

Application architecture to efficiently manage formal and informal m-learning. A case study to motivate computer engineering students

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Abstract

Recent research is focusing on methods that enable effective consumption of digital content. Students are continually exposed to streams of digital content. An information system for learning was designed. Such a tool intends to connect learning in formal channels with the ability to learn in informal channels. The proposed methodology built upon the application was tested through a quasi-experimental research, implementing and evaluating its influence on how engineering students learnt in an advanced engineering course where concepts are complex. The sample is of fifty-eight students enrolled in Computer Engineering at Universidad de Almería. Their knowledge was evaluated using a specifically designed exam. Results suggest that the effectiveness of the methodology used and the learning tool itself were both robust and fulfilled the hypothesis. The contrast tests Snedecor F for ANOVA two tail and two-sample T-student test suggested the effectiveness of the learning tool proposed.

Keywords: Mobile learning; conceptual map; informal learning; social networking; engineering learning tool.

Sistema para gestionar eficientemente el aprendizaje formal e informal en m-learning. Aplicación a estudios de ingeniería

Resumen

El consumo efectivo y eficiente de contenido digital es un tema de ardua investigación. Gran parte de la población está expuesta al streaming digital, especialmente los estudiantes. En este sentido se ha construido un sistema de información para conectar el aprendizaje formal e informal con alumnos de ingeniería. La metodología ha sido probada con investigación de corte quasi-experimental sobre una muestra de cincuenta estudiantes matriculados en cursos de ingeniería avanzada. Para evaluar su aprendizaje se diseñó una prueba especial. Los resultados obtenidos sugieren que la metodología es efectiva en relación al sistema implementado. Los test de contraste prueban la efectividad del sistema propuesto.

Palabras clave: m-learning, mapas conceptuales, aprendizaje informal, social networking, sistema de aprendizaje en ingeniería.

1. Introduction

Resources, spaces, timing and expressive ways of communicating have shifted somewhat vertiginously over the last decade and this fact has influenced the new rising profiles of university students. In the context of the era of mobile communications, they are active users with increasing self-learning capabilities, whether or not they are under the supervision of a faculty. The main professional cross-skill of any university degree, is the ability to digital technologies and to transform the knowledge (the ability to learn is considered as a generic skill at the University of

Almería) by gathering and considering all the perspectives together with those that build their own thinking [1]. At the same time, [2] state that current university students are prepared for the potential of digital technologies and especially mobile technologies in which the main type of learning is visual learning as it was referred to by Halsne 2002, cited in [3] or what [4] called the innate ability to learn by observing. In this sense, m-learning becomes an alternative way of encouraging visual learning and concurrently provides an open space for the critical analysis of knowledge and different points of view. At the same time, faculty members have found conceptual maps to be

key for creating a connection between visual learning, technological skills and critical thinking.

Although mobile technologies have an important presence in our students' day-to-day lives, m-learning is an unexplored field [1], and above all, the role of learning related to visual aspects and to the receipt-delivery of information within different contexts and situations [5]. There is no doubt that for current university students, the use of mobile technologies in their day-to-day lives has an important social value. This is why it is necessary to design different teaching resources based on m-learning that consider the strategy of instruction, design, accessibility and usability [6, 7] that take into account students and their way of interacting with them (mobile resources) in different spaces/locations and situations [8]. Although the cited characteristics are required and ideal, they are not enough because as declared in [5]: "Isolated use of mobile resources does not develop cognitive skills, only teacher's activities in the classroom, supervision, a correct schedule of activities that smoothly integrate supervised activities with m-learning resources, and the union of both formal and informal learning schemes is a path to achieve students outperformance and their achievement of high cognitive skills."

Concurrently, [9] state that several research studies show how students get organized (as a football team) in order to carry out working collaborative activities within virtual communities or social networks such as Facebook, Twitter, etc. So, if social networks are employed in a convenient way, faculties can enhance students' motivation and, therefore, improve their cultural perspective as a consequence [10-12]. Several authors indicate the appropriateness of the new communication channels to motivate learning [13-16]. This can be a good method to help the success of the student, given that failure, as pointed by authors in [17], is a reason why students abandon university.

