"Tap it again, Sam": Harmonizing the frontiers between digital and real worlds in education

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“Tap it again, Sam”: harmonizing the frontiers between digital and real worlds in education

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Abstract – **Lifelong leaners are intrinsically motivated to embed learning activities into daily life activities. Nevertheless, finding a suitable combination of the two is not trivial since lifelong learners have to face conflicts of time and location. Hence, lifelong learners normally build personal learning ecologies in those moments they set aside to learn making use of their available resources. On the other hand, the advent of Near Field Communication (NFC) technology facilitates the harmonization in the interactions between the digital world and daily physical spaces. Likewise, NFC enabled phones are becoming more and more popular. The contribution of this manuscript is threefold: first, scientific literature where NFC has been used with a direct or indirect purpose to learn is reviewed, and potential uses for lifelong learners are identified; based on these findings the Ecology of Resources for Lifelong Learning is presented as suitable setup for the scaffolding of learning activities with NFC augmented physical spaces; finally, this ecology is piloted and different learning scenarios are proposed for further extension.**

Index Terms – lifelong learning, Near Field Communication, seamless technology, learning ecology, smart home

INTRODUCTION

The European Commission has identified time, location and conflicts with other activities as the core barriers to lifelong learning [1]. Lifelong learners constantly re-design their learning context to optimise opportunities for interactions with social and other resources towards their objectives. However, there is little technological support for lifelong learners that typically try to learn in different contexts, are busy with multiple parallel learning tracks, and must align or relate their learning activities to everyday leisure and working activities.

On the other hand, visions of ambient intelligence emphasize on the importance in the natural interaction between user and services embedded in the environment or available through mobile devices. *Natural User Interfaces* and the *Internet of Things* have been predicted to have an impact on education in the short term [2]. Tagged objects are widely accepted and the number of connected devices could reach 50 billion by 2020 [3]. Different tagging methods (e.g. visual codes, text recognition, image recognition) allow enriching physical objects of the world with educational resources [4]. In particular, the prominent adoption of Near Field Communication (NFC) readers in mobile devices has moved this technology from an innovator to an early adopter phase. This frictionless technology will enrich our environment, facilitating natural interactions, and harmonizing the frontiers between daily physical and digital objects.

Lowing the barriers for access to relevant information and support services anywhere, anytime, and anyhow represents an essential challenge for lifelong learning support. To give efficient access to services and link the different activities together, Wong et al [5] have identified ten seams by which learning experiences are disrupted today and for which Mobile Seamless Learning (MSL) technology has to find new solutions. The identified ten gaps in seamless learning support are of high relevance for lifelong learners. The current manuscript focuses on the four following seams:

- (MSL5) Ubiquitous knowledge access. A combination of context-aware learning and ubiquitous Internet access.
- (MSL6) Encompassing physical and digital worlds
- (MSL7) Combined use of multiple device types, including “stable” technologies such as desktop computers, interactive displays.
- (MSL8) Seamless switching between multiple learning tasks, such as data collection, analysis, and communication.

A learner-centric view of mobile seamless learning [6] suggests that a seamless learner should be able to explore, identify and seize boundless latent opportunities that his daily living spaces may offer to him (mediated by technology), rather than always being inhibited by externally-defined learning goals and resources. Hence, lifelong learners build personal *Ecologies of Resources* to scaffold learning so that a wide range of the resources available to a learner can be used to best support his learning needs [7]. The proliferation of smartphones is enabling the scaffolding of new learning scenarios. These devices offer us an increased ability to collect/deliver data from/to the world by retrieving/gathering the information supplied attached to physical objects.

This manuscript is distributed as follows. Section 2 reviews scientific literature in the field of NFC with a special focus on empirical research. Shortcomings and best uses are classified and highlighted. Section 3 presents the Ecology of Resources for Lifelong Learners as an approach to cover MSL5-8. This ecology is built towards the harmonization of learning experiences connecting objects existing in the digital and in the physical worlds (Figure 1). Application Programming Interfaces (API) and the different existing approaches to tag physical objects play a key role in this setup. Additionally, different seamless learning scenarios instantiating the Ecology of Resources for Lifelong Learners are presented as proof-of-concept to scaffold learning activities within daily environments.

