Adaptable multivariable m-leaning framework

Andres Mrad

Estudios de Informtica, Multimedia y Telecomunicacin

Universitat Oberta de Catalunya

Master thesis

Master in Multimedia applications

2014 07

1. Reviewer: Enric Guaus Termens

2. Reviewer: David Garca Solrzano

Day of the defence: June, 29, 2014

Signature from head of PhD committee:

Abstract

Online education has played a crucial role in institutions and companies from around the word, this, due to it being a powerful tool for knowledge acquisition.(1) The aforementioned reason has lead to the development of tools, learning systems, and methodologies(1, 2, 3, 4, 5) to solve variables identified by different knowledge branches. such as allowing students and educators to perform properly(4, 6, 7, 8, 9), adaptability of the process to account for new and emerging devices that can enhance the learning process (10, 11, 12, 13, 14, 15, 16, 17, 18), while minimising the complexity added by the new paradigms,(11, 14, 19, 20), the individual needs of the users(21), which become imperative to the correct execution of the m-learning process.(1, 10, 11, 12, 13, 17, 18, 19, 22) , the mobile nature of m-learning and it's student oriented approach(11, 12, 13, 15, 17, 18, 21), the limited nature of some of the learning resources requeired for this process to be successful (14, 19, 23)(24, 25, 26)(24, 25, 26, 27, 28), the proper implementations of visual elements inside the learning process(9, 20, 29, 30, 31, 32, 33) and so on.

Taking into account all the aforementioned variables, the objective of this research is the design of an adaptable multivariable framework to be used in the creation of flexible m-learning management systems that give students and teachers, the abilities to manage and obtain information regarding their learning process and the associated variables in an efficient way, while allowing the system to be extended to account for changes on the variables, be it existing, or the identification of new ones.

Dedicated to all the people that have made it possible for me to get to this point of my life, may the faith they bestowed upon me be rewarded.

Acknowledgements

I would like to thanks my family and my friend, my girlfriend, and everyone who has made it possible for me to be here today.

Contents

List of Figures

List of Tables

Listings

LISTINGS

1

Introduction

Online education has played a crucial role in institutions and companies from around the word, this, due to it being a powerful tool for knowledge acquisition.(1) The aforementioned reason has lead to the development of tools, learning systems, and methodologies(1, 2, 3, 4, 5) to solve variables identified by different knowledge branches. Despite this, getting this systems to allowing students and educators to perform properly is still a work in progress with different approaches(4, 6, 7, 8, 9), specially if the growing number of technological tools and devices, such as smartphones and tablets are brought into the equation. Said devices can enhance the learning process (10, 11, 12, 13, 14, 15, 16, 17, 18), but do also add complexity by adding new paradigms such as usability, design and implementation(11, 14, 19, 20). Between the identified variable we have, first of all, the individual needs of the users(21), which become imperative to the correct execution of the m-learning process.(1, 10, 11, 12, 13, 17, 18, 19, 22) Secondly, the mobile nature of the education model requires that the users has ability to access whatever educational resource they need, when, and where they require it; that is to say, the educational paradigm now shift towards a student oriented one, where the student is not required to be at a specified place and time to study, which in turns means that the learning systems must adapt to the where, when, and how the users access the application (11, 12, 13, 15, 17, 18, 21); but what happens when the of the educational resource (laboratory, software, material) in question is of limited nature (14, 19, 23)?. In resent years, solutions such as virtual laboratories(24, 25, 26) have been created as a way to try and solve the limitations of this resources, but have end up coming short, as seamless implementation of this tools on learning systems have been problematic(24, 25, 26, 27, 28).

Finally, the growing number of visual elements inside the learning process, which have been implemented as a way to enhance said process, have in turn disrupt the process leading to undesired results(9, 20, 29, 30, 31, 32, 33).

Taking all this variables into account, Is it possible to design a multivariable, adaptable framework that allows institutions to create m-learning management systems that give students and teachers, the abilities to manage and obtain information regarding their learning process and the associated variables in an efficient way, while allowing the system to be extended to account for changes on the variables, be it existing, or the identification of new ones?.

2

State of the art

2.1 Educator's perspective

In the past, several learning management systems have been proposed as a tool that allows for educators to have an easier time assessing the learning process of their students and courses by means of visual representations which allows for an easier identification of obstacles or failures of the learning process while alleviating the mental burden of the task for educators.(4, 6, 7, 9) Such is the case of the proposed methodology by Garcia-Solrzano, D. Et. All.(4), they suggest the usage of "Faceted Browsing" and "Data Portraits" as a method for information visualisation of course and students status. Figure 2.1 shows and example of "Faceted Browsing", we can observe how the different course goal are represented by levels which the educator can move around to segment the data and obtain insight on the course status, as for individual levels, each student in the course is represented by it's photograph, and the information regarding each student process, is presented by a background that establishes the percent of completion of the proposed goals. Other means of tracking students progress are presented by "Data Portraits" as can be seen in figure 2.2, the figure shows how each student behaviour in the forum is color coded so that the "student profile" can be visually inferred by the educator, the colours represent 5 different levels of participation measured by the system, and the combined results of the 5 colours is what allows the teacher to identify the student profile.

The proposed system is then capable of enhancing the educator's leaning management experience, but does not directly impact the student's learning experience, and

Figure 2.1: *"Faceted browsing" interface proposed by Garcia-Solrzano, D. Et. All(7)*

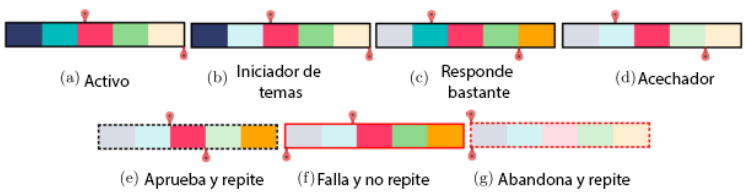

Figure 2.2: *Ejemplo de los diferentes "Data portraits" propuestos por Garcia-Solrzano, D. Et. All(7) junto con algunos "perfiles" que pueden ser identificados*

does nto acknowledge the special needs of each individual, which other researchers(7)(21) have pointed as an important factor for the learning process; we will delve into this topic on the following section.

2.2 Student preferences

As suggested by Garcia-Solrzano, D. Et. All.(7) and Graf, S. Et. All(21), students have the need to be educated in a way that corresponds to their learning style as a drive to achieve better results from the student's learning process, from here, each researcher proposes different adaptable learning systems as an integral solution to the problem by means of implementing learning styles(21) than can be used as the core factor to drive the adaptable competes of the system on the direction needed by each student. Educational literature on learning styles is vast, but researchers have proposed the Felder-Silverman model(7, 9, 21), as the that best express and reflects the student needs.

2.2.1 Felder-Silverman Learning Style Model

As mentioned before, there is a vast quantity of learning style models in existence, but the "Felder-Silverman Learning Style Model (FSLSM)" is regarded as the one that best suits to the student's needs and drives.(21) The model classifies the learning styles of the students in 4 tuples, each tuple is defined as follows :

- Active/Reflective dimension: Learning process of students on the 'Active" end of the spectre are characterised by having a tendency to be communicative and preferring to work in group, they are also characterised by having the ability to learn better when they are actively involved with the learning material, in other words, when they get to apply said knowledge. On the other hand, students on the"Reflective" end of the spectre are characterised by their desire to reflect on the learning materials to draw their on conclusions, they also have a tendency to prefer to work alone or in small groups.

- Sensing/Intuitive dimension: The "Sensing" dimension refers to students who prefer to learn form concrete facts using their sensorial experiences from particular instances as a primary source for learning; they prefer to solve problems using standards. By contrast, students who belong to the “Intuitive” dimension, prefer learning objects with abstracts contents such as theories, general principles and so on. “Intuitive” students enjoy discovering new possibilities and relations, and have a tendency to be more creative and innovative than their fellows on the other en of the spectre.

- Visual/Verbal dimension: This dimension measures how the students prefers to receive information. Students who prefer information in the form of flow diagrams or other visual representations are classified in the “Visual” end of the tuple. Students who prefer textual or verbal information are classified as “Verbal”.