This paper intends to follow this hypothesis by merging both approaches: formal networks where students are given supervised content and informal networks where the content is selected by themselves, this leads them to select the information sources and to create their own digital identity. Authors highlight that such a process of enhancement lies in how the management of knowledge and sharing of knowledge is accomplished, in how students deal with the loss of privileged positions related to direct influence on their peers by achieving global social consideration within their group or community (a student might find it useful to share that piece of knowledge that makes him/her unique, as the social recognition is a worthy income). In this sense, [18] and [19] state that the use of social networks as a Personal Learning Environment (PLE) improves collaborative and learning capabilities.

Note that under the worthy perspective of the distributed cognition theory, the environment and specifically PLEs are considered part of a cognitive processing system in a way that cognition is mediated and distributed by the agents (in this particular case, the students), by the artifacts (mobile devices and applications) and by the environment (students' formal network which is made up by their classmates and

teachers and other informal networks made up by social networks). Therefore cognition is fully embedded and/or extended by themselves and by the resulting interaction between one another [20,21].

Furthermore, social networks can also be considered repositories of pills of learning (defined as pieces of reusable and interconnected content designed to cover a certain concept) and in this way, faculties can take advantage of this fact in order to fulfill a double target: making students realize their own digital identity and as a second target, let them build their own repository of learning pills, which, whether shared or not in informal networks, can be used as a merit when seeking a position or job interview [22]. These students' work contributes to focusing their attention on the main contents explained by the teacher [14].

The above creates a framework in which the research objectives developed in this paper are justified; objectives that can be, briefly, enumerated as designing and implementing a tool that the student can use when working autonomously and that allows the creation of a PLE based on the visual learning through the creation of conceptual maps; and on the other hand, being able to evaluate the tool's impact on learning when used in advanced engineering courses.

2. Materials and methods

2.1. Materials

The work presented is being carried out in a university classroom along with the Computing Architecture course, which is part of a university degree in Computer Engineering at Universidad de Almería. The tool developed is ready to be tested in the course under study (which is divided into two sections (a) smartphone application and (b) Web application to edit maps, connecting them, in a repository, with other conceptual maps) and an exam designed to measure the tool's impact on learning. This is a methodology already applied in other cases, as in the study of older people and the use of mobile devices [23].

2.1.1. Description of Mindmaps.

MindMaps is a tool with two clearly separated roles. The tool can be used for teaching as well as for learning. The application has two main components, which are well differentiated as depicted in Fig. 1. As the tool aims to create (and populate) a repository of pills for learning, a website application was developed to this end, for the creation and edition of conceptual maps which are later stored in (public or private) repositories. In this scenario, maps can be accessed from any computer that has a browser and a working Internet connection to download maps and navigate (edit / discover new connections and so on) through them. In order to exploit the pocket-size devices and to unlock learning at any location, an application has been created for Android devices, which is also able to access the repositories using them for downloading and navigating conceptual maps at any time. This application is designed to comfortably access light content so learning is favored.

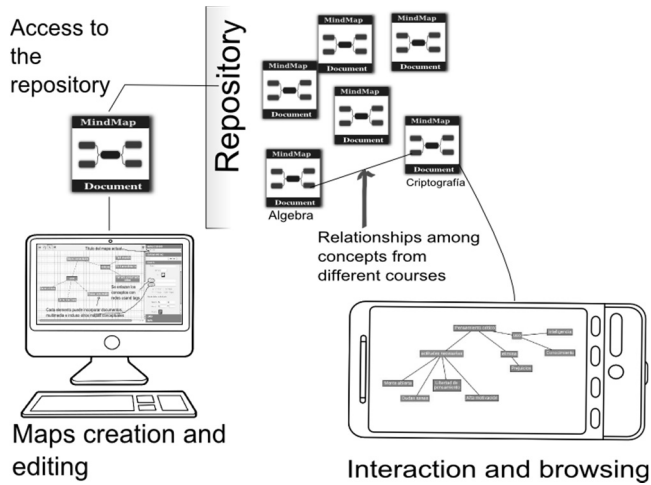


Figure 1. MindMaps: general overview
Source: own elaboration.