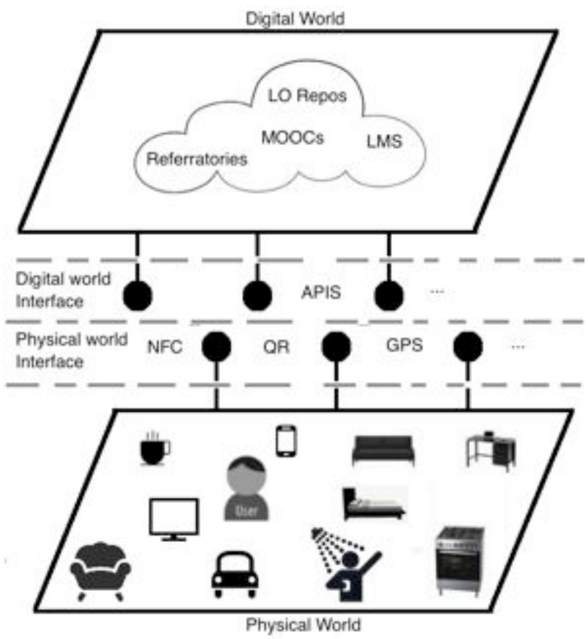


Figure 1. Physical/digital objects for learning in daily environments

LITERATURE REVIEW IN NFC TECHNOLOGY FOR LEARNING

NFC is a radio technology that supports transactions at distances of a few centimetres. NFC standards cover communications protocols and data exchange formats, and are based on existing radio-frequency identification (RFID) standards. In the current review, we have covered both terms since NFC is an extension to RFID technology. RFID is capable of accepting and transmitting beyond a few meters while NFC is restricted to within four inches.

The underlying search was conducted utilizing the online research repositories of the ScienceDirect, Springer, as well as the IEEE Computer Society. The focus on these repositories is reasonable as they cover a sufficiently large number of relevant publications. Within the Springer digital library an advanced search was performed in January 2014 querying all articles of type journal, proceeding, or transaction that had been published since 2007 when the first NFC enabled mobile phone was released[1], and matching the keywords *"(NFC learning mobile) OR (RFID learning mobile)"* as part of the body. The query revealed 1912 results where the first 100 occurrences ordered by relevance were selected. These items were filtered to 15 by title and/or abstract. The rest of the repositories where analysed analogously. Nevertheless, this review does not aim to be accurate and strict, but rather a review that identifies a set of learning scenarios where RFID can be used with successful results.

Variations in the use of RFID technology have been reviewed in the field of retailing, library services, animal detection, food, logistics and supply chain management anticipating this technology as a hot topic [8].

Formal education

Recent work [9], envisions some of the potentials NFC technology brings for teaching and learning materials in formal education, with a special focus on implementations to connect digital media and printed learning resources:

- Distributing learning/teaching materials in face-to-face classrooms. It is cheaper and faster to deliver materials transferring the files from teacher to student (or vice versa) via NFC technology than printing on paper and delivering them manually.
- Enriching printed materials. NFC tags stuck on printed materials like books or posters facilitate the enrichment of physical materials with multimedia content.
- Students can visualize the digital content by approaching the mobile devices.
- Sharing materials among students. Peer-to-peer communication between devices.
- Delivery of practicals. NFC tags can be configured so that they do not only contain static information (student's identifier, files from exercises, readings, etc.), but they can also be configured with pre-defined actions (procedures) that the NFC-reader will execute when the NFC tag is scanned. For instance, when a student delivers a practical work, the teacher scans student's tag with the NFC reader to confirm his/her identity and automatically submit back an email to the student as acknowledgment of reception.
- Integration of social networks. Another possibility is to use a tag to identify the social network and upload the data using the connection information received from the tag.
- Access to control materials. Teachers can pre-configure in the NFC readers how the materials will be distributed depending on the specific profile (identity, age, course level, etc.) of the student given in the NFC-tags.

[1] Nokia 6131 NFC phone taps into mobile payment, ticketing and local sharing. , Press. http://bit.ly/1stNFC

[2] Microsoft Corporation Domestic Home in Redmond. http://research.microsoft.com/en-

- Examinations. NFC tags can be stuck to identity cards so teachers can verify the identity of the students and check whether they are allowed to participate in exams.

