Quiet Captures: A Tool for Capturing the Evidence of Seamless Learning with Mobile Devices

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Abstract: Seamless learning environments help students in extending their learning experiences across social, personal and environmental dimensions, and are supported by different tools, information and communication technology. In order to capture the evidence of the ways students utilize mobile devices in their formal and informal learning pursuits, a quiet data capture program was designed and pilot-tested. It is used to capture both quantitative and qualitative data about device use, to track user generated data and artefacts persistent across time and to generate and render aggregated reports identifying usage patterns. It is supposed to serve as a mechanism of identifying affordances of mobile devices within the landscape of seamless learning. Some preliminary findings raising multiple questions and inevitably sharpening our research lenses are presented towards the end of the paper.

Introduction

Mobile devices are nowadays used by younger generations on a daily basis to access web content, to capture different artefacts (e.g. photos, voice recordings, notes etc) documenting daily activities, and to communicate with peers via synchronous (e.g. Skype for mobile devices) and asynchronous tools (e.g. SMS). However, their popularity is hardly ever extended into classrooms since school policies see mobile devices as a disruptive factor. Moreover, lesson plans and assessment strategies employed in many educational institutions usually do not allow these innovative technologies to be used as pervasive learning tools.

On the other hand, mobile devices are, according to some researchers, an enabling force to transform education (Roschelle & Pea, 2002; Sharples, Taylor, & Vavoula, 2005; Waycott, 2004; Zurita & Nussbaum, 2004). At this point, there exist numerous case studies illustrating innovative ways of incorporating mobile devices into various classroom activities (Anastopoulou, et al., 2008; Ardito, Buono, Costabile, Lanzilotti, & Pederson, 2007; Chen, Kao, Yu, & Sheu, 2004; Colella, 2000; Dufresne, Gerace, Leonard, Mestre, & Wenk, 1996; Facer, et al., 2004; Klopfer, Squire, & Jenkins, 2009; Proctor & Burton, 2003; Rogers & al., 2002; Roschelle, 2003; Sharples, Lonsdale, Meek, Rudman, & Vavoula, 2007; Vahey & Crawford, 2002). Moreover, some researchers have produced encouraging results for policy makers willing to participate in this exciting process of educational change (Klopfer, et al., 2009; Sharples, et al., 2005)

Although there is still lack of theories of mobile learning from pedagogical perspectives (Sharples, et al., 2005; Vavoula & Sharples, 2008), it is evident that mobile devices are becoming pervasively integrated into student activities outside schools. While there is no doubt that students utilize them in their daily leisure activities, it remains unclear whether there is an added educational value brought into students' lives with the help of these ubiquitously present tools. Even more intriguing questions start to emerge as we delve into this heavily under-explored area on pedagogical issues: is there a way of establishing a link between classroom and informal daily activities with the mediation of mobile devices? What kind of skills can be better taught with mobile devices? Can they be used for inquiry learning redirecting knowledge from informal into formally structured learning environments or vice versa? All these together with other emergent issues are being examined under the Seamless Learning project conducted in Singapore (see Looi, 2010 for more details). Both formal and informal learning spaces are being explored together with the synergistic effects of linking the two in order to achieve the continuity of learning experiences across different learning scenarios. The project tries to achieve so called "seamlessness" with the combinations of different parameters across multiple dimensions of learning environments.

The aim of this paper is not to answer all the above stated questions, but to focus on designing a tool that can be both used to capture and analyse invaluable information generated from everyday activities with mobile devices that primary school children are involved in. In order to collect the evidence of the ways students utilize mobile devices in their formal and informal learning pursuits, a quiet data capture program was designed and pilot-tested. The program is used to capture both quantitative and qualitative data about device ussage and to track user generated data and artefacts persistent across time and locations. The gathered data is aggregated in a form of reports helping researchers to pinpoint the areas of informal activities relevant to formal learning. Experiences gathered this way can be used in designing lesson plans which incorporate mobile devices

and to accordingly design innovative applications for learning with mobile devices. Ideally, these should coincide with students' informal learning interests and broaden possibilities for seamless learning experiences.

The paper is organized as follows: we first present the theoretical background of the Seamless Learning project in relation to mobile learning. Then, we present the design and development of the quiet capture tool, followed by some collected data and preliminary reports used to better understand seamless learning experiences; and we conclude with future research plans and implications.

