TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

PERE VEGAS CASABONA

FUTURE COEVOLUTION OF HIGHER EDUCATION AND TECHNOLOGY: CASE CATALONIA

Master of Science Thesis

Examiners:
Associate Professor Tomi Nokelainen
Professor Saku Mäkinen

Examiner and topic approved by
the Council of the Faculty of Business and
Built Environment on 7 May 2014

ABSTRACT

TAMPERE UNIVERSITY OF TECHNOLOGY
Master's Degree Programme in Business and Technology
VEGAS CASABONA, PERE: FUTURE COEVOLUTION OF HIGHER EDUCATION AND TECHNOLOGY:
CASE CATALONIA
Master of Science Thesis, 85 pages.
May 2014
Major: Industrial Management
Examiners:
Associate Professor Tomi Nokelainen
Professor Saku Mäkinen
Keywords: Higher education, Catalan university, technological transition, multi-level perspective, social media, Massive Open Online Courses, virtual learning environments, user interfaces, augmented reality.

It is widely recognized that today the higher education is going through several structural as well as seasonal problems and weaknesses. The Catalan university system is not an exception since there are some relevant issues creating pressures between different actors and systems inside the sector such as an increase of the tuition prices, or a low attendance rate of students. Thus, the main goal of the thesis is to analyse and evaluate how the entrance of different technologies may improve the actual situation of the Catalan higher education and provide some worthwhile ideas for decision-makers.

The theoretical basis that supports the whole study is the multi-level perspective of technological transitions. The first part of the thesis aims to collect all the information needed to apply the framework, and structure it for the later analysis. The second part constitutes the analysis itself which has been specifically designed for this case since the multi-level perspective does not specify how it has to be done. In the first part of the analysis, the theoretical potential and influence of the technologies over the higher education system are corroborated matching their features with the needs present in the sector. Then, due to the existence of an important degree of uncertainty, three possible future states of the Catalan higher education are created using scenarios building.

The thesis mainly concludes that all the five technologies considered may have influence in the higher education and change the actual teaching and learning paradigm. Hence, all three scenarios are positive in terms of needs fulfilled although they have some downsides like the investment costs required. Overall, it is suggested to decision-makers to give financial and political support to develop MOOCs, more effective virtual learning environments, and make use of multi-touch screens in order to move towards internationalisation, more interaction, and less overhead costs in the long-term.

.

PREFACE

The work presented in this thesis was carried out at the Department of Industrial Management, Tampere University of Technology, from January to May, 2014.

First of all, I would like to express my deepest gratitude to my examiner, Associate Professor Tomi Nokelainen, for accepting my proposal, inspiring me with new ideas, and reviewing my work, but mostly for being disposed to help me at any time.

I would like to specially thank to my boys, Miguel Mendes and Clément Nguyen, for just being here this year. You have showed me that not everything is about experience...

I would also like to express my greatest thanks to all my family and friends, especially those who unfortunately cannot read this text, for being always close and showing me that the distance is only something that can be easily recoverable.

Most importantly, I would like to thank my parents, Pere Vegas and Rosa Maria Casabona, for giving me everything and always encouraging me to achieve something better. You have taught me how to live and now I am living.

Tampere, Finland, May 2014

Pere Vegas Casabona

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Motivation of the study

Nowadays, it is widely recognized that the higher education is going through several structural as well as seasonal problems and weaknesses. The Catalan university system is not an exception since there are some relevant issues creating pressures between different actors and systems inside the sector. For instance, the increase of the enrolment rates which is depriving certain people of higher education, the low mobility ratio of students and mostly staff what does not match with the globalisation trend of the whole economy, or the low attendance rate of students in classes which reflects the rift between students and universities. Both governments and leader boards of universities are trying to fix the situation by commencing large studies to identify the specific problems and taking some actions to overcome them. However, all these efforts are addressed to make some kind of managerial and organisational changes. Hence, technological aspects are by and large neglected. This should be surprising as well as concerning since one of the few novelties that currently seems to add freshness to the university systems is the entry of a young and low developed technology, the Massive Open Online Courses.