Likewise, there is a remarkable number of scientific literature providing empirical research on the implementation of RFID/NFC technology beyond the walls of the classroom. These are some significant examples:

Guided tours

Excursions of art and museum are significant scenarios where content is delivered based on the parameters supplied by the mobile device. Mobile-guides delivering contextualized audio, video and text, are reviewed in recent work [10]. This work claims that the current trend is to gradually abandon some of the older localization technologies such as Wi-Fi, infrared and manual user position input. Most of the times, the leading figure of a guide is not necessary because visits to museums are mostly in small groups, and visitors do not want to be overloaded with information. RFID interaction offers a non-intrusive and intuitive interaction where the user can customize his own learning by approaching the smartphone to a tag attached to a physical object depending on his interests on a concrete author, topic, age, etc. Kuflik et al. [11] implemented a methodology for multimedia presentation adapting the content delivered in the presentations to various perspectives for the whole museum. Hence, visitors with limited motivation prefer a more broad presentation. Visitors who expressed interest in additional information enjoyed the adaptation. Well-motivated visitors, especially if coming for a second time or more, will probably behave differently. As a conclusion of their research [11], the authors suggested the use of RFID as the simplest available technology that can avoid requiring explicit position specification reported by the user and they also reported that accurate positioning inside a building to be an open issue. Previously, Miyashita et al. [12] had combined RFID tags, and a mobile-PC to use already existing audio guides during a six-month exhibition on Islamic art.

Access control

Badges are used in identification cards to track persons with different purposes. Locating persons is one of the possible uses of RFID. Buildings of universities (or companies) are clustered in different floors/rooms with different policy access. Students cannot access to certain resources of the lab out of a defined schedule. Teachers can only access the facilities supplied by their department. Traditional keys are being supplanted by badges that give access to certain places depending on the profile of the user. Mobile phones are carried around the whole day and offer an interesting opportunity not only to define a policy of access but also to locate persons in any educational institution during office hours. The work from Bacheldor [13] describes an implementation on how to locate medical assets by using an RFID-based real-time location system (RTLS). Sandberg et al. [14] provide a real time unauthorized access alert to clinical staff by integrating instant messaging technology and RFID. If teachers would use this technology, students would be able to locate in which classroom a teacher is giving a lecture. Occasional changes of classroom would be detected by the presence of the teacher in a different classroom, so that a SMS notification would be sent to the students, or displayed on digital boards. Analogously, this technology can be used by parents/teachers to have a real-time account on when do their children/students go to class.

Wearables

NFC tags are increasingly embedded into wearables like key-rings (Figure 8ef), bands, clocks, collars, or bracelets. Theses tags can be readable from a distance through material such as wallets and clothing. The GerAmi system [15] provides insight on how this technology can be successfully applied in wearables. The objectives of this system are to monitor the patients and manage the work of the doctors and the nurses. The system is configured setting ID-readers above each door in rooms and elevators in the facility. Nurses and Alzheimer patients wear a bracelet containing an RFID chip. Additionally, nurses are equipped with PDAs in order to follow the information, set controllable alarms and locks. Additionally, these hospitals provide wireless access points.

Activity recognition

The work from [16] uses RFID technology to identify which operation the user is doing. The operations in their activity theory consider three arguments: *object*, *location*, and *time*. *Object* refers to tangible things that humans can interact with (e.g. dishwasher, fridge, microwave). *Location* represents the environmental information where an operation occurs. *Time* is the duration over which an operation was conducted. As a result of this study, the authors stress that some activities are more recognizable when temporal information is ignored.

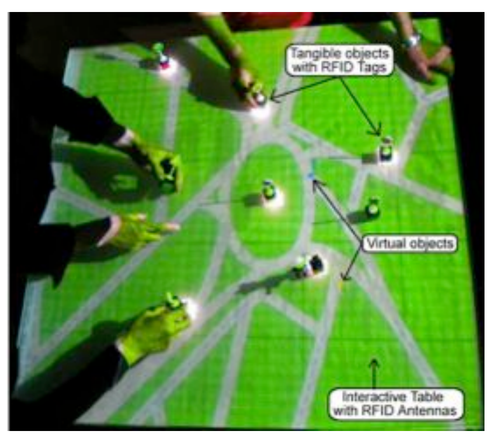


Figure 2. Tangisense. Several specialist (security, pollution, etc.) simulate different equipment simulations and their consequences

Tangibles

RFID technology has been experimented supporting the simulation of scenarios on interactive tables. Figure 2 illustrates how tangibles equipped with RFID simulate different strategies (equipment configurations) and their consequences [17]. As result of this experience, the authors highlight RFID as an interesting approach for simulation of scenarios as it features the identification of objects and allows the storage of information directly within the objects.

Smart home

There is an increasing number of publications in the field of smart homes. The work from Saldri [18] surveys ambient intelligence and its application in different contexts, in particular, Saldri provides examples where NFC technology has been embedded in different appliances of smart homes. The GENIO project [19] presented a fridge that keeps track of the (RFID tagged) goods consumed by the user. The fridge is equipped with an RFID antenna and an RFID reader inside, allowing it to read the goods stored in it. Also related to logistics, the Microsoft Corporation Domestic Home in Redmond[2] provides an augmented mailbox tracking mailman's location via GPS. Users read on the mailbox display or by cell phone, real-time estimations on when the mail will arrive.