From Mobile Learning to Seamless Learning

The *technological strand* of researchers in the area of mobile learning has focused on mobile devices, such as identification of device characteristics important to learning, the development of systems for mobile learning, appropriation of mobile devices for effective learning. An example of device-focused definitions of mobile learning can be described as learning activities using mobile phones, handheld computers, digital portable devices for music reproduction, digital cameras, voice recorders and digital pens (Excellence, 2006; Freitas & Levene, 2003; Wikipedia, 2009; Wood, Keen, Basu, & Robertshaw, 2003) The other strand of mobile learning research still focuses on devices, but explores the role of related technological aspects, including wireless networks, intelligent user interfaces and generally the advancements in the development of both hardware and software computer equipment which makes mobile learning possible (Boticki, Mornar, & Bozic, 2006; Holzinger, Kickmeier-Rust, & Albert, 2007; O'Malley & al., 2004; Wang, 2004). On the other hand, the *pedagogical strand* positions technological solutions coupled with the areas of learning and teaching they can best support (O'Malley & al., 2004). According to this strand, technology should be designed to support learning, rather than being appropriated to reach certain pedagogical goals. Hence, mobile devices are seen as mediating tools for activities supporting constructivist and situative approaches to learning.

Some researchers analyze the *mobility* of the learners as the primary characteristic of mobile learning (Kress & Pachler, 2007). Since learners learn on various locations, knowledge acquired at one location can be applied to others (Freitas & Levene, 2003; Sharples, 2000). Mobility of knowledge can be seen in terms of time scales as well. Previously acquired knowledge is supplemented with new ideas and strategies over time. For instance, Sharples and colleagues (2005) suggest that Some researchers suggest hat by placing the "mobility of learning as the object of analysis we may understand better how knowledge and skills can be transferred across contexts such as home and school, how learning can be managed across life transitions, and how new technologies can be designed to support a society in which people on the move increasingly try to cram learning into the interstices of daily life (p.2)".

The *Seamless Learning* project in Singapore presented in this paper examines synergistic effects of linking formal and informal learning environments in order to achieve the continuity of learning experiences across different learning scenarios. It examines both individual and social approaches to learning and tries to determine the role of one-to-one TEL (technology enhanced learning) in Primary (elementary) School children's learning experiences (Looi, et al., 2010)..

From pedagogical perspective, seamless learning examines an inevitable shift from teacher-centred to learner-centred learning environments and tackles the issues of traditional schooling practices suffering from the excessive amount of decontextualized information, indirect and abstract knowledge, and second hand experiences (Barab, 2002). Many of today's classroom learning still have a strong focus on individual cognition, pure mental activity without tool use and overly context-general learning (Brown, Collins, & Duguid, 1989). Through the notion of seamless learning, we aim to examine learning that takes place through the individual learning in private spaces, collaborative learning in public spaces, together with the cognitive artefacts created across time and physical or virtual spaces mediated by technology within a context. These artefacts facilitate knowledge construction and social discourse, and mediate interaction among a community of learners. To achieve so, we have employed distributed cognition as a theoretical lens and have integrated ethnographic approaches into our research design, especially in examining informal learning experiences (Hollan, Hutchins, & Kirsch, 2001; Looi, et al., 2010).

Our research is twofold: on the one hand, it examines formal learning environments and proactively tries to "mobilize the curriculum" or to achieve systematic changes in terms of how in-class learning can be implemented, sustained, and assessed through the use of mobile technologies. For this purpose, existing curricula have been "unpacked" to designing lesson plans that promote collaborative, inquiry-centred, and self-directed learning experiences (Looi, et al., 2009). Mobile devices and applications play an important role in this. For example, our participants, 39 primary school students, organize and externalize their knowledge with the help of GoKnow mobile learning suite (Figure 1), practice collaborative skills using the Seamless Mobile Forum (Figure 2), and other applications available on their HTC Windows Mobile 6.0 based smartphones.