- Sequential/Global dimension: Students classified as “Sequential” learn by means of sequential increments, in other words, steps to be followed from point A to point B to achieve a certain goal. “Global” students on the other hands, prefer to tackle the “whole” of the contents and move around the contents of this “whole” in an almost random pattern, once they have finished studying the contents, they will proceed to create relationships between them.

2.3 M-learning

As exposed by Lam, P. Et All(13) there is currently a huge interest in the effects of mobile technology in education; that is why there have been numerous research to shed light on the effects this technologies may have in the students. This studies have concluded that the effects are not disruptive(10), on the contray, they can bring lots of benefits to the users(10)(13), said effects are described bellow:

1. Students are able to actively participate on their learning process(13, 18), allowing them to experience abstract concepts by means of a direct approach.

2. La posibilidad de los estudiantes de participar activamente en su proceso de aprendizaje(13)(18), permitindoles experimentar conceptos abstractos de manera directa.

3. For the most part, the learning process is self-regulated(7), which in turn means that students can go at their own peace when tackling different activities.

4. Students are not restricted to a physical space(7)(17)(14)(13), this allows for the student to have the freedom to control where and how he access the learning objects.

The aforementioned effects are, in other words, evidence of the adaptive nature of m-learning, where the learning process is the one that must adapt to the each student's specific needs, that, in turn, is why there are so many m-learning models in existence each with it's own view on how to be adaptable.(17)(7)(18)(16)(12)(14)(11)

Shih, J. Et All.(18) suggest an approach to m-leaning using every day activities combined with "pervasive games", this is achieved through a clue hunting like game, where each player is tasked with finding the answers to some questions using their cellphones or finding QR codes to solve the mystery; This ensures that the students get to learn about their surroundings while competing for a high score. Results from this research highlight how face to face interaction and having an active role on the process, helps generate an ideal environment that complements e-learning spaces.
Razek, M. Et All.(16) propose an adaptable m-learning system, this system suggest different learning objects depending on the student's profile. To achieve this, a multi-agent system is proposed, each agent is tasked with controlling an specific part of the process, as expressed on table 2.2. The system allows for the deffiniton of user learning style, categorisation of learning objects, and filtering of the learning objects to accommodate for each of the learning styles.
Yau, J. Et All.(17) suggest that the environment that surrounds the student does also play a fundamental role in it's learning process and implements this idea into their system taking advantage of functionalities already embedded in mobile devices such as positioning services to determine the current position of the student and suggest activities that can be completed in the current location. A more concrete example of the works of this systems goes as follows; a students travels by means of public transportation, the system can identify the current location of the user and suggest byte size lecture form him to complete during his travel, on the contrary, a student that is at home would be presented with a movie as its learning material. Table 2.1 presents the locations that have been confirmed by students as the places where they prefer to study. Following are the main characteristics of this system :

- Student profile: Allows for the system to keep track of the student learning preferences, this can be done thanks to a survey thats presented to the user when he first uses the system, the survey inquires the student about the place where they prefer to study, distraction and noise levels presented on the environment, and how important this factor are for him.

- Personalisation mechanism: This mechanism allows the user to choose between the suggested material or all the available materials at their own will. When suggested materials is chosen, the system gather data from the environment via GPS, microphones and any other data collecting capability present on the mobile device, to determine the location, and noise distraction levels and suggest material accordingly.

- Learning objects repository: This are the learning object that will be presented to the user, they can be external or internal. In the research presented by Yau, J. Et All.(17), the suggested repository is a external one (www.codewitz.org)

While this system does take into account the student's needs and the environment as key elements of the learning process, it does not, however, distinguish between materials types and students profiles. Martin, S. El All.(15) propose, in essence, a similar solution but from a different perspective, that is to say, they propose a model for creating systems such as the one described by Yau, J. Et All.(17).
Other researchers such as Gil, D. Et All.(11) propose a decentralised architecture as the core for a m-learning system, this means that, while other proposals(12)(19)(15)(17)(22) require that the student connect to a university server where all the information is stored, this system divides the task in nodes, each node is then grouped in layers depending on the function they serve, each node, can also communicate with other nodes, be it form it's own layer, or some other layer, depending on user requirements. Table 2.2 resumes the functionality of each agent.

2.4 Time limited resource management

Even tho the learning management system exposed so far provide tools to aid the learning process of the student, they have not propose mechanism to deal with resources of limited nature. Social behaviour theories such as the one proposed by Ostrom,

Study locations included home and library
Study locations included home and office.
Study location included home
Study locations included home and computer laboratory.
Office
Home, library, learning grid, caf
Learning grid and computer laboratory
Home and quiet rooms on campus
Only communal spaces of home and computer laboratory
Library, computer laboratory and train
Home, computer laboratory and learning grid
Home, library and learning grid
Home, library and corridors between lectures
Student lounge
Home, library, computer laboratory, learning grid, student lounge
Home, biology laboratory and office Insights

Table 2.1: Preferred study location of students as classified by Yau, J. Et All.(17)

Filtering Agent	This agent is in charge of obtaining the student's profile using a survey which helps determine the user learning preferences.
Information Agent	This agent is tasked with presenting the student the learning objects that best suit their profile.
Pedagogical Agent	This agent is in charge of organising the course structure and the learning resources in such way that other agents are capable of presenting the user with the required information for each step of the course.

Table 2.2: Agents that compose the system proposed by Razek, M. Et All.(16)

E.(35) suggest that common goods, specially those whose nature is limited, should be managed and regulated by the community that needs them; unfortunately, this can be a problematic solution to be implemented in on-line systems, this, due to an increase in antisocial behaviour, product of on-line anonymity.(36) That is why this research will look into other disciplines to implement solutions given to this problem form other branches of knowledge,

2.4.1 Resource management in project management

Project management refers to organisation, planning, evaluation and execution of a group of task tho achieve an objective, be it the construction of a building, or the development of a new software. One of the phases of the project management process is called "planning phase", the main objective of this phase is to coordinate the efforts of the different parties, and organise tasks so that the delivery times and the dependent activities can develop without delays. Onces this guidelines are defined the project transition into the "project time management phase", in this phase, each task defined in the resource plan are transformed. it's also in this phase where estimations on the resources required by each activity are created. Afterwards, figures such as Gantt diagrams are created to shed some light onto the amount of resources required.(37) Following is a resume of the project management phases that are are related to resource management task.

- Define activities: Activities definition is the process in which required actions to generate the project deliverables are identified. To achieve this, deliverables are used to identify "work package", this packages are later decomposed onto the several activities that the project must follow to achieve consider a package completed, this activities are used to do time estimates, generate the schedule and work analytics.

- Activity sequence: In this step, relationships between each activity are identified and documented, this helps identify antecesor and predecessors of each activities and dependency between them; afterwards, an evaluation is followed to determine if lags and head starts are needed to realistically represent the project's activities relationships.

- Resource estimation per activity: In this step, resources necessary to for each activity to be achieved are defined. The required resources can range from, equipment, materials, personnel, are any other goods deemed necessary.

- Activities estimation: This segment deals with predicting the number of working periods required to complete the tasks with the estimated resources. To achieve this, information available at the time is used, such as work scope, type of resources required, resources estimated quantities and the resource calendar. The predictions are made in an iterative was, as more information is being known during the execution of the process.

- Schedule development: Deals with the analysis of the activities sequences, durations, resources, requirements, and schedule restrictions to create the project schedule. This process is usually an iterative one, meaning, an initial schedule is created, with a start and end date, and then tweaks are made to the schedule as information and the current situation of the project demands it.

- Schedule control: This process consist of the project status tracking, to update and manage changes to the project schedule as new information is made available.