The work from Tran & Mynatt [20], [21] presents a pilot where an RFID enriched mirror recognises and tracks logs of the activities accomplished during the day. This work is motivated on the idea that memory confusion arises between the repeated episodes of frequent tasks (e.g. "*Did I take my vitamin today or was that yesterday?*", "*Has anyone fed the fish?*", "*Did I take pain medication an hour ago, or did I decide to wait a bit longer?*"). This system is presented as a long-term memory system for activities that are repeated often and are not part of a strict routine.

Logistics

The ten-year academic review conducted by [8] reveals the increasing importance of this technology in the field of logistics. As a consequence of this review, the authors highlight RFID technology as a hot topic in the field of retailing, library services, animal detection, food, and supply chain management. More specific, the work from [22] reviews the use of RFID in medical organizations for the purpose of managing and tracking medical equipment, monitoring and identifying patients, ensuring that the right medication is given to the right patient, and preventing the use of counterfeit medicine. Additionally, the author present an exploratory case study conducted in a medical organization offering valuable insight on the use of RFID in medical organizations.

[2] Microsoft Corporation Domestic Home in Redmond. http://research.microsoft.com/en-us/um/redmond/groups/cue/homeautomation/

SEAMLESS ECOLOGIES ACROSS DIGITAL AND PHYSICAL WORLDS WITH THE 3LHUB

In the literature review we have presented how NFC technology can be used to facilitate seamless interactions in different contexts. The following section presents the *3LHub (LifeLong Learning Hub)* as a tool for self-regulated support in lifelong learners. In the next section the *3LHub Digital Media Player* pilot, its implementation, and a proof-of-concept are described. This work implies a suitable instantiation on how NFC technology can support the scaffolding of personal learning ecologies combining the approaches presented in the review, namely, smart home, activity recognition, wearables, tangibles or access control.

The LifeLong Learning Hub[3]: 3LHub

The 3LHub [23] is a standalone application developed for NFC-enabled Android (4.03 or above) devices released in March 2014 in Google Play[4]. The 3LHub has been designed based on the seamless notion that lifelong learners can learn in a variety of scenarios and can switch from one scenario or context to another easily and quickly, using the personal device as a mediator. This tool has been conceptualized on the idea that mobile technology can be smoothly integrated in daily life activities whenever interacting with it requires the least number of clicks (zero) possible and the duration of any action with the tool lasts not longer than 20 seconds.

Focusing on lifelong learners, Candy [24] proposes a learner-centric model with four stages: planning for learning; understanding how to learn; self-monitoring; self-awareness. Inspired on these stages, the 3LHub provides an NFC based natural interface to accomplish the following self-regulated procedure:

Set goals

This stage assumes that the user reflects on his autobiography as a learner mapping learning goals to learning environments identified by NFC tags. Whenever the user sets a new goal in 3LHub, he should get a NFC-tag, tap it with the NFC-enabled mobile device, characterize the goal with a name, specify the expected outcome when the goal is finished, estimate how much time (in minutes) will he devote to this goal on daily basis, and indicate when the goal should be finished. Placing an NFC-tag in a physical learning environment enables the connection of a variety of tracking data with the learning activity. For example the "check-in" at a NFC tag can track the learners use of a specific resource, at a certain time of the day, in a specific location.

[3] The Lifelong Learning Hub Project. https://sites.google.com/site/lifelonglearninghubproject/
[4] Lifelong Learning Hub's app in Google Play. https://play.google.com/store/apps/details?id=org.ounl.lifelonglearninghub

Perform/ track learning activity

Lifelong learners recur to specific locations (e.g. desktop, coach) and moments (e.g. waiting times, transitions) to accomplish their learning activities along the week [25]. Learning activities should be tracked in a way that the transition from/to daily life activity can be done with effortless interaction, otherwise the user will not bother to track such a short learning moments, and as result it will never be accounted as learning time. This feature considers that the user will tap the associated NFC-tag every time he starts/stops a learning activity. Hence, 3LHub harvests all learning moments and accounts them as real learning time with frictionless interactions.

Monitor learning analytics

The 3LHub features the following visualizations with the aim to foster understanding on learning habits, optimise learning, and, bind successful learning environments: percentage of time invested on each learning goal; distribution of learning moments along the day; monitoring accomplished goals. A representation of effective learning time versus expected time towards a learning goal.