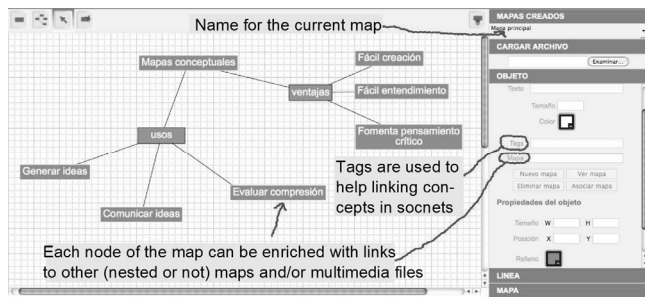


Figure 2. Web application to create and edit conceptual maps
Source: own elaboration.

The main function of the Web application is to allow faculties and students to visually create maps using different concepts related to the subject. In terms of maps creation, the application allows users to: a) connect to the repositories (private or general) in order to enrich already existing maps or to set up links between them, b) connect to existing maps within physical storage elements (computer hard disc, flash memories (usb), etc. or virtual ones (Dropbox, Box, etc.)), c) incorporate lightweight multimedia material (lightweight videos, voice memos, etc.), d) create hyperlinks to contents that are on social networks, e) publish the map in the repositories or linking to them on different social networks (providing an URL to retrieve them), f) export data to external storage elements, and g) send them to the faculty in order to be evaluated or to request for advice or guidance (Fig. 2).

Concerning the mobile application for Android devices (Fig. 3), it is able to access the repositories (either general or private) in order to download maps and to navigate them worldwide and at any time. Students and faculties are given the opportunity to review, modify, enrich, their course materials in a context where their location is not significative as long as they are provided with a smartphone or tablet. In this sense, the student can download conceptual maps by using his / her mobile technology and can also navigate through them in a way that each concept is addressed

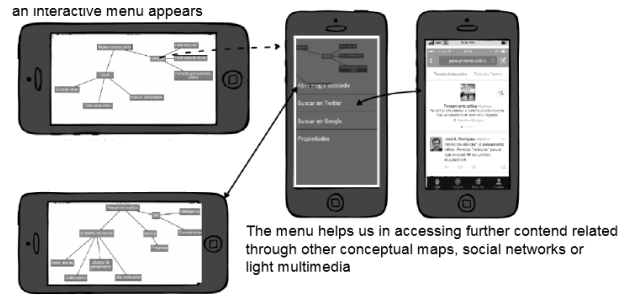
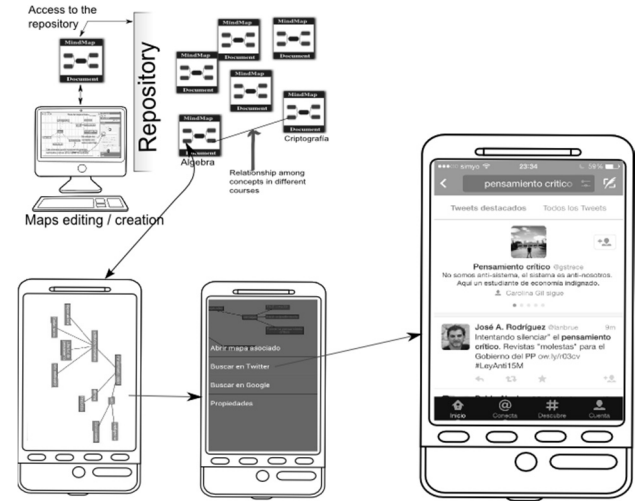


Figure 3. MindMaps, mobile application for Android devices.
Source: own elaboration.