2.4.2 Time management in web services

Time management is crucial in the realm of web services, but, as exposed by Fan. Et All(34), tools or documentation that allows for time management of web services is scarce, that is why they propose a model to solve that problem. The proposed model suggest that each web service provides a method to expose it's execution time, this would reduce the complexity of the composition time, while allowing them to be autonomous. The elements of this model are explained below:

- Activity: A activity possess process identification elements (id), and a real integer number that represents the time required for it's execution (r).
- Dependency: This attribute represents a tuple of the form (id1,id2), where id1 and id2 are two activity identifiers. The tuple represents a dependency relationship, meaning that for activity "id2" to start, "id1" has to be completed beforehand.
- Shortest time restriction: This attribute is represented by five elements, (a1,t1,a2,t2,r), where,"a1" and "a2" represent activities, "t1" and "t2" represent the end time of their respective activities, and "r" a real positive number that limits the time units. this restriction requires for the start or end time of "a1" to be less than the start or end time of "a2".
- Longest time restriction: This attribute is represented by five elements, (a1,t1,a2,t2,r), where,"a1" and "a2" represent activities, "t1" and "t2" represent the end time of their respective activities, and "r" a real positive number that limits the time units. this restriction requires for the start or end time of "a2" to be less than the start or end time of "a1".

With the elements defined above a web service with a structure similar to that of the figure2.3 is defined, this structure is later use to create a web service decomposition. To achieved this, the process start by joining the different web services involved in the process, the resulting composition can be observed in the aforementioned figure, as we can observe, onces joined, each service depends on the ones before them, this makes it difficult to calculate the estimated time of execution of a web service that's part of this network. the proposed model allows to take a web service composition and reduce it to it's minimum expression thats equivalent to the original configuration.

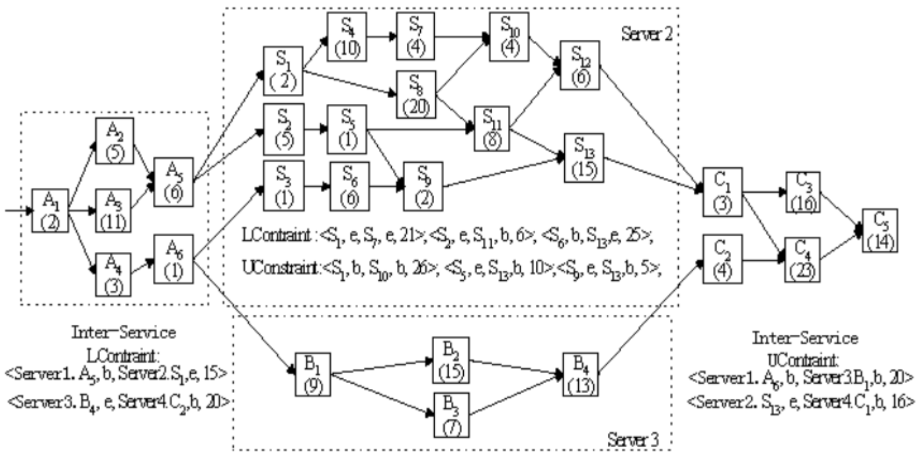

Figure 2.3: *Webservice composition example(34).*

Figure 2.4: *Decomposed web service composition(34).*

This decomposed web service composition allows for the calculation of the execution time as shown in figure2.4

2.4.3 Virtual Machines

Virtual machines are defined as a software abstractions that try to simulate the structure of a determined hardware architecture, this architecture can be physical or theoretical.(38) This programs have to deal with the increasing number of changes to the existing architectures, which evolve every single year to give support to the increasing need for multitasking, which means that this software must adapt to this changes.(39)

In some cases, as exposed by Wang, L. Et All(40), virtual machines and their inner workings are treated as "black boxes", monolithic entities tan can consume host resources however they see fit; that is why, their propose a middleware system that allows for communication between the layers that compose the virtual machine and their host, helping the overall resource distribution between the host and the layers of the virtual machine. This is achieved in the following fashion, the virtual machine sends a petition list of the form (r0, ... , rn), to be processed by the host, this allows the host to determine the work load, (W0, ... , Wn). The host can then organise the resources to be distributed among the tasks. The host, in this case, is an online cluster that learns and adapts to the given petitions.

Janik, A. Et All.(41) suggest that a middleware, and not the host, should be in charge of distributing the resources, allowing the host and virtual machine to work as usual without any modifications needed.

2.5 Information visualisation

As explained by Filho, M. Et All(12), when designing a user centred application such as a m-learning system, it must achieve the following :

- Visual attractive.
- User Friendliness.
- Must be stimulating.

It is also important to highlight how crucial the way in which information is presented to the student is, as it helps him to gain a better understanding of the information the teacher is trying to transmit(33), but this can only be happen if the visualisation is not distracting, and if it does something to reduce the complexity of the concept being transmitted(33)(42)(5)(2). Not only must the visualisation achieve the aforementioned, it also has to overcome the intrinsic problems associated with its nature, Chen, C.(20) expose ten of this problems, a resume of said problems can be found on table2.4. Garcia-Solrzano, D. Et All.(4, 6, 7, 9) suggest the use of visual metaphors to present the teachers the information they requiere so they can easily assess the current situation of the course, find problematic areas, and give solution to said problems, examples of this proposal can be found in figure2.12.2.
Naps, T. Et All(32) suggest that visualisation can also play an important role in the evaluation of knowledge, and that it is directly related to the "engagement" level of the student. From this levels they suggest some best practices when implementing visualisation in pedagogical environment, this "tips" are resumed below:

- Provide resources that help the student correctly interprete the graphical representation. Concrete representations can help the student understand complex algorithms, but some visualisations can be difficult to understand. To solve this problem, there are two options, the first one is to explain the relationships by embedding explanatory text or narration; the second one, is to reinforce the relationships by spending some time explaining them during the course.

- Visualisation must adapt to the knowledge levels of the student. Some inexperience students can be overwhelmed by overabundance of details or windows, they prefer to interact with a simple animation with predefined initial values. Advance students, on the other hand, could benefit from additional spaces to control the complexity, or being able to set their own initial parameters.

- Present multiple representations, in other words, and algorithm, for example, can displayed as a flow diagram showing how the code flows during execution or it can be displayed flags reflecting the status of the information structures. Presenting different representations helps the student with it's process of concept assimilation.

- Include performance information. this allows the student to understand better the inner working of the represented material.

- History records or logs can help student remember the results from previous executions and in turn help him understand the effects of changes done to the studied representation, which would allow him to form a global perspective about the current state of the case of study.

- Giving support to flexible execution control, allows the student to freely control the visualisation flow, allowing him to "play" the visualisation "clockwise", "counter clockwise", and so on, much like the the functionalities of a video player.

- Support student created visualisation, this will allows for the student to create their own artefacts, in turn, helping him gain more clarity, and responsibility, about his process and the knowledge he is acquiring.

- Allow the student to freely explore the visualisation, in other words, give them access to set their own initial values which will allow them to learn from direct experience.
- Provide dynamic "pop-up" quiz questions that helps the student reinforce the learned concepts.
- Provide support for dynamic feedback will allow the student to obtain information about the current state of it's learning process, or about how well they are understanding a concept.
- Visualisations should go hand on hand with an explanation about what the student is currently watching as a means to guide it's exploration process and enhance it's learning experience.

Naps, T. Et All(32), also suggest that visualisation can be used to evaluate the knowledge levels of an student about a given topic taking into account how well they have assimilated the concepts embedded in the visualisation, depending on this they are classified in six levels which are explained in table2.3

Level	**Description**
Level 1	The first level, also known as "recognition level", is characterised the students ability to remember some facts without this meaning an underlaying understanding of the associated concepts.
Level 2	Also known as "comprehension level", here, the student is able to understand the meaning behind the facts.
Level 3	The "application level", here the student El nivel de aplicacin indica que el estudiante puede aplicar los conceptos aprendidos durante sus estudios.
Level 4	The "analysis level", here the student can identify components present on visualisation presented to them and decompose them into smaller parts

Level 5	The "synthesis level", is obtained when the student can create it's own conclusion about what he has learned.
Level 6	The "evaluation level", is the level where the student is capable of comparing different ideas and methods, assign values or priorities to them, and take actions based on argumented reasoning.