3LHub Digital Media Player

Harmonizing the frontiers between the digital and the physical worlds implies facilitating seamless access to these learning contents, in particular, faster access and suitable visualizations. Herby, we present the *3LHub Digital Media Player* feature extending 3LHub with the aim to smoothly integrate learning activities in daily life with NFC tapping interactions (Figure 3).

A recent survey to 21 content repository owners (overall hosting of ~1.5 million educational resources) highlights the need to provide suitable access to learning contents via mobile devices [26]. A 72% of the repositories considered that providing a suitable mobile app would increase the access rates to their repository. Additionally, the 81% of the repositories would consider providing an Application Programming Interface (API) for their content to be accessed via other sites or apps. The increase of the size of the smartphones' screens has augmented considerably the degree of excellence for consuming contents. However, videos are not always well suited to be displayed in the screen from mobile devices. The original learning objects were created for eLearning platforms and some of their features are missed when moved to a mobile context.

On the one hand, videos conform a big proportion of the learning materials provided in online courses (e.g. Learning Management Systems, Massive Open Online Courses). These videos are normally hosted within the proper learning management system, or, they are publicly shared in repositories (e.g. Youtube, Vimeo). On the other hand side, starting a learning activity in an online course normally requires the user to open a browser, login the platform, navigate it, and look for the desired resource to display the video. Hence, most of the times reaching the content requires more time than watching the video itself. For instance, a lifelong learner could enrol an online course pretending to finish it by watching the videos sat on the couch at night during every commercial pause on TV. If this routine implies that the user will have to switch-on the computer (or take the tablet), open the browser to login the platform (if not expired session), navigate and display the desired resource, the lifelong learner will probably not bother to iterate over this routine and will not be able to transform these small gaps into productive learning times.

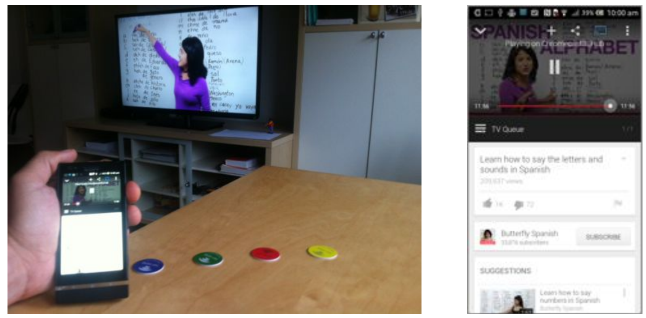
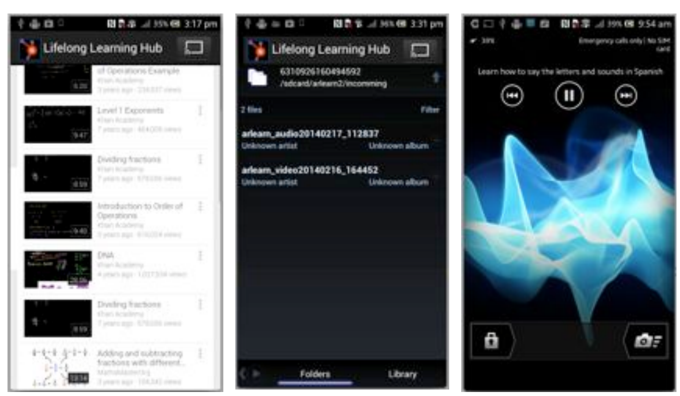


Figure 3. 3LHub Digital Media Player. Video playlist broadcasting

Outline

The work from Tabuenca [25] on lifelong learners' mobile usage habits reveals that there is an association between the type of learning activity being performed (read, write, listen, watch) and the concrete location where it takes place. Herby we assume that lifelong learners map learning activities to NFC tags located in specific learning environments or physical artefacts (See examples figure 8) living in our daily routines that are naturally associated by the lifelong learner to learning activities.

