Adaptable multivariable m-leaning framework

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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.

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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

Proposal

This research proposes the design and development 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.

2.1 Justification

We understand as variables each and every factor that influences a process, be it directly or obliquely. For online education, which has been a crucial tool for institutions and business around the world,(1) several variables have been identified from different knowledge branches, each variable, has in turn prompted the construction of tools, learning systems, and methodologies(1, 2, 3, 4, 5) as a solution to said variables. Variables such as the students need for personalised acquisition of knowledge, have been approached by methodologies such as mobile learning (m-learning), which give users the power to access resources when, where, and how they desire it,(13) in other words, its a student centric education paradigm; (10, 11, 12, 13, 14, 15, 16, 17, 18) this implies that educational resources are of the outmost importance for the learning process to be successful. Despite this, there are variables such as the limited nature of some of the educational resources (laboratories, books, licensed materials, ...(35, 36, 37)), that, to the best of our knowledge, have not been taken into account by the learning management systems created to date;(1, 2, 3, 4, 5, 21) this in turn, hinders the learning process of the students, as said resources strengthen the learning process as they allow the user to become an active part of their learning process(1, 4, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 31, 32, 33, 38, 39, 40, 41, 42)

Social theories such as the one proposed by Ostrom. E. (43), suggest that common resources of the limited nature should be self regulated by their users, but researchers on internet behaviour such as Christopherson. K.(44) suggest that online collaboration can be difficult as individuals tend to engage in antisocial behaviours during online interaction, thus creating a new variable, the need ta manage resources of limited nature in a seamless, non-disruptive way.

Lastly, variables such as information visualisation, have been approached by means of visualisations techniques, thus allowing students and teachers to obtain information in such way that process of knowledge abstraction(19), identification of difficulties during the learning process(8), and the creation of new knowledge for the correct execution of the course objective(19, 21, 32), as well as generate motivation towards the course(5); unfortunately, some times, the way this visualisations are implemented are produce undesirable results(5), in some cases, it can be due to visual elements being too distraction from the main message, thus making it difficult for users to achieve their goals(9, 20, 29, 30, 31, 32, 33), in others cases, external factors such as user location, noise levels, temperature of the room, and other unaccounted factors can hinder the effectiveness of visualisation as a tool.(14, 17)

Is then pertinent that we ask ourself, what visualisation tools and techniques are the most adequate to be used on the information presented to the user depending on user internal (user preferences, learning style(21), etc...) and external (noise, light levels, time of day, etc..) factors?, which could be some of the methodologies to achieve an effective fair distribution of the resources with limited nature for m-learning environments, taking into account users needs?, in what way could we create a framework that allows for the creation of m-learning systems that can adapt to each of the aforementioned variables?. This document presents some of the proposed approaches to each of the variables and then presents a novel approach in the form of a multivariable adaptable framework for the creation of m-learning management systems.

2.2 State of the art

2.2.1 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 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.

2.2.2 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

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

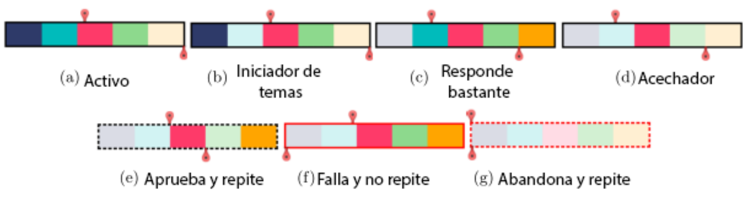

Figure 2.2: *Ejemplo de los diferentes "Data portraits" propuestos por Garcia-Solrzano, D. Et. All(7) junto con algunos "perfiles" que pueden ser identificados*

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.

2.2.3 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.

2.2.4 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.

2.2.5 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, E.(43) 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.(44) That is why this research will look into other disciplines to implement solutions given to this problem form other branches of knowledge,

2.2.6 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

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)

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.(39) 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.