Table 2.3: Levels of concept assimilation proposed by Naps, T. Et All.(32)

Problem	**Description**
Usability	The complex analytic process that takes place when the visualisation is generated leaves behind a gap that makes it difficult to the en users to understand how the raw information was "magically" transform into "colourful graphics".
Understanding of the precognition and perception tasks	This must be substantially updated in the field of information visualisation. It is of the outmost importance to collect empiric evidence of the new generations of information visualisation systems.
Previous knowledge	Visualisation is a vehicle to communicate abstract information, thats why the user is must have previous knowledge of the topic in order to understand it.
Education and entertainment	There is an urgent need for information visualisation field researchers to learn and share, about visual and semantic communication skills. This will allow users outside of the immediate visualisation scope to understand it's importance and possible ways to implement it on their field of action.
Quantifiable quality assurance	The is a huge lack of quantifiable way to measure the quality of visualisation, to date, this problem have been neglected in behalf of innovation and originality.

Scalability	High performance computing techniques, such as super computers, have not been used in this field with the same amount of frequency as other fields such as scientific visualisations.
Aesthetics	There are no holistic empiric studies about what makes the users think that a graphic is visually appealing. There needs to be more research about the relationship about graphic aesthetics and their ability to transmit the desired concept.
A change of paradigm, from structured to dynamic	There is a lack of visualisation systems that can detect patterns and tendencies from a dataset. An inter-discipliner study that joins artificial intelligence and artificial intelligence should be the way to go.
Casualty, visual references, and predictions	The creation of highly sensible and selective algorithms that can, reduce the noise and solve conflicts between evidences in the information, allowing the user to obtain clarity about what's a pattern and what's a causality.
Knowledge of the visualisation scope	Being able to tell what's information and what's knowledge, this problems, in essence, constitute a combination of all the aforementioned problems.

Table 2.4: Ten information visualisation problems expressed by Chen, C. Et All(20)

2.6 Virtual Laboratories

Virtual laboratories are workspaces where persons can experiments, obtain results, and analyse said results to obtain conclusions;(24, 25, 26) for this reason, they have been recognised as important variables to the educative environment.As such, they have been implemented inside learning environments as means to allow students to put into practice the acquires knowledge, in other words, be an active part of their learning process.(24, 25, 26, 27, 28) Auer, M. Et All(24) expose the main benefits and characteristics of virtual laboratories; we resume them as follows:

- Costly and complex tools can be used by different branches of an organisations or shared by different organisations.
- Complex experimental systems, can be monitored by tools or teams located in

specific places and controlled from the scientific office.

- Team members in different locations can cooperate effectively, and obtain the same results from experiment without them having to relocate.

- Long term experiments can be monitored from remote locations (for example, from home on weekends).

The aforementioned characteristics are the main drive to try and implement said tools into the learning environments, unfortunately, as explained by Abdellaoui, N. et All.(25), even tho virtual laboratories provide an excellent platform for m-learning students as they allow for remote access and practical work, on the flip side, this tools offer no integration with the existing m-leaning systems, which difficult crucial task such as tracking the student learning process progress, which hinders the teacher's abilities to, observe, guide, and help the student whenever he encounter a problem during his learning experience. Some partial solutions to this problems are known as "widget based laboratories", which does allows for some integration, but the gap is still to big for to be a seamless solution to the problem.(25, 28)

3

Research work

3.1 Framework definition

3.1.1 Introduction

To start defining our framework we must define the variables or characteristics that will serve as a core for our framework, this items are listed as follows:

1. The specific need of the students when tackling a m-leaning process.
2. Each student is a unique entity with it's own patterns, behaviours, needs, and learning styles.
3. The framework must offer a method to easily select learning objects.
4. An effective method to maana time limited learning resources.
5. Student's location and environment aware.
6. Visual representations used must match factors such as environment, location, and learning style.

From this core, we can then define some extra features that our framework should take into account, for this components, we will tour ro what's proposed by Garcia-Solorzano, D. Et. All(7), they suggest that the ideal start point of a student centred application should be a tailored system with an underlaying pedagogy that best suit a student centred approach, for this reason, the selected pedagogy is the one known as "constructivism"(7), this pedagogy will dictate the additional principles that our framework will follow, said principles are resumed below:

- Learner centred: The students take control of their learning process, acting as autonomous individuals, planning and executing learning activities. In other words, students self-regulate their process, and teachers take a step back becoming guides or facilitator of the learning process.
- Reflection: Students must reflect on their process to gain insights and enhance their learning experience; aids and tools that can improve this reflection process must be provided.
- Feedback: Personalised information, and constant guidance must be provided to the student during it's learning process. Tools such as evaluations should be use as means to promote auto-analysis.
- Multiple perspective: The use of multiple representations to explain concepts is an important tool that allows students to have an holistic vision about a concept.

Other key features that the framework should take into account is how the course information is going to be structured(7), taking into account the student centred nature of the framework, and, as suggested by Garca-Solorzano, D. Et. All(7), since activities are the closest element to the student, the information should revolt around this element, as can be seen in figure3.1. Following is a resume of this structure:

- Objective and competences: This space establishes the relationships between competences, course objectives, and activities. Competences are defined as the skills a students is expected to develop through the course, objectives, are small goals to be achieved during the execution of the activities.(7, 13, 21)
- Schedule: As explained before, the learning process is self regulated, but there must be some guidance to this process, and thats what schedule is all about, in this space, "sessions" are proposed to the student as "packages" of activities , with tentative start and end dates, and is up to the student to regulate his learning as how he sees fit during this session.(7, 16, 18)

- Content table: This deals with the specific structure of the individual course and how they relate to the activities, for example, some course have a guide book, this space would define the relationships between each chapter of the book and class elements associated with it, such as activities or sessions.(7, 12, 18)

- Evaluation: As mentioned earlier, evaluation is a tool that must allow the students to self-analyse their learning process, this means that the student's learning process, which is a gradual process, must be evaluated in the same fashion, in other words, with each set of objectives that the student achieves there must be an evaluation that allows him to confidently state the status of his learning process and the abilities he acquired.(7, 12, 22)

With the structure of the information and course out of the way its time to delve into definitions about how the suers is going to interact with the information presented framework, and how that information is going to be presented, in other words, the usability. As some researchers have pointed out in the past, usability and information visualisation implementations have been know come at their own cost(20), to overcome this challenges and having as our guide research works done by other experts on the field(7, 12, 17, 19, 22, 31), we propose the following consideration that our framework will take into account to offer the best user experience possible, this considerations are as follows:

- The interface must be centred around visual metaphors, such as colours, shapes, icons, and so on, this will allow the suers to quickly understand revenant information that is being presented to them without this representing a mental burden.(2)

- Provide multiple course perspective, this will allow the courses to best suit the students needs and learning styles.(6, 8)

- Interfaces should be considered, and used as course elements, thus actively promoting the learning-teaching process.

With all the core elements of the framework defined and ready to guide our framework, it's time to design the components that will constitute our framework.

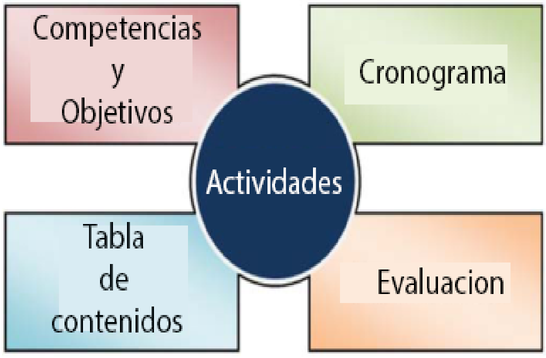

Figure 3.1: *Information structure proposed by Garca-Solorzano, D. Et. All(7).*

3.1.2 Components

To allow the framework to achieve the proposed core objectives set on the previous section while allowing the framework to be flexible and adaptable, in terms of to new challenges, scenarios and variables, the components of the framework must be designed in a modular fashion. This modular design will allow control the flow of information, detect and manage errors and problems efficiently as it reduces the collision domain to the specific module in charge of a process, it will also allow to expand and update functionalities of the framework without impacting other components of the framework. The proposed components of the framework will be explained in the following subsections.

3.1.2.1 User management component

This component, as it's name indicates, is in charge of of managing the users of the system, that is to say, it will be tasked with acting as an access filter (log-in), retrieving the user profile (table 3.1) and preferences(17), and user creation, figure3.2 exposes this component.