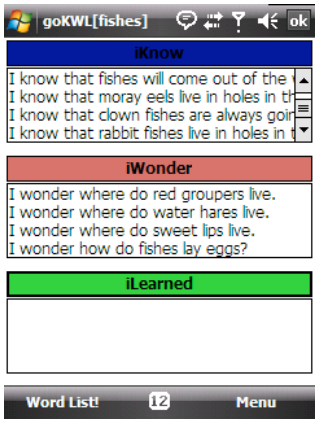

Figure 1. goKWL module of the GoKnow's MLE Mobile Learning Suite

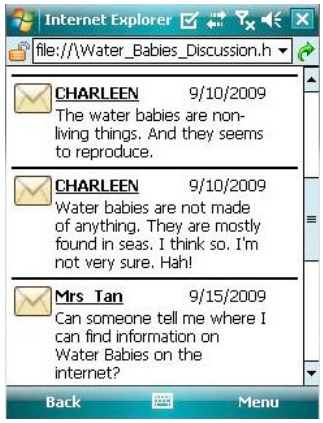

Figure 2. Seamless Mobile Forum Created Within the Seamless Learning Project

Capturing the Evidence of Seamless Learning on Mobile Devices

Choosing a Data Collection Approach

In addition to examining seamlessness within formal learning environments, our goal is to examine student-initiated learning that is impromptu and emergent (Sefton-Green, 2004). To achieve that, we have decided to employ a concurrent mixed method as a data collection and interpretation approach (Creswell, 2009). Quantitative data collection helps us in getting the idea of general trends while qualitative methods allow us to extract specifically significant patterns or cases for more in-depth analysis. Qualitative and quantitative data collection mechanisms are exercised concurrently, thus bringing us towards a clearer picture of informal learning spaces, together with the role of mobile devices in facilitating such learning experiences.

In our Seamless Learning project, qualitative data collection methods include sustained classroom observations, interviews with the students and their families, and observational studies (Sefton-Green, 2004). Sustained classroom observations enable us both to gain the holistic picture of the classroom atmosphere and to capture the emergent social processes. Interviews are done in participants' homes and include students and their family members primarily focusing on the informal learning experiences outside classrooms. Observational studies are used in designed spaces (currently in a science museum) to capture both video and sound clips of entire family visits to examine family interaction and discourse in a designed informal learning space.

Quantitative instruments utilized in the project include surveys, experiments and log files. Surveys primarily serve as a mechanism for longitudinal evaluation used to compare formal assessment results and students' attitudes towards the mobile device use at project milestones. Survey instruments therefore both guide us in our future research pursuits and provide us with a means of evaluating long-term effects of our inevitably interventionist approach. Experiments are used to test out novel tools, such as mobile computer supported fractions software, primarily in order to gather usability and learning experience feedback. Unobtrusive methods such as log files provide an authentic, time-efficient means of recording student learning behaviours and can capture a wide range of data that reflect student practices, activities, context, situations and events (Buckley, Gobert, & Horwitz, 2006; Cole, 1995).

Mixed Method Approach to Quiet Captures

One of the common methods of collecting data from mobile devices is through log files that support an objective data collection method of acquiring quantitative data on device usage. Due to the convergence trend (i.e., mobile and communication devices merging into a single device), mobile devices are becoming powerfully connected computers allowing the development of specialized applications to be installed and used on them. Log files are sometimes referred to as the quiet captures emphasizing the unobtrusiveness of the way they are embedded into user's experiences. They typically capture the data on applications used and the overall time spent.

In addition to their obviously limited coverage and purely quantitative orientation, current log file applications require researchers to periodically gather logs from participants' devices, thus to a certain level interfering their experiences. Furthermore, user generated artefacts are not tracked persistently across time (i.e. students delete self-created videos), and do not capture the context of student-device interaction during the identified patterns of usage. *Therefore we propose a mixed mode quiet capture approach with the following features: (a) the ability to capture both quantitative and qualitative data about device usage, (b) the ability to transfer and track user generated data and artefacts persistently (i.e., created movies, sound clips and pictures) to researchers in real-time 24/7 and (c) the ability to generate and render aggregated reports identifying usage patterns.*

Qualitative approaches to collecting device usage data consist of capturing device screenshots when some specific applications are used and/or when users start interacting with the device. Those screenshots are timely ordered and sent to the central repository through the 3G wireless mobile connection. Captured screens are then available to researchers in form of a web site and can be browsed and filtered according to the attached contextual information. Quantitative approaches to collecting data rely on the classical log file method of collecting the duration of application usage extended with a possibility of transferring content to the central repository in real-time.

Our subjects are equipped with mobile broadband plans with unlimited data transfer package. In this context, 3G connection serves as a means of providing affordable real-time 24/7 data transferring channels to central data repositories. This eliminates two drawbacks of the classical quiet captures approaches: (a) researchers do not have to manually gather the collected data from mobile devices in order to analyze it, and (b) data is available for the analysis whenever the need exists. Moreover, student generated artefacts are stored across time: pictures, files and videos are stored and become inerasable proof of user activities available for future analysis.