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

2.2.8 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.(45) 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.(42)

In some cases, as exposed by Wang, L. Et All(41), 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

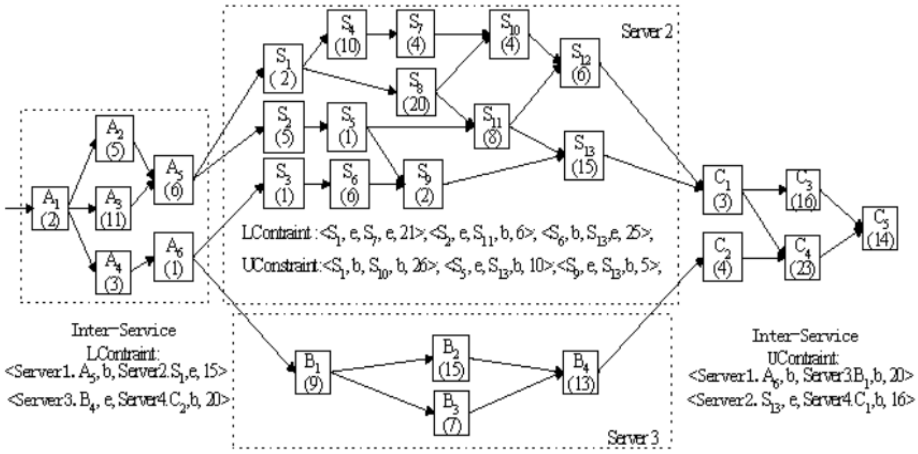

Figure 2.3: *Webservice composition example(34).*

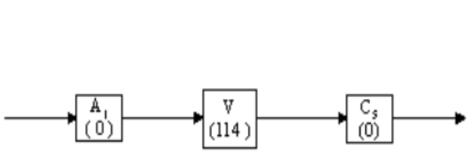

Figure 2.4: *Decomposed web service composition(34).*

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.(46) 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.

2.2.9 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)(47)(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)

2.2.10 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)

2.3 hypothesis, research questions and objetives

2.3.1 Research questions

- what visualisation tools and techniques are the most adequate to be used on the information presented to the user depending on user internal (user preferences, learning style(21), etc...) and external (noise, light levels, time of day, etc..) factors?.
- which could be some of the methodologies to achieve an effective fair distribution of the resources with limited nature for m-learning environments, taking into account users needs?.
- 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?.

2.3.2 Main objective

Design of a multivariable adaptable framework for the creation of m-learning management systems.

2.3.3 General Objectives

- Constructions of the state of the art document containing the following topics:
  - Student preferences.
  - Student adaptable learning.
  - Information visualisation.
  - Visual information impact on the student.
  - Limited resources management.
  - M-Learning.
  - Importance of laboratories in education.
  - Remote learning laboratories.
- Work plan definition.
- Framework's structure definition.
- Framework's elements design.
- Framework design.
- Framework testing and evaluation.

2.4 Research plan

2.4.1 Methodology

The research methodology to be used on this project is known as "Design and Creation" as defined by Oates B. on his book "Researching Information Systems and Computing"(48); following is a list resuming the definition of the steps to be followed by our research as well as what it implies in the context of our research.

Awareness: ”Is the recognition and articulation of the problem”, which in this case, comes from studying the literature, observation of the world and its surroundings, findings in other disciplines, to identify current problems and possible solutions.

Suggestion: ”Involves creating a leap from curiosity about the problem to offering a very tentative solution”. In other words to define the drive for our research (it's justification).

Development: ”Is where tentative design idea is implemented”. In our case, is the design and development of the adaptable multivariable framework for m-learning management systems and the m-learning system prototype following the stablished framework.

Evaluation: ”Examines the artefacts and looks for an assessment of worth and deviations form expectations”. In the context of out project, once the framework is constructed, we have to test it be means of creating a prototype m-learning system, said prototype should be tested by using a randomly sampled group of students taking a course(48), where, final group would be divided in 2, one control group, which would proceed to take the course as normal, and one test group which would be using the prototype system created with the framework. Once the testing period is over (a semester), results will be collected using 2 methods. Firstly, an online survey will be given to the students involved on the test to measure their perception of the whole test, and how they felt bye using their given study method (”normal education”, or the system). Secondly, the students process and statistics will be collected from the systems (”normal education” and the prototype) and compare via graphical analysis(48), to find insights on improvements created by the prototype, each insight will be the contrasted with an analysis of the students survey to support any posible insights derived form this tests.