As mentioned before, new users to the systems must complete the "Index of Learning Styles Questionary", as proposed by Graft, S. Et. All(21), to allows for the proper identification of the user's learning style, which in turn allows the system to provide learning objects that best suit this profiles. To account for learning resources with limited nature (from now on called referred as "Laboratories"), a second questionary

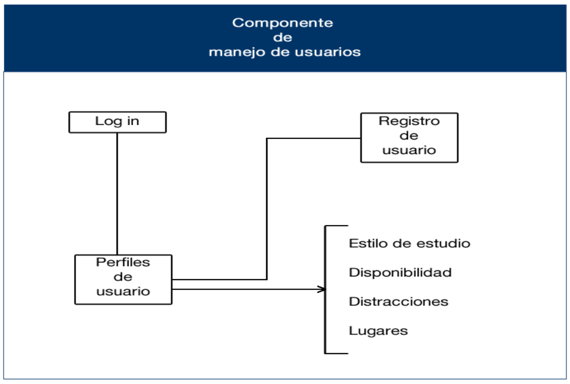

Figure 3.2: User management component.

Name	Name of the user
Lastname	Last name of the user
Username	Friendly name that allows the user to access the system.
Study locations	User preferred locations to study.(17)
Learning style	Learning style that best suits the student. This learning style is inferred using the Felder-Silverman learning style questionary.(21)
Distraction level	The noise/distractions level present in the environment that the user feels suitable for studying.(17)
Current location	User's current location, this information is collected using the built-in functionalities of the user mobile device.
Current distraction level	Measures the distraction level of the current position of the student; microphones, cameras, and other input methods that allows to capture the environment are used to determine this level.(17).

Table 3.1: User's profile elements.

is proposed, this will allow the system to accommodate the usage of the resources by means of a turn base system, the listing3.1 shows the structure of this second questionary.

```
(1) Are you currently working ?
Yes                    No

(2) At what time frames will it be easier for you to access the laboratories ?
(Input one or several as you see fit)

( If your answer to question one (1) was affirmative please respond the
    following questions )
(3) What's your working schedule?

(4) What's your time zone ?

(5) What days of the week do you work on ?

(6) Does your working activity requieres you to travel constantly ?
Yes                    No
```

Listing 3.1: *Prototype of the student's time availability questionary which will allow the system to distribute the time usage of learning resources of limited nature*

3.1.2.2 Learning objects management component

Onces the user's profile is loaded, it's time for the "learning objects management component" to act as a bridge between the "learning objects repository", the "user management component", and the "content management component", by means of receiving the user profile, using this information to retrieve the learning objects that best suit the given profile and sending them back to the "Content management component" which presents the information to the user. Figure 3.3 show the processes of this component.

When dealing with learning objects of limited nature(24, 27), it's necessary to think of a solutions the problem of distributing said resources, for that reason, as mentioned before, a "turn based" system is proposed as a solution to this problem. To achieve this, the system is based on a combination of project management theory(37) and virtual machine resource management techniques(40, 41). The result, is a system that

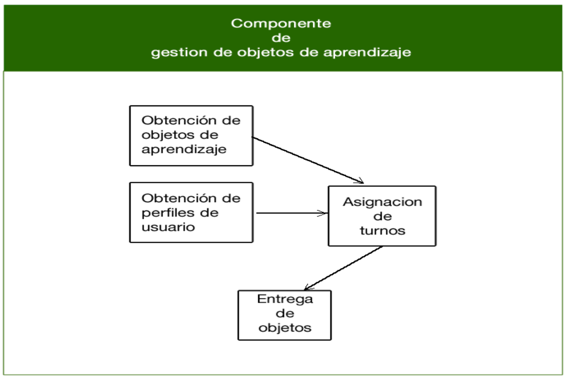

Figure 3.3: Learning objects management component

organises turns by priority and availability; to determine the student's priority a factor evaluation is applied, each student's priority starts at cero (less priority), and a set amount of priority units are added for each factor that applies to the student, the factors are resumed bellow.

- The student is part of the work force: A student that is also a worker has a very restricted time frame that he can dedicate to studying, as his working schedule is usually one that is inmutable, for this reason, a working student must have a higher priority that those who are dedicated one hundred percent to studying, where they have control over their studying time frames.

- The student has to constantly travel: This could be considered a internal filter to be applied to working student's it it only affects them, the idea behind this filter is simple, people that are required to constantly travel due to work, have an even tighter time frame where where they can access this resources, and thus, they are assigned a higher priority.

- Learning style: Taking into account that some student's learning styles may lead to them seeing more benefits out of the usage of the laboratories that their counterparts, in other words, learning styles should also be one of the factors to be taken into account for determining the student's priority. Following is the proposed method to assign priorities to each of the learning styles.

  – Active/reflective: Since this leaning style is the most dependant on direct, active interaction with the learning materials(21), students that belong to this leaning style will have their priorities set in the following fashion; if they are on the "active" end of the spectre, +2 units will be added to their current priority level, the amount of units added will decrease by 0,5 units the closest the level grows to the "reflective" end, that is to say, "reflective" students are given a priority of -2. Working students that are classified on under this learning style, and that are on any of the levels of the "reflective" spectre, are not affected by negative values given by this priority system, in other words, only the positive values are taken into account when dealing with working students, as their time frame for studying is more tighter than that of the their nonworking counterparts.

– Sensing/intuitive: Students on the "sensing" extreme, learn from concrete materials, this puts their learning process in a position where laboratories can be beneficial, but not essential to it's development, thus, the priority assigned to students on the "sensible" extreme is +1, and as they grow nearer to the "intuitive" level their priority diminishes by 0,25 all the way to -1 on the other end of the spectre.

– Visual/verbal and Sequential/global: From the documentation gathered(17, 21, 32), there seems to be no direct impact on this learning styles produced by laboratories, as such, their priories are not affected in any way.

The pseudo-code exposed in listing3.2, explains the underlying algorithm that processes the information collected by means of the "time availability survey"3.1 and the "learning style questionary"(21), in other works, the inner workings of this turn assignment process.

```
Retrieve the users profiles and time availability.
Determine the users priorities,
Segment users by priority order.
For each user, starting with the highest priority do :
{
  Randomly select a user.
      {
      If the user first preferred time is available:
      {
          Assign the turn.
```

```
      }
      Else
      {

             Determine if any of the other preferred times is available.
             {
             if so, assign the turn.
          }
             Else.
             {
             Determine if the user works, if so, search for an available
                 turn close to the availability time frames, else assign a
                 stand by status.

             If found, assign it, Else, assign the closest turn to his non
                 working schedule.

          }End if else

      }End if else

    }End if else

  }End do, when no users are on unassigned or stand by status.
```

Listing 3.2: *Pseudo-code exposing the resource distribution algorithm*

As can be seen3.2, the “turn assignment process”, tasked with assigning the turns for using the laboratories, it works by taking the previously collected data on learning styles and time availability of the students, then, students are grouped by their priority level which allows for the creation of the “activities schedule”(37), in other words, in what order must the task (student turns) be executed taking into account the required resources versus the available ones and their restrictions. This leads to the creation of the network diagram for the course, this diagram is represented as a matrix M of the form $M = h, d, e$, where h = Time of day, d = Day of the week and e = Available resource. this matrix, once solved, allows for the creation of the “project schedule” or in our case the complete allocation of the turns, the solution to this matrix becomes trivial using the “critic chain method”(37) if we consider every d as an independent

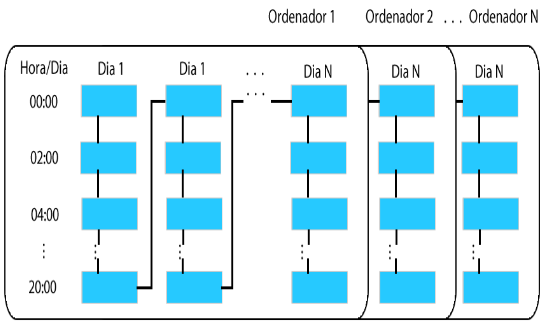

Figure 3.4: *"Project schedule" solved using the "critical chain method" having each resource be it's own independent "project".*

project, as seen in figure 3.4.