1.2 Objectives of the study

The thesis aims to look at which role technology may have in the higher education and hence provide decision-makers a new kind of study which has not a managerial or organisational nature, but technological. Specifically, the study is focused on the Catalan higher education and hence characteristics of this particular system are taken into account. Thus, the thesis has two main objectives:

- Study how the current state of the Catalan higher education may evolve as a result of the entrance of some selected technologies.
- Provide Catalan higher education decision-makers valuable ideas for short- and mid-term future about technology-related decisions.

Furthermore, several secondary objectives, which can be considered as intermediate steps of the final goal, are also defined:

- Identify a set of technologies with high potential in education.
- Create an updated literature review of each of the selected technologies regarding scope, typology, and current and future applications.
- Apply the multi-level perspective to a future case of technological transitions.

1.3 Methodology of the study

Given that this thesis aims to figure out how a sector may evolve as a consequence of the entry of some technologies and what will be the resulting state, this study is considered a practical case of technological transitions. Considering this, the theoretical basis that supports the whole study is the multi-level perspective of technological transitions which mostly states that there are three different heuristic levels of complexity involved in the process. Structurally, the study is divided in two main parts. The first has a searching character, and it aims to collect and structure all the information needed about these three levels for the later analysis, while the second part constitutes the analysis itself and hence it is where more new contributions are done.

The structure of the thesis is designed as follows. Chapter 2 provides the two theoretical frameworks that are used in the thesis; the multi-level perspective which give sense to the whole study, and the scenarios theory which is used for a specific part of the final analysis. Chapter 3 has two main goals. First, introducing the context where the study is focused on underlying the current problems of the system. Second, given that the system is one of the three levels of the multi-level perspective, compiling information enough for the later analysis. Chapter 4 focuses on the second level of this perspective which is social and economical trends affecting the Catalan higher education. Chapter 5 includes an updated literature review about five selected technologies, which are later used as inputs in the analysis, and hence it is a rather large chapter. Chapter 6 can be considered the core of the thesis since is where the analysis is developed. Basically, the multi-level perspective is used to theoretically support to the whole study while other more specific methods are used in the analysis itself to finally aim to meet the goals of the thesis.

2. THEORETICAL BACKGROUND

The thesis utilises two main frameworks that constitute the theoretical basis of different aspects and parts of the study: The multi-level perspective of technological transitions, and the scenarios building theory. The first one gives meaning to the whole study since it describes how technological transitions occur, that is exactly what the thesis is about. Indeed, the thesis can be considered a practical case of this multi-level perspective. On the other hand, scenarios building theory is used specifically in the analytical part of the thesis to handle with the uncertainty present and to complement the multi-level perspective.

2.1 Multi-level perspective of Technological-Transitions

The aim of this chapter is to explain the reader the theoretical framework which the thesis in based on: the multi-level perspective of technological transitions. To do it easier to read and more understandable, I include not only the theoretical terms and concepts but also insights from a real study case which helps the reader to clarify the concepts and see their possible practical application. The chosen case is “The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860-1930), developed by Frank W. Geels in 2005.

The study focuses on urban passenger transport in America between 1860 and 1930. This is because the transformation from horse-based transportation as a dominant technology to gasoline automobiles happened first in that specific sector, location and time. It has to be highlighted that the focus in on the whole urban passenger transport since Geels does not only study the horse-based vehicles and the gasoline automobiles but also other technologies that had an important role in that transition such as the bicycle, the electric car, and the electric tram. In short, to better understand the whole multi-level perspective, case snippets are inserted in the framework review throughout the text to complement the theoretical concepts introduced just before.

2.1.1 Technological transitions

Technological innovations which are defined as technologies newly introduced have happened throughout the history since there have always been new needs to fulfil and novel opportunities to benefit. There are innumerable technologies have been developed, introduced in the market, competing with the old ones and finally replacing them.

