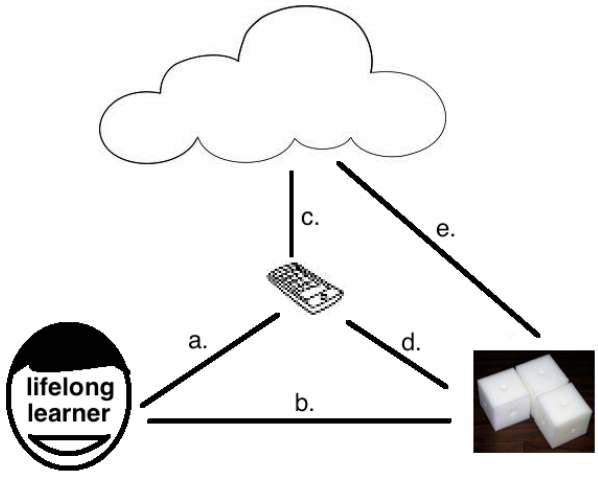

Figure 9. Possible interactions in the integration of tangibles (e.g. *Smart Blocks*) within the ideal technical setting for a personalized learning environment.

5. FUTURE WORK

Based on the idea that the opportunity lo learn and to grow is all around and should not be a chore for lifelong learners, we will extend this research creating a learner-centred model in which smartphones will be able to interact with smart learning objects, ambient displays for learning (Börner, Kalz & Specht; 2012), learning containers (Tabuenca, Drachsler, Ternier & Specht; 2012) and tagged physical objects, that could trigger different activities and lead to learning events (See figure 10). This model will define how channels and artefacts can be linked in order to adapt and serve the information according to adults' preferences (location, embedded in learning activity, time of the day, duration of the task, gender, etc.).

Figure 10. Learner-centred model for lifelong learning supported by mobile devices, tagged tangibles, smart devices, cloud services and embedded in daily physical spaces.

From the ubiquitous learning paradigm perspective, we will provide empirical argumentations to support the provided patterns by testing with ARLearn (Ternier, Klemke, Kalz, Van Ulzen & Specht. 2012) the combination of learning scenarios arisen in the questionnaire. This tool provides capabilities to augment physical spaces by pushing/pulling learning contents addressed by NFC and QR indexes. This software will also be able to launch learning contents, to be presented and consumed in different channels and physical spaces. The purpose of this work is to make the best use of learning resources that are available to lifelong learners, to give them technological support across

physical spaces, switching between learning tasks, and making use of smart objects embedded in daily activities.

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