Interaction and navigation in social networks
Figure 4. Distribution, interaction and navigation on social networks.
Source: own elaboration.

either in formal information networks such as the university Learning Management Servers (blackboard systems, moodle) or in informal information networks such as Twitter or Facebook. It is worth noting that the role adopted by the faculty varies depending on the sort of network used. While in formal networks the faculty is identified by the students as a source of content and is provided with a role of authority. In informal networks, the faculty is a member with a common role like the rest of the network's members (and it is even possible that the faculty is not present in a certain network), his role, therefore, is much closer to the rest of the members (students or people not enrolled on the course). In these informal networks, the authority and the importance of the content generated depends on the social value of the individual regardless of his/her role. Concerning the conceptual maps created by the Web application, they are interactive which means that when selecting a concept, a contextual menu is shown to the user and it allows further concept exploration through related conceptual maps, or by information related to social networks, multimedia elements, etc. (Fig. 3).

Finally, we can state that the tool as it is designed now is an educational tool (see Fig. 4), that allows the faculty member to mark a connection point between he/she and the students, as well as among the students themselves and

between them and informal networks of knowledge, in a visual environment that should be leveraged as the primary communicative modality for mobile interfaces [24].

2.1.2. Impact on learning: description of the test used.

To assess the degree of learning achievement, students have to fill in a questionnaire at the end of the learning period. This exam is the same for all the students, and it consist of eleven questions where ten questions are typical exercises that can include theoretical or practical aspects with an increasing level of complexity (question number one is the least complex and question number ten is the most complex). This test has an additional open question that is to be freely chosen and answered by the student (question number eleven is named Q11 in the statistical table shown in the Results section). This question weights the whole exam qualification as it multiplies the score of the ten questions with the interval [0.7, 1.3].

Throughout the course, both groups (control and experimental) have received the same training and shared lectures and the classroom. The methodological design follows a mixed model that combines master classes with activities based on collaborative learning. A conventional lecture was designed to take thirty-five minutes of pure master class where concepts were presented and developed by the faculty, the remaining twenty five minutes were devoted to collaborative activities such as discussions with the students, brainstorming about the concept or small groups that worked on tasks related to the concept. For example, let's think about a complex concept in engineering: the evaluation of a processor's workload then, each part of the mathematical expression will be analyzed and during the last twenty five minutes, the faculty would propose some changes to the expression depending on theoretical scenarios proposed either by the faculty or by the students. Finally, activities (such as exercises, readings, etc.) will be proposed in order to fix and/or to go into more in-depth detail about the recently studied concepts. The evaluation test was designed to evaluate the knowledge of the students and their abilities to interrelate it (which is the main concern). As mentioned above, each question has a different and increasing level of complexity. Questions with a basic level are designed to evaluate the degree of understanding of core concepts shown by students within different scenarios treated during the lectures. These questions are related to different situations studied in the last twenty-five minutes of each session. Finally, more complex questions are designed to evaluate students' ability to deal with situations and scenarios that are not prepared during the lectures and that interconnect concepts with knowledge that students must have previously. These questions are related to activities that fix concepts, that go into detail about the subject and that are proposed at the end of each session.

Concerning the number and distribution of the questions in the evaluation test, these have to be agreed upon by faculty members and students at the beginning of the course. Also, when the course ends, a final session is devoted to study the key concepts that will be eligible as

questions, so students do not leave anything out. Following, a couple of questions, one of each type, are presented. The former is an example of a question ranked as 'basic level'. In it, the concept of **efficiency** (which is key for the course) is presented, it also includes the context (scenario) where students must deal with the concept (Gustafson's Law). The latter, is an example of a complex question, which expects students to use critical thinking and apply what they are supposed to know to a concrete field or problem. So this question shows one new mathematical expression which has not been explained before and which is based on a complex scenario. In this case, it is a problem based on the average harmonic throughput in which students must apply their knowledge about the performance concept studied in the classroom:

Basic level questions:

Explain how to calculate the increase of throughput (S_n) supposing that the enhanced system needs the same time but it does much more work than the initial system, which was not improved (Gustafson's Law). The result must be applied to the case, which has a sequential part α . When is it (cite the cases) interesting to apply this law? Please explain your answers.