3.1.2.3 Learning objects repository component

This module is in charge of storing, classifying, and filtering the learning objects, this is achieved by saving information about the resource, such as it's type (video, image, text, audio) and the recommended usage location(17). This classification helps managing petitions from the "content management module" regarding learning materials for a given student profile, with a set learning style, and the current external factors such as location and distractions levels.

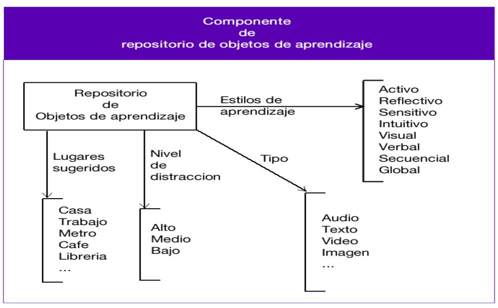

Figure 3.5: Learning objects repository component.

3.1.2.4 Content management component

This module is the one that could be consider the closest to the user, as it's main goal is that of displaying the content back to the user, retrieving his inputs and sending them to the adequate component to be processed, in other words, this module could be consider as a "View" in the MVC model(**?**), this allows for fast responsive and transparent execution of the task while keeping the process scalable.(**?**) Figure 3.6, presents the inner working of this component, as can be observe, there is a view element, which acts as the central axis of this component, allowing other component to present information back to the user, this information can be presented in ways that range from forums, task, activities, schedule, teacher's room, and so on(4), each of this elements can then receive new petitions from the user that are sent back to the corresponding modules, and the corresponding answer to the user petition is then displayed back to the user, this cycle could be consider the main process of our framework.

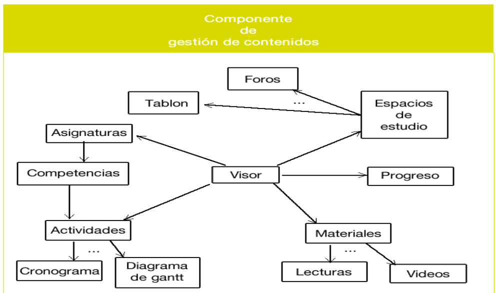

Figure 3.6: Content management component.

3.1.3 Student tracking component

To help the teacher labours (as well as the student learning process), tracking the student learning process is necessary as means of giving precise feedback and identifying problems and difficulties that may arise during this process. This component is divided into 2 elements, tracking and evaluating. Tracking, deals with keeping track of the user and course statistics, and application usage (actions taken while using an application derived from the framework), say, te average grades, the average time to turn in an activity, or the usage they give to course workspace such as forums(4); evaluating, in the other hand, deals with processing this information and storing storing it, and presenting it to the user when required, be it an enquiry, or a programmed alert when some indicators goes over a set boundary, this means, teachers can have an easier time assessing the state of the course.

3.1.4 Information visualisation

As discussed before, the importance of the information being presented in a mostly visual way is important to help the teachers and student quickly learn about their the status of their learning process without it becoming a mental burden(33), as such, we presente the suggested interface to be used when presenting information back to the suers, following this line of thinking. The figure 3.8 presents "Students" information page using the concept of "faceted browsing"(4) as a tart point, but adding learning styles(21) informations to the "facets"; the end result is an interface that presents segmentation tools on the lateral panel, to allow the teacher find insights about the course and it's status, in the other hand the the teacher can easily access information regarding each individual student in the form of completion percentage, represented by the black bar, and it's learning style, represented by a color code, using saturation to represented the level of the spectre where the student is at, as shown on figure**??**

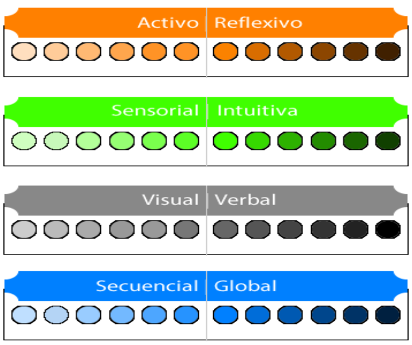

Figure 3.7: Felder-Silverman visual representation of the spectres levels.

Figure 3.9, presents the "Schedule" interface, which provides information regarding the academic calendar, such as start and end dates for activities, important dates, special events and any other event thats related to the student's learning process. It is also here that the teacher can keep track of the proposed learning track (the course

Figure 3.8: *Prototype "Students" teacher interface.*

Figure 3.9: *Prototype "Schedule" interface.*

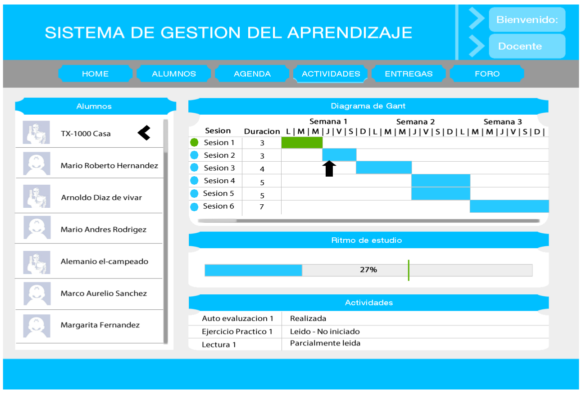

Figure 3.10: *Prototype "Activities" teacher interface.*

structure); this is achieved using a main windows with a side panel, the side panel shows resumed information on a selected event while the main windows shows the schedule for the month and visual cues about the elements to be developed on that month. The bottom most panel of the main window presents the events for the currently selected day (the current day by default) .

Figure 3.10, shows the "Activities" interface, this interface is tasked with presenting information back to the educator regarding the status of the activities proposed to the student to develop during the course; as to alleviate the mental burden of processing this information, it is presented as a Gant diagram; additional information regarding the student pace, as proposed by Garcia-Solorzano, D. Et. All(4), is presented as a progress bar, with an indicator of the minimal aceptable level. Other data regarding the activities status is also presented as means of tracking the student process. Students, on the other hand, are presented with the interface shown in figure3.11, here, the student is presented with a Gant diagram regarding the proposed course schedule, and the suggested learning objects to complete said activities, if he so desires, he can also have access to a complete list of all the available learning objects.

Figure 3.12 presents the information on deliverable activities that the student must develop thought the course to be evaluated by the teacher, here, the proposed activities get graded as a mean for the student to be able to assess his knowledge; information regarding the general status of the course is also provided as to provide contest to the grade that the student is being presented with.

Figure 3.11: Prototype "Activities" student interface..