Researchers are provided with the web interface through which qualitative and quantitative data can be analyzed (Figure 3 on the next page). Quantitative data can be examined through the various reports while qualitative data is given to researchers for further detailed analysis. Both can serve as a connecting point not only in cross-modality verification of the results, but also in the interpretation of data acquired by employing various collection methods.

Quiet Capture Tool Architecture

The tool gathers various types of information, such as application usage, student generated artefacts and screenshots to transmit them to the server side web service over the 3G wireless network. The transferred data is kept persistently into the server-side database for later retrieval. The stored data is available to researchers in the forms of predesigned reports 24/7. Students can therefore be monitored real-time, and usage statistics are generated on demand (Figure 4.)

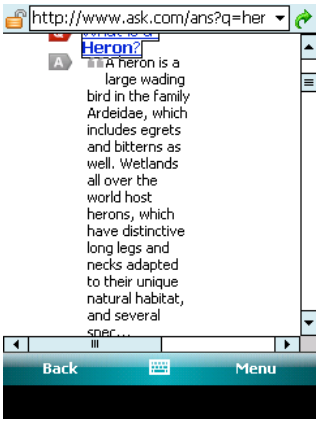

Figure 3. A (quiet) screen capture used to examine emergent inquiry based learning (a student searching for information on Heron birds)

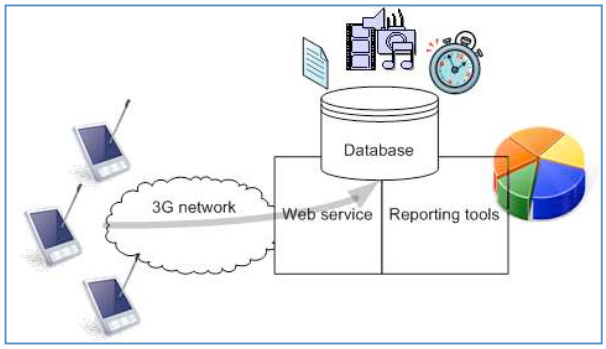

Figure 4. Quit capture tool system architecture

Needless to say, such a design requires mobile devices to be equipped with mobile broadband wireless Internet access plans with adequate bandwidth. In our project, students, in addition to the devices themselves, are given the 24/7 Internet access with unlimited data transfer plans. Instances of the quiet capture tool were installed onto the student devices, and they run as long as the devices are on. As soon as students decide to turn off the device, the tool's activity is suspended, thus saving resources such as battery life and Internet data connection. The client-side component of the quiet capture tool is composed of the following modules: Activity Detection Module, Artefact Gathering Module, Screen Capture Module and Data Transfer Module.

Reports on the Formal and Informal Device Use

The value of the described quiet capture approach lies in the analysis performed on the collected data generating aggregated reports about device use. At this point, we are able to share rough reports generated from the data of our 39 primary school students tracked both in and out school over one month. Although the amount of data is not significant to draw any final conclusions, we feel that the reports match and supplement the findings from other employed data collection instruments and surely inform us of behaviours exhibited by the students.

To depict the average time students spent on using the devices, we employ the functional framework in informal learning activities on mobile platforms (Clough, Jones, McAndrew, & Scanlon, 2007; Patten, Sánchez,

& Tangney, 2006). Activities are therefore classified into (a) Collaborative, Location-aware, (b) Data collection, (c) Microworld, (d) Administration, (e) Referential, (f) Appropriation and (g) Interactive (Figure 5).