Advanced level questions:

Consider the use of a shared memory computer, which has 4 processors for the execution of a mixed program. The multiprocessor can be used in 4 different execution modes, which correspond to the active use of one, two, three and four processors, respectively. It assumes that each processor has an execution peak rate of 5 MIPS.

f_i being the percentage of time that the computer will be using i processors on the previous program and $f_1+f_2+f_3+f_4=1$. We can assume the following execution speeds R_1, R_2, R_3 and R_4 , which correspond to the distribution (f_1, f_2, f_3, f_4) respectively.

(a) Obtain one expression to show the average harmonic throughput R of the multiprocessor in terms of f_i and R_i for $i=1,2,3,4$. Write an expression that depicts the average harmonic throughput of T in function of R .

(b) Which is it the average harmonic throughput T for the previous program given $f_1=0,1, f_2=0,2, f_3=0,3, f_4=0,4$ and $R_1=4MIPS, R_2=8MIPS, R_3=11MIPS$ and $R_4=15MIPS$?

2.2. Method

Although the method has been presented in two well-differentiated sections, in order to facilitate the reading, they should not be conceived as separated elements. We described the tool (how it is made) and how we used it. However, the tool had to be built in conjunction with didactical and educational assessment as it is a tool for teaching (so faculty members should be involved) and for students (so they must evaluate its usage). Results obtained can only be correctly interpreted (and understood) if both, faculty members and students review them. All such reviews were incorporated into the building of the tool, implying many changes to the original concept, which did not really fully-observe the roles of faculty members and students correctly. Thus, two phases were required: (1) the design and implementation of the tool and its evolution to

fit the roles, and (2) the use of the tool in class and during study sessions, where results can now be interpreted.

Concerning our first objective, i.e., the design and development of the educational tool MindMaps (Web application and mobile application), the tool has been developed by computing experts, a specialist in didactical issues and an expert in applied economy who acted as external evaluator. Due to his experience as a faculty member and his non technical profile, his reviews of the tool were truly useful. The process followed to create this tool was based on a collaborative work methodology using loops, where each loop consisted in: (1) Computing specialists dealing with programming aspects and with developing the applications, (2) educational expert studying the aspects related to didactical issues, (3) meetings held in order to tune prototypes that (4) were tested under external experimentation taking into account his observations and proposals on how to improve the methodology. Finally, after several cycles, and before starting the experimentation with students, a consensus was reached.

Throughout the development of the application, the established and required rules related to the users' experience (UX) were observed in-depth and considered. The Web application was developed according to the suggestions cited in [6]. On the other hand, the mobile application was implemented with all the UX/UI (User Experience and User Interface) patterns stated in Mendoza's manual [25], given that it proposes several design patterns which mean that the application can be used transparently when compared to the daily use that students experience with their devices. A design requisite was that the students should not have to exert extra effort in using the application, but that it should build on their skills in terms of using mobile devices [26]. Some of the patterns introduced were: the advanced rotate (to spin the maps around easily) or log-in pattern (log-in screens intuitive with easy navigation).

In a previous phase, the prototype of the application was created by using the tool for fast prototyping called Balsamiq [27]. This allowed the evaluation of the theoretical model, which, once approved started the implementation process. Before the implementation phase and following current trends [28], JustInMind Prototyper was used to evaluate the model of interaction. Once the first version of the application was completed, it was distributed to the students so we could get useful feedback, and also so that they could evaluate being part of the experimental group that would use the application as a tool for autonomous work. Those who wanted to be part of this group, also participated in the feedback process of the definitive design of the application. As a result of this evaluation, a need was clearly identified: light content (especially designed for mobile devices) was appreciated and necessary. Being able to quickly download and consume content is a must if we aspire to use the Internet as a source. Even though a high percentage of the students are connected to the Internet at home using high speed links, light content was widely demanded as the real scenario where students wanted to extend their learning included; i.e. outdoors where Internet connection is restrictive. It is a must for the content to be light (all documents must be optimized before being integrated into the platform). The students revealed that the

tool was perfect for their commutes where they use cellular connection. This change was implemented through the 'maps and location pattern' [25].