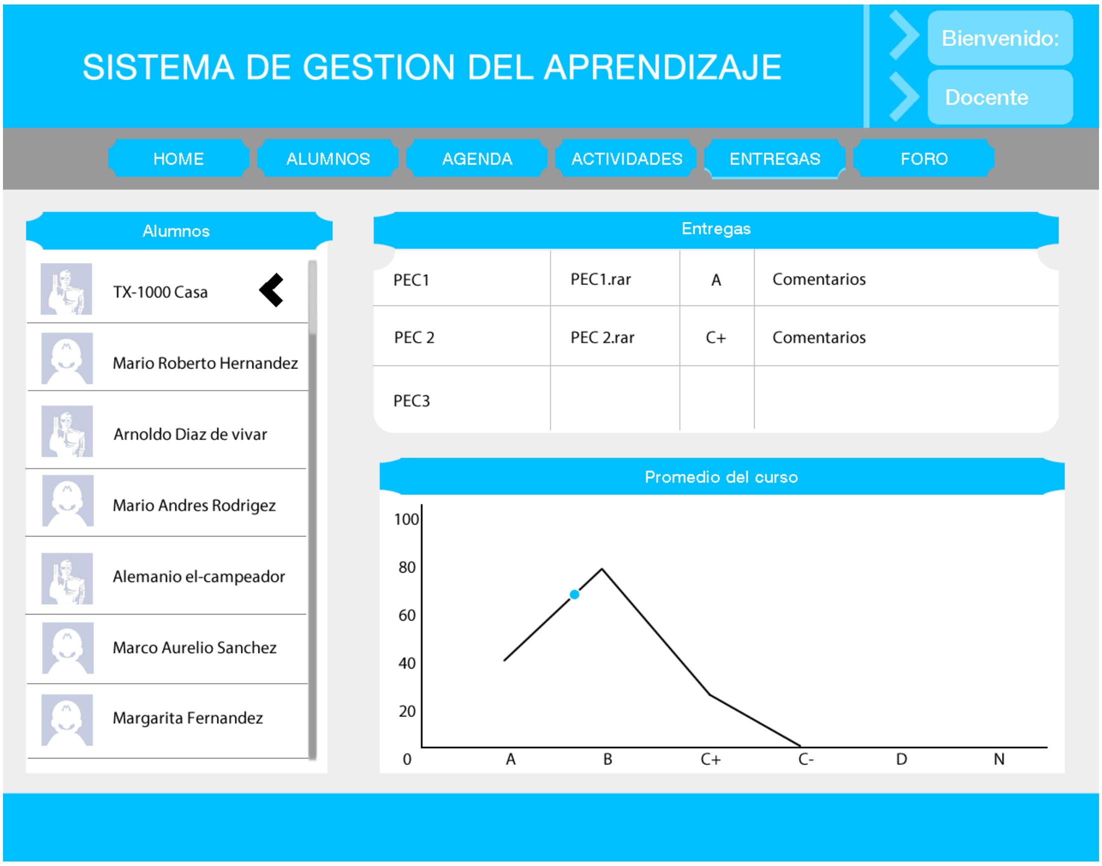

Figure 3.12: Prototype "Deliverables" interface.

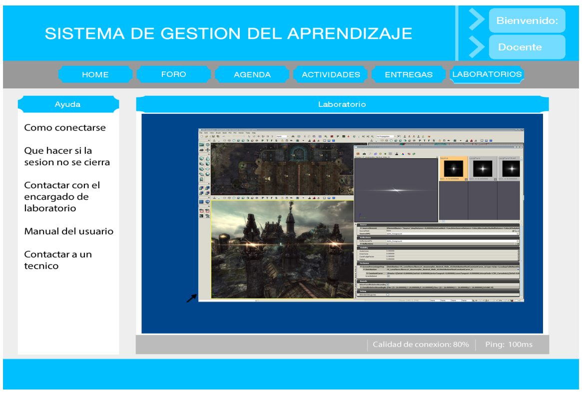

Figure 3.13: Prototype "Laboratories" interface.

Figure 3.14: *Prototype "Forum" interface.*

Figure 3.14, presents the forum interface, it's divided into a side bar and a main section, the side bar presents information regarding recent activity in the forum, such as new posts and replays. The main section is used to presents forum navigation, as such, first of all the user can see all the forum topics, and by selecting one, frame is populated with the information about that topic; to keep track of the user's location on the forum navigation, a "bread crumbs" menu is used as well as navigation buttons to advance a level, go back a level, or go back to the root of the forum.

Figure 3.13 shows the "Laboratories" interface, in here, the student can have access to learning objects of limited nature such as licensed software, as an example, the figure shows the "Unreal Engine SDK" being accessed remotely by the student, a side panel is used to trouble shot whatever problem the user may have during the execution of the laboratory.

3.2 Conclusions

This document presents a survey identifying the state of the art of current learning management systems, information visualisation and learning resources, identifying several key points. First of all, learning management systems, evidence show that this systems seem to focus in solving one problems at a time giving birth to several learning systems, each with their own specific characteristics, which in turn makes this systems restrictive. On the other hand, information visualisation, a tool that helps enrich the learning process of the student, could in fact be counterproductive if the elements take more focus than the actual message that it's trying to convey, Lastly, some learning resource types are not being acknowledge by learning management systems, and the ones that are, such as remote laboratories, lack proper integration. For this reasons a nobel approach in the form of a multivariable framework is proposed, thus giving us an scalable, adaptable way of dealing with the current problematics. The proposed solution presents a modular structure, this structure divides the work between different components, which makes it so that elements are decouple, providing the ability to modify or add components into the framework without affecting the other components. The solution does also present standard visualisation elements to guide the creation of information visualisation elements, thus reducing the risk of this elements losing the focus of the message they are trying to comvey.

3.3 Future Work

Future works following this line of research could deal with solving the resource distribution problem when it is impossible to solve the turn signalment matrix, such as cases when overlapping occurs, which could be solved implementing "resource levelling"(37) inside the proposed algorithm3.2.

Other interesting lines of research could consider solving resource management implementations of this systems using social policies by convining concepts exposed by Ostrom, E.(35) and Christopherson, K.(36).

Bibliografia

[1] R. E. Derouin. **E-Learning in Organizations**. *Journal of Management*, **31**(6):920–940, December 2005. iii, 1

[2] Kirsten R Butcher. **Cognitive Processes and Visualization**. In *Teaching Geoscience with Visualizations: Using Images, Animations, and Models Effectively*, pages 2–4, Northfield, 2004. iii, 1, 14, 23

[3] Christopher R Butson, Georg Tamm, Sanket Jain, Thomas Fogal, and Jens Kruger. **Evaluation of Interactive Visualization on Mobile Computing Platforms for Selection of Deep Brain Stimulation Parameters.** *IEEE transactions on visualization and computer graphics*, **19**(1):108–117, March 2012. iii, 1

[4] David García-Solórzano, Jose Antonio Morán, Germán Cobo, Carlos Monzo, Eugènia Santamaría, and Javier Melenchón. **Educational monitoring tool based on faceted browsing and data portraits**. In *Proceedings of the 2nd International Conference on Learning Analytics and Knowledge - LAK '12*, page 170, New York, New York, USA, 2012. ACM Press. iii, 1, 3, 14, 31, 32, 34

[5] Ute Kraidy. **Digital Media and Education: cognitive impact of information visualization**. *Journal of Educational Media*, **27**(3):95–106, October 2002. iii, 1, 14

[6] David Garcia-Solorzano, Germn Cobo, Eugènia Santamaria, Jose Antonio Morn, and Javier Melenchon. **Representation of a Course Structure Focused on Activities Using Information Visualization Techniques**. In *2011 IEEE 11th International Conference on Advanced Learning Technologies*, pages 443–445. IEEE, July 2011. iii, 1, 3, 14, 23

[7] David Garcia-Solorzano, German Cobo, Eugenia Santamaria, Jose A. Moran, Javier Melenchon, and Carlos Monzo. **Evaluation of a Learning Management System focused on activities**. In *Proceedings of the 2012 IEEE Global Engineering Education Conference (EDUCON)*, pages 1–6. IEEE, April 2012. iii, v, 1, 3, 4, 5, 6, 7, 14, 21, 22, 23, 24

[8] Riccardo Mazza and Vania Dimitrova. **Visualising student tracking data to support instructors in web-based distance education**. *Alternate track papers & posters of the 13th international conference on World Wide Web - WWW Alt. '04*, page 154, 2004. iii, 1, 23

[9] David García, Germán Cobo, and Eugènia Santamaría. **Herramientas para la gestión del proceso de aprendizaje en un entorno virtual**. *... para el Aprendizaje, ...*, 2009. iii, 1, 2, 3, 5, 14

[10] Carlos Delgado Kloos, Sergio Martin, Baltasar Fernandez Manjon, Gregorio Robles, and Edmundo Tovar. **Will m-learning bring disruption into education? Advances from the eMadrid excellence network**. In *Proceedings of the 2012 IEEE Global Engineering Education Conference (EDUCON)*, number June in IEEE Global Engineering Education Conference (EDUCON), pages 1–2. IEEE, April 2012. iii, 1, 6

[11] Didac Gil, Jesper Andersson, Marcelo Milrad, and Hakan Sollervall. **Towards a Decentralized and Self-Adaptive System for M-Learning Applications**. In *2012 IEEE Seventh International Conference on Wireless, Mobile and Ubiquitous Technology in Education*, pages 162–166. IEEE, March 2012. iii, 1, 7, 8