Only in the 20th century, there are many highly prominent examples such as the Internet, the automobiles, the nuclear technologies, the electrification, or the agricultural mechanization (Meieran 2012). It can be seen that all the previous examples represented an important step forward for a big part of the society if not for the whole. Thus, it seems clear that a technological innovation can represent not only a technological change but also social. In this direction, technological transitions describe how technological innovations occur and are incorporated into society considering elements such as user practices, regulations, industrial networks, infrastructures, and symbolic meaning.

Multi-level perspective is one of the most used ways for researchers and analysts to understand, model, explain, and even predict technological transitions. One common description of the multi-level perspective in a general manner is as follows (Geels 2011):

> *"MLP is a middle theory that conceptualizes overall dynamic patterns in socio-technical transitions. The analytical framework combines concepts from evolutionary economics (trajectories, regimes, niches, path dependences, routines), science and technology studies (sense making, social networks, innovation as a social process), structuration theory and neo-institutional theory (rules and institutions as deep structures on which knowledgeable actors draw in their actions, duality of structure)".*

As it is said, Geels uses many concepts from different areas of knowledge to conceptually explain technological transitions. Some of these concepts such as regime, or niche are deeply explained later since they are main elements in this view. Other concepts from economics, technology studies, or new-institutional theory, which is a theoretical perspective to understand organisational behaviour as situated in and influenced by other organisations and wider social forces, complement and give more sense to the whole perspective.

2.1.2 Introduction to multi-level perspective

The first step towards the current multi-level perspective was done in 1977 by Nelson and Winter when they coined the concept technological regime to represent the path of the successful designs and technologies considering mainly the beliefs and actions taken by firms. In 1998, Rip and Kemp criticized the inexistence of society as a path factor in the previous formulations, and using insights from economics and sociology, they created what they call "multilayered backdrop of novelty and irreversibility" which is based on two views: the "landscape" view and the "artifact" view. This last one makes equivalent technology to "artifacts" (or gadgets) which can be used without any suggestion or instruction of how they internally work. In 2001, Rotmans et al. developed this multi-level trait defining the three current levels of aggregation; the macro-level or socio-technical landscape, the meso-level or technological regime, and the micro-level or niches. Finally, in 2002 Geels switched the concept technological regime to socio-technical regime incorporating ideas from sociology, culture, policy, and users' characteristics.

The actual perspective is based on two main characteristics. First, it sees technological transitions as non-linear processes that results from the interplay of evolutions at three levels; niches (micro-level), socio-technical regimes (meso-level), and socio-technical landscape (macro-level). Second, transitions are defined as changes from one socio-technical configurations (or regime) to another one, meaning that technology has no power and does nothing by itself. Moreover, two characteristics have to be highlighted about the three levels. First, they "are not ontological descriptions of reality, but analytical and heuristic concepts to understand the complex dynamics of socio-technical change" (Geels 2002). Hence, the three levels are not absolutely true by nature but they may be modified if they are not valid in future cases. On the other hand, "each level refers to a heterogeneous configuration of elements where higher levels are more stable than lower levels in terms of number of actors and degrees of alignments between the elements" (Geels 2011). This statement refers to the idea that elements of lower levels are more autonomous and hence they are more changing and instable while higher levels are formed by many elements highly related and compacted what makes difficult to create changes and instability.

In the "horse-drawn carriages to automobiles" case, the two main characteristics of multi-level perspective are easily recognizable. About the non-linear nature of processes, the transformation from horse-based vehicles to automobiles also occurs in a non-linear way because of the repeated interaction between the three levels: the landscape which is composed by social and economic trends such as industrialisation or urbanisation, the regime which is composed by the current mainstream socio-technical configuration of the urban passenger transport, and niches which are composed by premature and isolated technologies separated from the regime such as the bicycle, the electric tram or the automobile in their first stages before entering to the main market. About the socio-technical nature of transitions, the case also exemplifies perfectly this idea since the regime does not represent only the current technology configuration (drawn-horses, electric trams, or automobiles) but it also includes all the social actors, systems, and rules that are related such as politicians, private companies, citizens, daily habits of people, or laws.