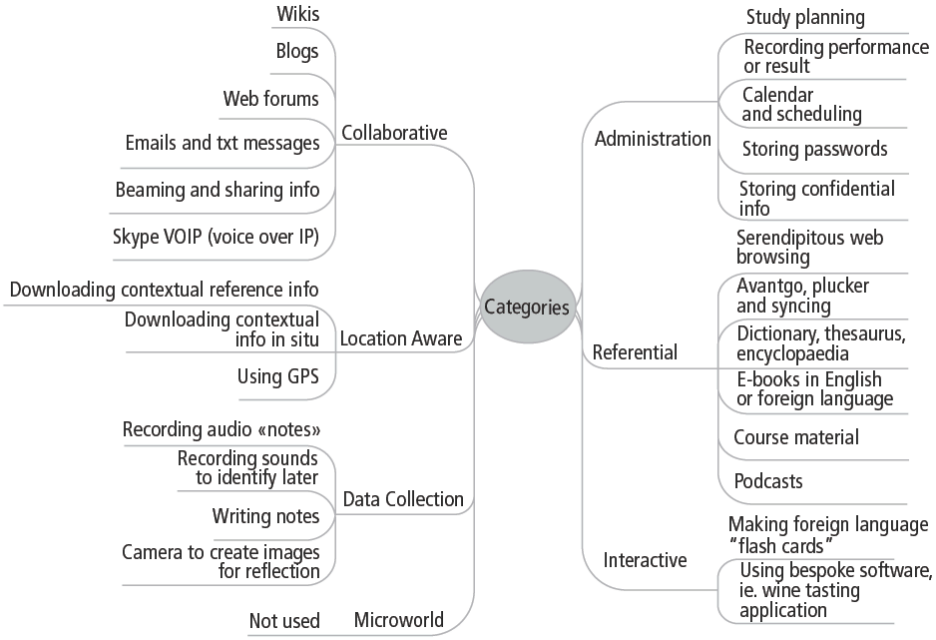

Figure 5. The map of the functional Framework in informal learning activities on mobile platforms (Clough, et al., 2007; Patten, et al., 2006)

Figure 6. shows that our students were mostly involved into the "Referential" activities (46% of the average time a student spent on purposely using the device) which include web browsing, checking dictionaries, accessing course materials, etc. In addition to that, students were often engaged into the Data Collection, Interactive Activities and Games. Since Patten et al's (2006) functional framework does not clearly state which category should mobile computer games assigned to, in our analysis we are considering them as a separate category (Figure 6).

To get a clearer picture on the data presented in the Figure 6, a more detailed report is made available to researchers (Table 1). In addition to the average time students spent on a specific activity type, the report shows minimum, maximum values and the standard derivation extracted from a month data of student activities. This report makes the differences in student interest more evident, particularly when some categories, such as games or interactive applications are concerned.

In order to gain an in-depth picture on the specific application use, researchers can drill-down the report and obtain specific application usage statistics (Figure 7). The figure shows 15 applications students on average spent the most time on (in minutes). The analysis reveals that Web browsing applications such as the Internet Explorer and Skyfire are the most utilized tools on students' devices, closely followed by the applications for watching videos such as YouTube, Player, and Streaming Media.

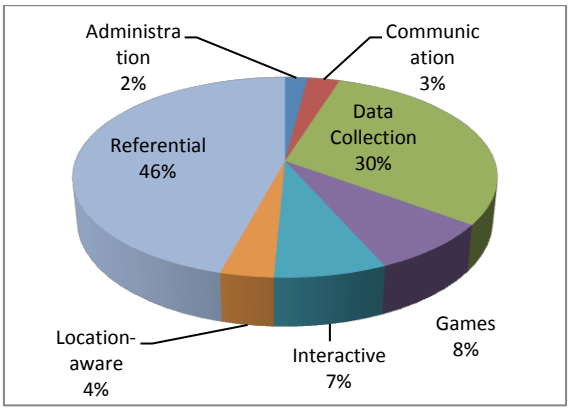

Figure 6. Distribution of student device use time according to the application types

Table 1. Monthly time (in minutes) students spent on an application type

Application type	*MIN*	*MAX*	*AVG*	*STDEV*
Administration	0.02	47.55	4.72	8.78
Communication	0.03	40.95	6.77	10.74
Data Collection	24.95	150.58	70.93	0.28
Games	0.12	169.13	19.43	3.55
Interactive	5.50	65.68	17.27	13.56
Location-aware	0.05	29.95	8.18	10.13
Referential	2.67	705.42	107.58	12.58

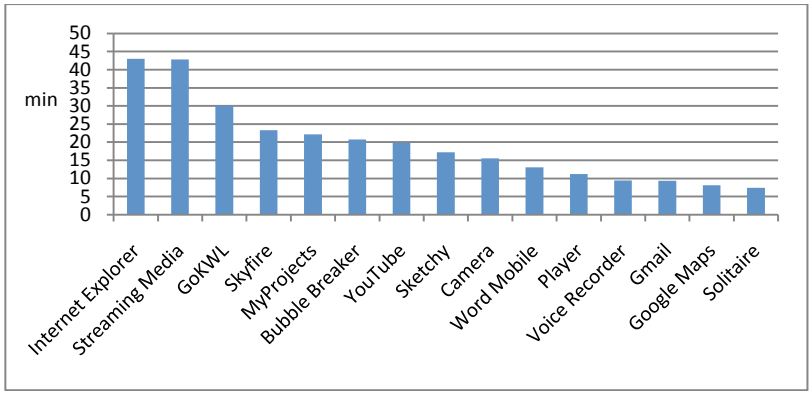

Figure 7. Average monthly time (in minutes) a student spent on using specific application (given only for the 15 top applications)