The second aim of this paper was treated from a quasi-experimental research point of view, and it consisted in the evaluation of the impact on learning of MindMaps as a complementary tool for autonomous work, by means of a specially designed examination that took place at the end of the term. The sample that was part of the research consisted in fifty-eight students of the computer engineering track, enrolled in the Computing Architecture course that takes place during their fourth year at University of Almeria. The experimental group was made up by volunteers, with a result of 22 students interested. The remaining students were part of the control group. All of them dealt with the same activities and the faculty used the same methodology during the master classes, except that the experimental group worked in the creation and discussion of conceptual maps through MindMaps.

As both groups were not created randomly, the initial equivalence between groups is not assured, so the quasi-experimental design seems appropriate to our purposes [29]. To proceed, a descriptive statistical analysis of the grades for the final exam was carried out together with the following hypothesis tests: Snedecor F used for the ANOVA of two samples and the T-Student for averages considering different variances. One where key question No. 11 is considered and the other where it is excluded.

3. Results

Concerning the application's usability, the suggestions of [30] which are available online at url: <http://www.measuringux.com/> were followed. From a real usage scenario of MindMaps, firstly, it is the faculty that creates an initial conceptual map that is later linked to other maps on the general repository. Once the seed map is created by the faculty members, students can proceed and make it grow by incorporating their personal repositories, and creating a separate instance that they now own. The cited enrichment of the map usually involved the inclusion of short videos, images, links to pdf archives, etc. (incorporation of contents) and links to social networks such as Twitter and so on (contents enrichment). Being able to link concepts with social networks provided an interesting tool to evolve contents by their own original conception (as conceived by the student, let's ignore the correction of the conception) to a more adequate content, by means of 1) how the concept was initially designed and evolved during the lectures, i.e., how the faculty related the concept with other concepts that will be learnt later or that have already been learnt; 2) how this concept is used in real world scenarios by the selected people to follow in social networks; 3) how the attached media (light content) associated to each concept varies and how this media finally conforms very selected and filtered working documents; and 4) maps can be sent to the faculty members for evaluation but focusing the discussion not on explaining the concept, but on improving the exploration of the concept and student's conception.

Table 1. Descriptive statistics. Q11 is the control question.

	Without Q11		With Q11	
	Control	Experimental	Control	Experimental
N	36	22	36	22
Average	5,82	7,33	5,95	8,55
Standard error	0,27	0,25	0,38	0,48
Median	6,01	7,58	5,87	8,48
Standard deviation	1,63	1,18	2,29	2,23
Sample's Variance	2,67	1,40	5,25	4,98
Kurtosis	-0,06	-0,56	-0,20	-0,58
Skewness	-0,46	-0,50	0,07	-0,29
Rank	6,88	4,2	9,281	7,68
Minimum	2,07	5,1	1,554	4,56
Maximum	8,95	9,3	10,835	12,24

Source: own elaboration.

Table 2. Snedecor F proof variances comparison between control and experimental groups

	d.f.	F
Without Q11	35	1,9*
With Q11	21	1,05*

* $<.05 F_{\alpha}=1,98$

Source: own elaboration.

Table 3. Proof t for two samples supposing different variances

	Without Q11					With Q11				
	N	Avg	sd	df	t	N	Avg	sd	df	t
Experimental	22	5,82	1,18	54	4,07*	22	5,95	2,23	45	4,25*
Control	36	2,67	1,63			36	8,54	2,29		

* $<.01$

Source: own elaboration.

Focusing on our second objective, impact on learning, the results show that the control group (n=36, average=5.82, standard deviation=1.63) obtains on average, less score than the experimental group (n=22, average=7.33, standard deviation=1.18), question number eleven (Q11 in results tables) not being so relevant for the control group and very relevant for the experimental group. The rank and variability of maximum and minimum scores show that the experimental group is more homogeneous in terms of the obtained score in the exam, than the control group (Table 1).