As it said, current multi-level perspective is composed by three different levels; the micro-, the meso-, and the macro-level which evolve and interact between them over time. In a general and conceptual manner, the way how these three levels are characterised and work is as follows (Fig. 1**¡Error! No se encuentra el origen de la referencia.**). The micro-level is the place where many small systems born in isolation with low interaction. They are created and developed with the aim to enter in the upper level which is much more extensive and complex. The meso-level is the one in the middle and hence it continuously interacts with the other two levels. It represents the environment or sets of rules where developed systems strengthen, evolve, and die. The macro-level does not contain any system inside but it represents the action gradient of the lower level, or in other words, it shows where the meso-level is moving through. It is the result of interactions between many different systems, rules and actors and hence it is highly complex. In short, the regime level can be seen as the main one since transitions happens there, and the macro- and micro-levels as derived concepts given that macro-level represents substantially practices or technologies that deviate from the existing regime and micro-level shows external environments related with niches (Geels 2011).

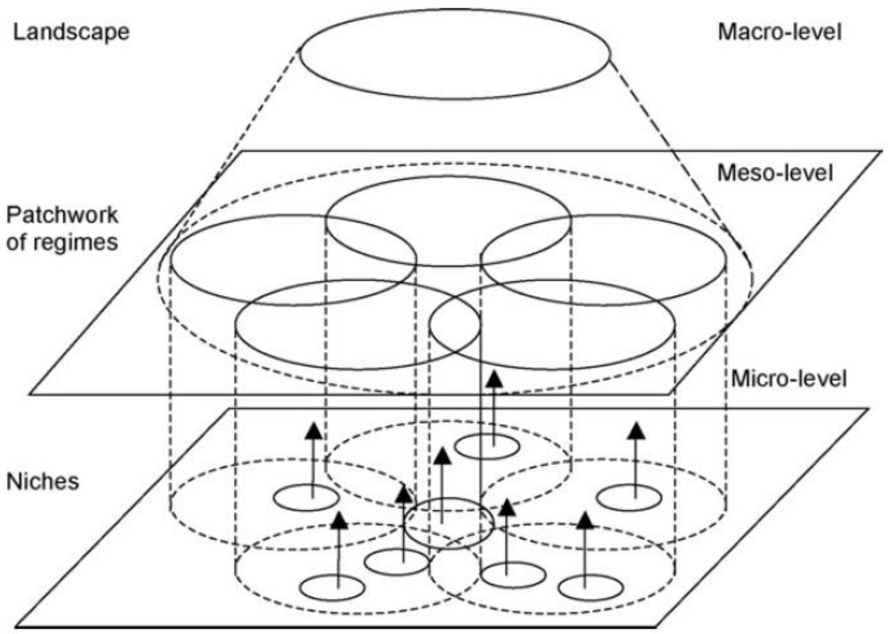

FIG. 1. The three levels of the multi-level framework. Reproduced from Genus & Cole (2008).

2.1.3 The three levels of multi-level perspective

The meso-level of this MLP is composed by the socio-technical regime. It is the locus of the cognitive routines or semi-coherent sets of rules that are currently shared in technical and social groups such as engineers, users, policy makers, or scientists within a specific industry. As it said before, this term was first defined only for engineers since it was easy to recognize that engineers in different organisations often search and work in similar directions. However, later this term was also extended because activities of engineers and socio-technical systems are also related to activities and hence regimes of other social groups (Fig. 2). Thus, this inter-groups relation and coordination is represented by the socio-technical regime concept. To better understand what this concept means it is interesting to know there is a basic ontology behind this socio-technical view composed by three different dimensions which interact with each other continuously:

- Socio-technical systems which are the tangible elements that fulfil the societal needs.

- Socio-technical actors and groups who create the socio-technical systems within a set of rules and routines.
- Socio-technical regime which is a set of rules and routines as a result of the action of the two other dimensions over time.