One of the main aims of our project is to examine the relationship of the formal and informal learning environments. In order to achieve so, we have analyzed specific application usage according to the time of the day: Table 2 has specific application names and times of the day as its two-dimensional base, while the third dimension contains average student monthly usage. The chart serves as a visual aid in determining the patches of significant user activities enabling researchers to drill down and identify specific sub-categories of interest.

Table 2. A table showing average monthly time (in seconds) a student spent on a specific application according to the time of the day

Application name/Time of the day	0	1	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Skyfire				279	1635	1699	1557	33	184	328	359	307		1466	73	474	995	2	2766	728	391	15	
Streaming Media	321					301	383	564	565	346	695	1019	345	774	898	557	634	349	374	414	1124	443	485
Internet Explorer	1924		510			352	141	568	328	650	548	367	301	294	373	373	221	350	235	123	358	198	1620
Youtube	281							442	5	1286	35	339	297	1378	984	674		436		5	2	116	688
Bubble Breaker						81		105	296	201	162	1936	261	205	507	660	934	693	147	238	212	45	
Sketchy								284	110	109	740		105	540	315	1265			2566	15		454	1
Google Maps	211							988		3	13			997		59		26		800	166	628	61
Camera							189	79	24	104	531	240	144	15	217	727	362	18		146	4	2	
Voice Recorder								107	4	3	131	118	5				531	656	823		196	41	
Player								92		33	117	122	17	17	419	419	142	214	157	186	625		
Solitaire								19	14		78				471	1204	71	106				91	
Gmail						101		148	237	279	292	59	83	313	68	73	72		56	21	80	21	12
GoKWL (GoKnow)									5	699	1189					16							
MyProjects								124	105	599	576	197		51	26	86			14	38	15	59	
Word Mobile								34	22	35	667	267			94	6					79	89	
Grand Total (s)	2737	0	510	279	1635	2534	2270	3587	1899	4675	6133	4971	1558	6050	4445	6593	3962	2850	7138	2714	3252	2202	2867

Researchers might opt to examine a specific application for a more refined analysis. For example, the contour chart signals high overall usage of the Internet Explorer application throughout the entire day, especially being the extreme in the end of the day.

Conclusion and Future Plans

The paper presented one of the tools in the mixed mode approach for capturing mobile device use data from both formal and informal learning environments. We presented the quiet capture tool to gather application usage information, student-created artefacts and screenshots. Researchers can use the reports generated from the collected data to examine students' use of mobile devices across different location and time scales.

Preliminary findings presented in this paper show that students tend to spend a significant amount of time on using the device in their personal spaces. They mostly browse the Internet for information and videos, and create interactive digital artefacts. For some students, the informal use of mobile devices produces a shift in cognitive processing skills, while for the others the device has become a social mediating tool facilitating interaction with the classmates.

It should be noted that all data reported in this paper is collected with the participants' consensus for confidentiality and privacy issues. Researchers need to consider that such quiet capture tools may collect private data unwanted by the participants so that it is important to ensure user anonymity and ethical use of collected data.

Future research plans include working with researchers on developing new views on the collected data, developing triangulation methods for merging data gathered from other data collection methods and further expanding the amount of data to be collected. As an example, there are plans to introduce geo-tagging of all collected information in order to enable the creation of location-based reports. In addition to analysing informal learning experiences according to a new spatial dimension, we will employ data mining and aggregation techniques to determine in what extent our students use the devices in and out school, specifically focusing on several spatio-temporal categories: in-school, holiday, during weekends and during the week.

Although at this point we observe that students use mobile devices to learn beyond the walls of classroom and formal institutions, and the usage clearly impacts their formal learning experiences, we are still in the process of designing mechanisms to clearly prove so. We believe the Quiet Captures tool presented in this paper can be used to give us better understanding of the context in which the links emerge and vanish. We have only begun to understand the complex interplay of formal and informal learning spaces constantly having in mind that it is our job to nurture the link between formal and informal learning environments and to utilize this unique opportunity to promote holistic learning experiences.

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