On the other hand, as results show, the samples are not homogeneous regarding variances equality (Table 1) and that the scores T-Student (Table 2) for the two groups are significantly different in level $\alpha<.05$, in both cases, (see Table 3) both considering question number eleven (t(54)=4.07, $p<.001$) or not (T(45)=4.25, $p<.001$). Results suggest that those who used the tool showed a better academic performance than those who didn't.

4. Discussions and conclusions

It is common that during the early courses in engineering degrees, students have to deal with complex foundational concepts that help them assimilate more complex concepts upcoming in advanced courses. Frequently these concepts are hard to define, design and interconnect. However, the early courses provide students with a means to do this, allowing them to build much more solid links that ease the task when dealing with more

advanced concepts during later courses. It is, therefore, disappointing to see that key concepts are often incorrectly assimilated and that sometimes such concepts are simply memorized resulting in an insufficient learning process which may hinder the understanding of conceptual relations with other courses and interfere with students' future professional careers. Adapting to the target population is key when trying to create educational tools that may enhance the comprehension of concepts. In particular, we are referring to a technology-centered, very dynamic and deeply interconnected part of the population, the university/college students. People belonging to such groups are able to query a myriad of information sources, and are capable to deal with them by means of digital tools.

Nowadays, virtual systems to promote unlimited resources for education are already installed at educational centers (especially at Universities), which means that the student can access information, peers, and faculty members asynchronously without time restrictions. This positively favors education. Although these virtual education mechanisms have promoted new paradigms for teaching/learning, it is already integrated into formal education methods and, therefore, does not usually allow students to get connected dynamically with informal learning scenarios such as Facebook or Twitter. In this paper, we have tried to create a link between both learning scenarios through the educational tool MindMaps based on visual learning [2], increasing the educational effectiveness of student learning [32]. Now, students can seek out valued professionals who give their own view of the concepts which are being studied at each moment, therefore, allowing students to create and share their, what some authors refer to as, Personal Learning Environment (PLE). MindMaps helps the student to go further and to use the information to construct and improve her or his own digital identity.

MindMaps allows faculties to elaborate a way to navigate through their course contents, creating a logical and reasonable path concerning key concepts for the course by using conceptual maps which can be interconnected with other courses, all this within the formal network / scenario of the university. At the same time, MindMaps allows students to feel as if the maps and logical paths through contents are their own and lets them enrich the maps by integrating knowledge extracted from social networks allowing them to create contacts (followers) with important and valued professionals. Thus, the student benefits by enriching and enhancing the perspective (on a certain concept) provided by the faculty, and to accommodate such a perspective to his particular interests so the learning is directly put into value, transforming knowledge, as mentioned by [1]. MindMaps enforces students' self-learning during autonomous work sessions (non educational period) and throughout their lives after graduating, efficiently developing the generic competence of learning skills.

The research conducted has highlighted that students who decided to participate in the experimental group, had to undertake a greater quantity of work, which was also more complex. Consequently, they obtained greater reflection and

meta-search skills by creating cognitive structures for establishing their knowledge about key concepts. We found proof of this assertion in question number eleven, where these students outperformed their peers in the control group, as they created questions (and answers) that were much more advanced and applied than those based on concepts studied during the course. They were able to drift from classic scenarios, shifting to other scenarios where they could apply more particularized and advanced topics.

To that end, the mobile application should be designed in a way that will not break with their digital habits. In this sense, UX (user experience) methodology was applied and tuned considering all the interesting feedback that came from experts and students that tested the application before it was put into practice. The results allow the validation of the methodology used during the creation of MindMaps as well as the positive evaluation of the influence on the impact on learning.

Finally, although our results agree with those obtained by other authors such as [31], one limitation of our study is that samples are not homogeneous and although the design of the research conducted is appropriate, we have not guaranteed the randomness. The main concern that may arise is the existence of some correlation or dependence of results on the students' characteristics of experimental group, i.e., students were volunteers and therefore somehow more concerned with improving their learning and results. It is our future goal, to carry out the same experience with random samples and increasing the statistical population observed by taking into account other degrees and courses.

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