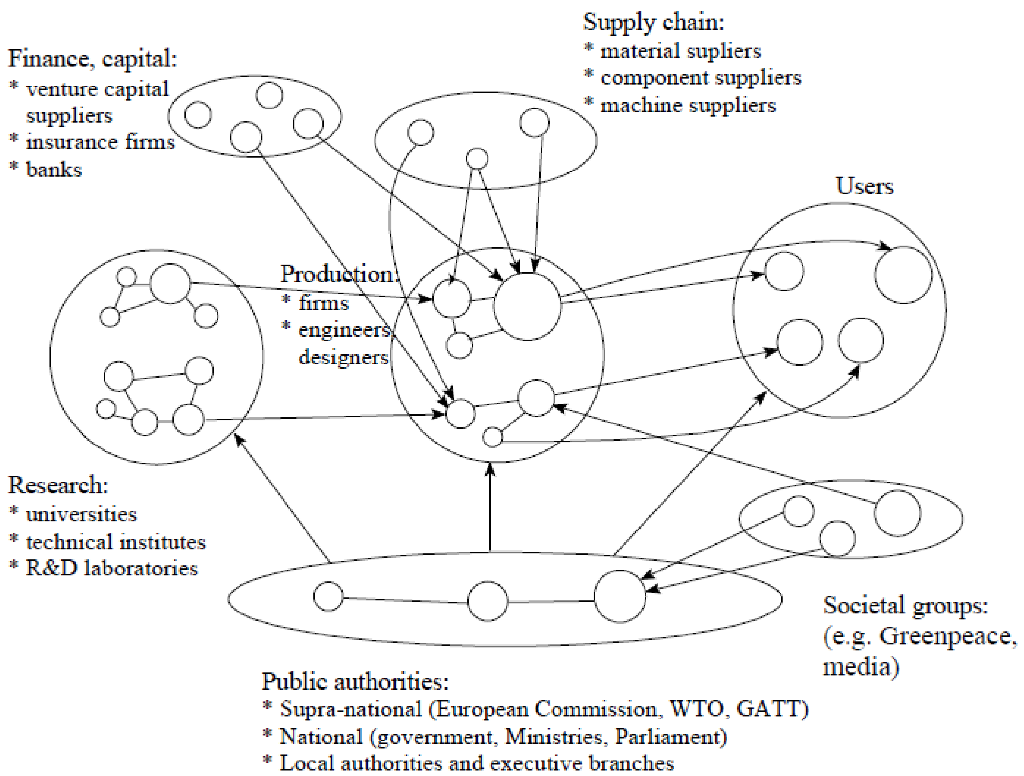

FIG. 2. Social groups that are part of a socio-technical regime. Reproduced from Geels (2005)

Practically, this inter-group coordination (or regime) leads to stability of existing socio-technical systems through many different rules and routines. For instance, sunken investments push companies not to abandon current products and systems but complete entirely their life-cycles, and hence sunken investments contribute to stability. Furthermore, organisations and companies of the same industry tend to create lobbies to have more power against possible new agents, products or systems which can steal part of their market share. Moreover, legally binding contracts, lifestyles and user practices, or favourable arrangements and regulations are also common elements that contribute to stability of the current systems. Overall, the meso-level (socio-technical regime) represents the socio-technical conditions that exist within an industry and that surround the socio-technical systems. As it said, this socio-technical regime promotes stability of the current systems and hence it avoids the entrance of new systems. Therefore, instability as well as radical innovations has to emerge from another place. The other two levels (micro- and macro-level) give answer to this issue.

The micro-level is represented by technological niches and it is where disruptive innovations originate in. These niches can have the form of small market niches or technological niches where resources are provided by public grants or private researcher investments, such as subsidized projects and R&D laboratories. New designs and technologies are not able to enter and directly compete on mainstream markets in the regime due to their low performance/price ratio. Thus, remote places like niches are the best place to grow and develop since they offer protection. Indeed, it is usually said niches act as "incubation rooms" with different selection criteria, more flexibility, and less pressure. Moreover, most of the niches actors are also different from the ones in the regime. Entrepreneurs, start-ups, and spin-offs are niche actors that work on their promising novelties with the goal to introduce them in the regime and even replace the current systems. However, this is not easy because of two aspects; the stability and lock-in mechanisms of current systems that the regime creates by its own, and the ease for niche-innovations to miss-match with the current regime dimensions. In other words, it is difficult to introduce novelties in mainstream markets because of barriers of entry and lack of appropriate supporting business processes. Nevertheless, to enter and succeed in the regime is obviously also possible as is discussed in the next paragraphs. In this direction, three specific internal niches processes that are vital for the first stage development are identified (Kemp et al. 1998):