Conclusion: ”Is where the results from the design process are consolidated, [...] and the knowledge gained is identified”, Here its where all the hard work will be resumed into the final artefact, highlighting the most relevant aspects of the research.

2.4.2 Data analysis tools

We have previously mention that the research project is going to collect data from the students to assess their experience, feelings, and opinions on their given learning method ("normal education" or the prototype) by means of an online survey, said survey are gonna be created using Google Forms(49), as they provide a reliable platform for the task at hand. Once the data is collected, it's then going to be exported to a spread sheet to be analysed using graphical analysis(48) of the segmented data(50) by identified relevant factor, product of a preliminar analysis(50).

2.4.3 Research schedule

Schedule for this research project will be handle as follows:

Daily Plan :

Days of the week	Mon	Tue	Wen	Thu	Fri	Sat	Total
Invested Time	7h	7h	7h	7h	7h	1h	36h

Table 2.5: Research Schedule - Number of ours invested per day.

Full project duration research plan (3 years and 6 month plan) :

Objective	Jan	Feb	Mar	Apr	May	Jun
Study of the body of knowledge	x	x	x	x		
Construction of the state of the art	x	x	x	x	x	x
Research plan definition					x	x

Table 2.6: Research schedule (Year 1, part 1) - Simplified view of the proposed schedule for this research project.

Objective	Jul	Aug	Sep	Oct	Nov	Dec
Framework definition	x	x	x	x	x	x

Table 2.7: Research schedule (Year 1, part 2) - Simplified view of the proposed schedule for this research project.

Objective	Jan	Feb	Mar	Apr	May	Jun
Framework Design	x	x	x	x	x	x
Framework element's definition			x	x	x	x

Table 2.8: Research schedule (Year 2, part 1) - Simplified view of the proposed schedule for this research project.

Objetivos	Jul	Aug	Sep	Oct	Nov	Dec
Framework element's definition	x	x	x	x	x	x

Table 2.9: Research schedule (Year 2, part 2) - Simplified view of the proposed schedule for this research project.

Objetivos	Jan	Feb	Mar	Abr	May	Jun
Prototype construction	x	x	x	x	x	x

Table 2.10: Research schedule (Year 3, part 1) - Simplified view of the proposed schedule for this research project.

Objetivos	Jul	Aug	Sep	Oct	Nov	Dec
Prototype test	x	x	x	x	x	x
Systems data collection	x	x	x	x	x	x
Survey data collection						x

Table 2.11: Research schedule (Year 3, part 2) - Simplified view of the proposed schedule for this research project.

Objetivos	Jan	Feb	Mar	Abr	May	Jun
Data analisys	x	x				
Result analisys	x	x	x			
Final document construction				x	x	x

Table 2.12: Research schedule (Year 4) - Simplified view of the proposed schedule for this research project.

3

Thesis director

3.1 Director proposal

3.1.1 Enric Guaus

Enric Guaus (Barcelona, 1974) is a researcher in sound and music computing at the Music Technology Group, Universitat Pompeu Fabra (UPF), and professor at the Sonology Department, at the Escola Superior de Msica de Catalunya (ESMUC). He obtained a PhD in Computer Science and Digital Communications (UPF), in 2009, with a dissertation on automatic music genre classification. His research interests cover music information retrieval and human interfaces for musical instruments. He is assistant professor in acoustic engineering at the Universitat Pompeu Fabra (UPF) and lecturer in maths, electronics and computer science at the Escola Superior de Msica de Catalunya (ESMUC). He is also a consultant professor at Universitat Oberta de Catalunya (UOC) and collaborator at different master programs. He is member of the Observatori de de prevenci auditiva per als msics (OPAM) i de la Barcelona Laptop Orchestra (BLO).

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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.

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Bucaramanga,