Figure 3 illustrates the case where the user has bound a different video playlist (fig. 4a) for each of the NFC tags. Whenever he taps the red tag, the 3LHub Digital Media Player queries his YouTube list to "*learn Spanish in 20 lessons*" and the videos are automatically broadcasted to his TV. Analogously, 3LHub the Digital Media Display has been piloted to play a podcast playlist (fig. 4b) on the mobile device when an NFC tag is tapped. The playlist can be stopped pushing on "Pause" button (fig. 4c), or shift tapping again.



a). Maths video b).Learn Dutch Audio c) Digital media player playlist playlist stop, forward…contols

Figure 4. 3LHub Display Media Player interfaces

Implementation

Figure 5 illustrates the resources taking part in this ecology. Hereby we provide insight on how this pilot has been implemented:

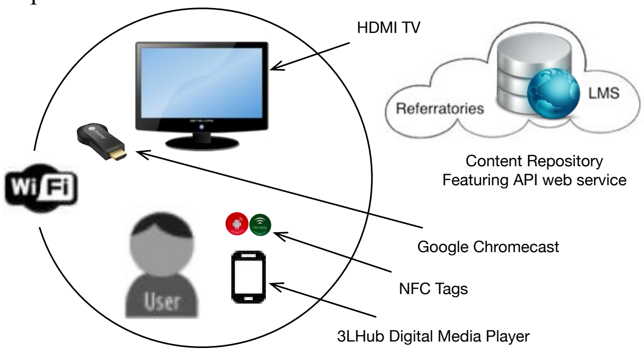


Figure 5. Ecology of Resources in 3LHub Digital Media Player

Digital media player. In the very last months, WI-FI enabled digital media players have arrived to the market: Google Chromecast[5] (July 2013), Roku[6] (March 2013); Apple TV[7] (January 2013). These devices play audio/video content on a high-definition television by directly streaming it via Wi-Fi from the Internet or a local network. These devices stream multimedia content based on the commands triggered from another networked device. The basic operation is that using a mobile device, tablet or laptop, and selecting a desired multimedia (YouTube video, audio, web browser, etc.), the content is automatically broadcasted in the display where the digital media player is plugged. This pilot has been implemented with Google Chromecast due to the fact that this manufacturer offers an API.

HDMI displays facilitate the visualization of videos independently of the dimension for which they were designed. When streaming video from the digital media player, the audio volume is controlled from the remote of the HDMI display and not from the client device (mobile device, tablet or laptop). This feature makes the interaction much more natural.

Smartphone with NFC enabled reader. The mobile phone plays the role of the learning hub communicating with all the previous elements in the ecology. A NFC-enabled smartphone is able to decode the tag (NDEF message) recorded in the tag. A native app (*3LHub Digital Media Player in our case*) should be able to request the web-service from the course to retrieve the playlist(s). The native app should map this message to one of the playlist and communicate with the digital media player API (Google Chromecast API[8]) to launch the videos in the HDMI display.

Content repositories with API web-services are key for the scaffolding of apps. Web-service architectures facilitate the compatibility and should be standardized towards the accessibility from any type of smartphone [26], [27]. The basic idea for this architecture considers that making a HTTP request, the service returns an structured file (normally JSON, or XML) with the list of URLs from the videos requested (that aggregate learning units). The *3LHub Digital media player* has been piloted making use of the resources available in one specific referatory (Figure 6). This API provides access to playlists of videos for a requested topic e.g. “Physics”, “Biology” or “Algebra”.


```
{
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  "description": "Why we study differential calculus",
  "download_urls": {
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    "mp4":"http://s3.amazonaws.com/KA-youtube-
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layer",
  "views": 75613,
  "youtube_id": "EKvHQc3QEow"
},
...
```


Figure 6. Khan Academy API[9]. Retrieve a list of all videos in the topic “maths” identified in the webservice request

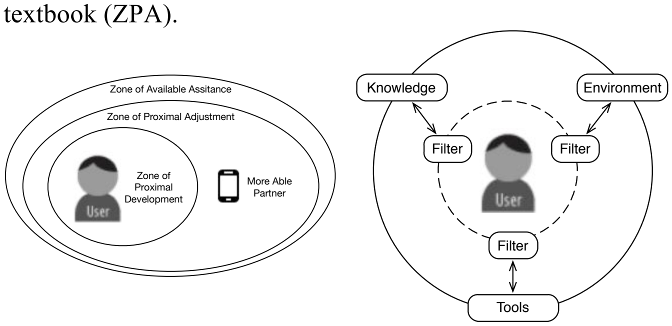
THE ECOLOGY OF RESOURCES FOR LIFELONG LEARNING

This section proposes a model entitled “*Ecology of Resources for Lifelong Learning*“ as an approach to support lifelong learners to integrate learning activities in daily life by making use of the resources and pilot presented in the previous sections. Hence, the previously described scenarios will be conceptualized in this model and illustrated in with the aim to provide cues for lifelong learners to scaffold new personal learning ecologies.