[12] Mauro Faccioni Filho, Lawrence Zordam Klein, and Moacyr Franco Neto. **M-learning tools on distance education: Overview and case study**. In *IEEE EDUCON 2010 Conference*, pages 677–683. IEEE, 2010. iii, 1, 7, 8, 14, 23

[13] Patrick Hak-Chung Lam and Sally Wai-Yan Wan. **Students' Voices: Enriching Learning Experiences through M-learning**. In *2010 6th IEEE International Conference on Wireless, Mobile, and Ubiquitous Technologies in Education*, pages 171–176. IEEE, April 2010. iii, 1, 6, 7, 22

[14] a. M. Solvberg and M. Rismark. **Learning spaces in mobile learning environments**. *Active Learning in Higher Education*, **13**(1):23–33, February 2012. iii, 1, 7

[15] Sergio Martin, Rosario Gil, Elio San Cristobal, Gabriel Diaz, Manuel Castro, Juan Peire, Mihail Milev, and Nevena Mileva. **Middleware for the Development of Context-Aware Applications inside m-Learning: Connecting e-Learning to the Mobile World**. *2009 Fourth International Multi-Conference on Computing in the Global Information Technology*, pages 217–222, 2009. iii, 1, 8

[16] Mohammed a. Razek and Hisham Jameel a. Bardesi. **Adaptive Course for Mobile Learning**. In *2013 Fifth International Conference on Computational Intelligence, Communication Systems and Networks*, pages 328–333. IEEE, June 2013. iii, vii, 1, 7, 10, 22

[17] Jane Y.-K. Yau and Mike Joy. **A Context-Aware Personalized M-learning Application Based on M-learning Preferences**. In *2010 6th IEEE International Conference on Wireless, Mobile, and Ubiquitous Technologies in Education*, pages 11–18. IEEE, April 2010. iii, vii, 1, 7, 8, 9, 23, 24, 25, 28, 30

[18] Ju-ling Shih and Cheng-ping Chen. **Approaching M-learning with the Application of Instructional Pervasive Game**. In *2012 IEEE Seventh International Conference on Wireless, Mobile and Ubiquitous Technology in Education*, pages 254–258. IEEE, March 2012. iii, 1, 6, 7, 22, 23

[19] I. Kondratova and I. Goldfarb. **M-learning: Overcoming the Usability Challenges of Mobile Devices**. In *International Conference on Networking, International Conference on Systems and International Conference on Mobile Communications and Learning Technologies (ICNICONSMCL'06)*, pages 223–223. IEEE, 2004. iii, 1, 8, 23

BIBLIOGRAFIA

[20] Chaomei Chen. **Top 10 unsolved information visualization problems.** *IEEE computer graphics and applications*, **25**(4):12–6, 2005. iii, vii, 1, 2, 14, 18, 23

[21] Sabine Graf. *Adaptivity in learning management systems focussing on learning styles.* PhD thesis, Vienna University of Technology, 2007. iii, 1, 5, 22, 24, 25, 27, 28, 32

[22] Oksana Hlodan. **Mobile Learning Anytime, Anywhere**. *BioScience*, **60**(9):682–682, October 2010. iii, 1, 8, 23

[23] K Jugdev, G Mathur, and T Fung. **Project management assets and project management performance: Preliminary findings**. *. . . Management in the Energy Smart . . .*, 2011. iii, 1

[24] Michael E Auer and Christophe Gravier. **Guest Editorial: The Many Facets of Remote Laboratories in Online Engineering Education**. *IEEE Transactions on Learning Technologies*, **2**(4):260–262, October 2009. iii, 1, 2, 18, 26

[25] N Abdellaoui and C Gravier. **Towards the loose coupling between LMS and Remote Laboratories in Online Engineering Education**. *Education Engineering . . .*, pages 1935–1940, 2010. iii, 1, 2, 18, 19

[26] SC Sivakumar and William Robertson. **Development of an effective remote interactive laboratory for online internetworking education**. *System Sciences, 2004. . . .*, **00**(C):1–10, 2004. iii, 1, 2, 18

[27] Carlos E. Caicedo Bastidas. **Enabling remote access to computer networking laboratories for distance education**. *2011 Frontiers in Education Conference (FIE)*, pages F3C–1–F3C–6, October 2011. iii, 2, 18, 26

[28] I Santana, M Ferre, and E Izaguirre. **Remote laboratories for education and research purposes in automatic control systems**. *Industrial Informatics, . . .*, **9**(1):547–556, 2013. iii, 2, 18, 19

[29] Jochen Ehret, Achim Ebert, L. Schuchardt, H. Steinmetz, and H. Hagen. **Context-Adaptive Mobile Visualization and Information Management**. In *IEEE Visualization 2004*, pages 8p–8p. IEEE Comput. Soc, 2004. iii, 2

[30] Hac Ali Duru, Murat Perit Çakr, and Veysi ler. **How Does Software Visualization Contribute to Software Comprehension? A Grounded Theory Approach**. *International Journal of Human-Computer Interaction*, **29**(11):743–763, November 2013. iii, 2

[31] G. Costagliola, A. De Lucia, F. Ferrucci, C. Gravino, and G. Scanniello. **Assessing the Usability of a Tool for Developing Adaptive E-learning Processes: an Empirical Analysis**. In *Sixth IEEE International Conference on Advanced Learning Technologies (ICALT'06)*, **91**, pages 265–269. IEEE, 2013. iii, 2, 23

[32] TL Naps, Guido Röss ling, and Vicki Almstrum. **Exploring the role of visualization and engagement in computer science education**. *ACM SIGCSE . . .*, 2002. iii, vii, 2, 14, 16, 17, 28

[33] Jiajie Zhang, KA Johnson, JT Malin, and JW Smith. **Human-centered information visualization**. *. . . on dynamic visualizations and . . .*, 2002. iii, 2, 14, 32

[34] F Fan, Y Li, and S Deng. **Time management for web service composition**. *. . . Work in Design, 2007. CSCWD 2007. . . .*, pages 550–555, 2007. v, 12, 13

[35] Elinor Ostrom. *Governing the Commons: The Evolution of Institutions for Collective Action.* Number 1 in The political economy of institutions and decisions. Cambridge University Press, 1990. 10, 38

[36] Kimberly M. Christopherson. **The positive and negative implications of anonymity in Internet social interactions: On the Internet, Nobody Knows Youre a Dog**. *Computers in Human Behavior*, **23**(6):3038–3056, November 2007. 10, 38

[37] Systems Engineering, Standards Committee, and Ieee Computer. *Adoption of the Project Management Institute (PMI) Standard A Guide to the Project Management Body of Knowledge (PMBOK Guide).* Number November in A Guide to the Project Management Body of Knowledge. IEEE Computer Society, fourth edi edition, 2011. 10, 26, 29, 38

[38] Mendel Rosenblum. **The Reincarnation of Virtual Machines - ACM Queue**, 2004. 13

[39] Zachary Anderson. **Efficiently combining parallel software using fine-grained, language-level, hierarchical resource management policies**. *Proceedings of the ACM international conference on Object oriented programming systems languages and applications - OOPSLA '12*, page 717, 2012. 13

[40] Lixi Wang, Jing Xu, and Ming Zhao. **Application-aware cross-layer virtual machine resource management**. *Proceedings of the 9th international conference on Autonomic computing - ICAC '12*, page 13, 2012. 13, 26

[41] Arkadiusz Janik and Krzysztof Zielinski. **Transparent resource management and self-adaptability using multitasking virtual machine RM API**. *Proceedings of the 2006 international workshop on Self-adaptation and self-managing systems - SEAMS '06*, page 51, 2006. 14, 26

[42] Yvonne Rogers, Helen Sharp, and Jenny Preece. *Interaction Design: Beyond Human - Computer Interaction*, **6**. WILEY, 2011. 14

Declaration

I herewith declare that I have produced this paper without the prohibited assistance of third parties and without making use of aids other than those specified; notions taken over directly or indirectly from other sources have been identified as such. This paper has not previously been presented in identical or similar form to any other German or foreign examination board.

The thesis work was conducted from February 2014 to June 2014 under the supervision of Enric Guaus at UOC.

Bucaramanga,