This ecology is formulated inspired by the Ecology of Resources (EoR) from Luckin [7] where the learner is encouraged to explore the forms of available assistance in his environment. Figure 7a illustrates this learner centric approach with different layers. The Zone of Proximal Develoment (ZPD) represents what the user can learn by himself with his potential ability and the interactions that can arise from his previous experiences. Lifelong learners are intrinsically motivated to learn and to re-design their context, with the aim to optimise opportunities for interactions with social and other resources capable of assisting learners perform towards their objectives (design a Zone of Proximal Adjustment (ZPA). Figure 7a) [28]. Here

[5] Google Chromecast. http://www.google.com/intl/en/chrome/devices/chromecast/
[6] Roku streaming stick. http://www.roku.com/products/streaming-stick
[7] APPLE TV streamcater http://www.apple.com/appletv/
[8] Google Cast SDK. https://developers.google.com/cast/docs/reference/
[9] KHAN Acadmy API http://api-explorer.khanacademy.org/

is where the figure of the More Able Partner (MAP) represented by the mobile device plays a key role as the main supporter for lifelong learners. The relationship between User and MAP is used to develop and support the progression from Zone of Available Assistance (ZAA) to ZPA. The ZAA describes the variety of resources within the learner's world that could provide different qualities and quantities of assistance that may be available to the learner at a particular point of time [7]. In this sense, NFC technology facilitates the scaffolding of learning activities bringing resources closer to the user (from ZAA to ZPA) supported by his mobile device. E.g. a user can watch a multimedia video stored in a repository (ZAA) by taping with his mobile device (MAP) an NFC tag attached to a textbook (ZPA).



a) b)

Figure 7. Ecology of Resources for lifelong learning

Figure 7b represents how lifelong learners create personal learning ecologies in this model. We will describe its components illustrating it with an imaginary character: John Michael, an English adult lifelong learner interested in learning a basic level in different languages to broaden professional markets:

1) Environment. This resource refers to the locations where the lifelong learner normally uses to learn. John is one of these persons that explores his habits to identify when and where he is more productive [29]. Hence, he sets aside time to learn, or spontaneously learns when his emotional state is high, his legs are stopped, visual and auditory distractions are low and few people are around him [30]. This ideal situation only occurs when his children are in bed at night. In this sense, John is the typical lifelong learner that studies at night in small intervals while sitting in the sofa or in bed during the commercials pause on TV [25]. John Michael has stuck an NFC tag to the TV remote (figure 8a) so he can easily shift from “leisure mode” to “leaning mode” and watch the video playlist from his Spanish course during the sub sequential commercials breaks. Analogously, John Michal loves to listen to radio podcasts while cooking. He has stuck an NFC tag to the fridge so he can easily start/stop the audio playlist from his Spanish course every time he is in the kitchen. The way John Michael models his personal learning environments is identified as *environment* in the EoR for lifelong learners. The lack of wi-fi connectivity in the kitchen would be a *filter* to scaffold this ecology.

2) Tools. This resource refers to the tools that the lifelong learner normally uses to learn. John always has his smartphone close at hand where he spontaneously takes notes along the day on mini-goals he would like to complete or the vocabulary he should lookup and learn. Additionally, he has recently registered in a course to learn Dutch with the aim to be more constantly engaged to regular assignments. John Michael identifies his Dutch book (figure 8b) and his pen vase (figure 8d) as frequently used artefacts to accomplish assignments in this course. Hence, John stucks a tag to both the book and the vase with the aim to launch the playlist of the audio assignments when these tags are tapped. These tags (fridge, remote or vase pen) represent EoR bound to static physical locations (kitchen, living room or study room). Nevertheless, NFC tags can be dynamic in the sense that they can be carried around by the user the whole day as wearables. Figure 8ef illustrates how NFC tags can be used to augment key rings or belts. These wearables have been piloted considering that the user can interact launching multimedia in different displays along the day (at home, waiting at the doctor, commuting in public transport). All this resources are considered as *tools* in the Ecology of Resources for lifelong learning. The incompatibility of NFC tags built by specific manufacturers represents a *filter* to scaffold this ecology (Figure 7b).

3) Knowledge. This resource refers to lifelong learners skills to learn, previous knowledge on the learning topic and experience. John has travelled abroad many times and believes he has some good intuition on the meaning of the words (Dutch is considered a sister language of English). Nevertheless, structuring sentences is not his strong point (*filter*: Dutch word order is often different from the English).

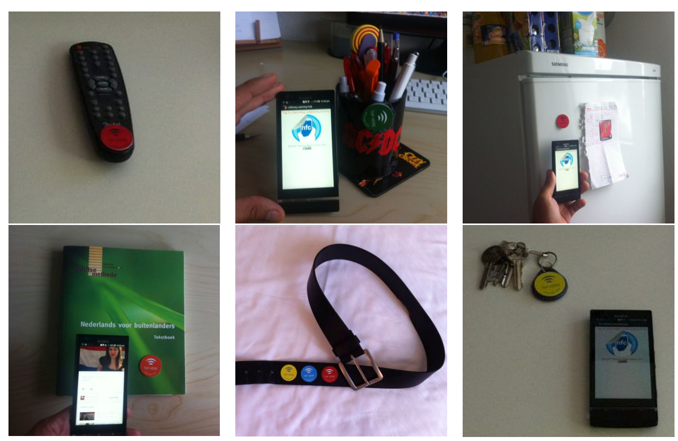


Figure 8. NFC tagged living artefacts in the Ecology of Resources for lifelong learning. Top a)b)c). Bottom d)e)f)

In this scenario, lifelong learners need to identify available resources and to know the extent to which these may support him as *More-Able-Partner (MAP)* [7]. Recognising the role of the MAP is fundamental to lifelong learners since MAPs are able to identify potential types of assistance to the learner. John uses a self-regulated approach to learn Dutch. As John’s wife is not interested in this language, he uses his mobile device as a *learning hub* [6] (More-Able-Partner) to learn across time and locations: taking notes, listening podcasts, accomplishing course assignments, monitoring goals, etc.

Filters. Luckin [7] defines filters as the constraints for learners interactions with these forms of available assistance: *environment*; *tools*; *knowledge*. These filters are clearly aligned with the ten seams [5] by which learning experiences are disrupted today and for which MSL has to find technological solutions. In the particular case this manuscript and focusing on our character:

- *Ubiquitous knowledge access* (MSL5). John's feature phone has no Internet access. He uses it to take notes during the day and listen previously downloaded podcasts. Nevertheless he cannot access to the MOOC platform or any online tool like dictionaries or videos.
- *Encompassing physical and digital worlds* (MSL6). John normally uses his laptop to learn digital contents during the TV commercials. Nevertheless, he does not continue this task at the bedroom while her wife reads a novel because he would need to move the laptop from one room to another, plug it, restart session etc.
- *Combined use of multiple device types* (MSL7). John uses mainly his laptop to learn Dutch. He wonders how practical would be to make the most of his devices by listening to podcasts while commuting by car, watch videos in a bigger screen, and do not depend on his laptop to accomplish every learning task.
- *Switching between multiple learning tasks* (MSL8). John's learning tasks encompass read texts, watch videos, listen podcast or writing assignments. Most of the times these tasks are associated with physical spaces [25]: listen while cooking; watch in the living room; read on the coach; write on the desk. He wonders how easy would be to shift between learning tasks without the need to use the laptop.

CONCLUSIONS AND FUTURE WORK

This manuscript proposes the use of NFC technology towards the harmonization between digital and physical worlds in education. Findings in the literature review reveal that this technology can be smoothly integrated in different learning approaches via wearables, tangibles, smart homes or activity recognition. The *3LHub Digital Media Player* and the *Ecology of Resources for Lifelong Learners* provide a real instantiation of these approaches and proposing natural interactions as a motivation to cover the four seams by which mobile learning experiences to be disrupted [5]: ubiquitous knowledge access; encompassing physical and digital worlds; combined used of multiple device types; switching between learning task.

The literature review envisages further daily life scenarios where NFC technology has potential applications. The proposed approach envisions that adopting this technology could increase the chances of learning in unconventional contexts (e.g. waiting times, transportation, having shower, cooking, walking the dog.) replacing this perceived "lost time" into perceived "productive time".

Basic learning activities in lifelong learners include *read*, *write*, *watch* and *listen* [25]. The 3LHub Digital Media Player has prototyped seamless solutions for watching videos and listening to podcasts both in dynamic and static scenarios. We will further advance this research providing seamless solutions for reading (NFC + text to speech conversion) and writing (NFC + speech to text conversion) towards encompassing daily life and learning activities.

Additionally, we will investigate not only how technology can facilitate the accomplishment of basic learning activities, but also on how to prepare the mental transition across learning activities with the aim to provide effective feedback services (ambient feedback, recommendations, power songs etc.). Sensor technology like iBeacons and smart tangible objects will be piloted with the aim to provided feedback in outdoors scenarios. Lastly, we will investigate the potential of these ecologies for the scaffolding of assistive learning in persons with reduced mobility.

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