- Articulation of expectations and visions: It provides planning, and aims to attract attention and funding from external actors.
- Social networking building: The aim is to get the enrolment of potential stakeholders to the new project.
- Learning and articulation processes: Technical aspects as well as supporting processes such as user preferences, infrastructure, or business models have to analyzed and developed.

The macro-level is exemplified by the socio-technical landscape which is the wider and exogenous environment. It highlights the technical, economical, demographical, political, and social backdrop that characterize currently industry or even society and that will probably sustain future systems. Hence, it indicates major trends of meso-level that escape from direct influence of actors and cannot be changed at will, at least in the near future. Thus, macro-level is influenced by meso-level but changes are usually slowly. On other hand, macro-level has also influence in the other direction, downwards. Thus, current regimes and niches, impulsed by actors, evolve according to identified trends and landscape in order to be well placed in the future. In short, macro-level, as well as micro-level, introduce instability to the regime what favours technological transitions.

In the passenger transport case, the regime is represented by the changing socio-technical configuration of the American passenger transport sector which embraces many components: The technologies themselves such as horse-drawn vehicles, electric trams, or gasoline automobiles; several actors like the working population, public authorities both estate and local, or companies; and rules and habits of the system such as estate laws, working and mobility costumes, companies' interests, or even types of pavement used.

On the other hand, the micro-level is modelled by the niches where the new technologies remain before entering to the regime. For instance, in the first stages of the analysis, bicycles and electric vehicles were not used for transport purposes but for fun and entertainment. Thus, these technologies were technically evolving in small markets separated from the passenger transport mainstream market. Finally, the macro-level is represented by social and economical trends such as globalisation, industrialisation, or sub-urbanisation. These were appearing slowly over time as result of the evolution of the whole society (which includes many regimes, not only the passenger transport) and at the same time they were putting pressure and creating windows of opportunity on the transport regime and also in the technological niches. For example, sub-urbanisation emerged as a result of the increase of a mid-class society and it favoured the apparition of a personal vehicle for this new class which was the gasoline car.

2.1.4 How Technological Transitions occurs

Multi-level perspective provides an ideal-typical view of how technological transitions occur. It proposes technological transitions take place only when dynamics between the three different levels become linked as it is drawn in the next page (Fig. 3). Thus, even though each transition is unique, the general pattern is characterised by interaction between the three levels: niches, regimes, and landscape. An important consequence of this statement is that transitions do not happen because a simple cause or driver but a circular inter-level causality since interaction goes in all directions and tendencies are constantly reinforced. (Geels 2005a; Geels 2011). Although this circular nature of the process, Geels (2005b) identifies three distinct phases since the radical innovation is born until it becomes part of the regime.

In the first phase, radical innovations originate in niches, usually outside of the current regime. Instability, fragility and variety are the main characteristics of these novel systems since they are many isolated undeveloped technical designs competing with each other, and changes and evolution occurs very fast. Actors improvise, experiment, and try new and unknown designs and systems within small networks with few resources. In short, innovations in this phase are not able to enter in the mainstream markets and hence do not represent a threat for existing regime.

In the second phase, innovations move from research niches to small market niches where production and commercialisation become a reality. This new source of capital allows innovators and researchers to continue developing their design or technology. Over time, this situation drives to the stabilisation of certain rules, habits, and technical characteristics, or in other words, a dominant design can begin to appear. The network around this innovation grows with new actors such as users of the niche market who can even create lobbies, or larger research and development groups. Despite this evolution of the new designs, they are not ready to enter in the main market yet because of technical specifications of the design itself or conditions of the main market which can be institutional, organisational, economical, and cultural. Indeed, these new designs and technologies can remain in this state for decades if the necessary and favourable conditions do not show up.

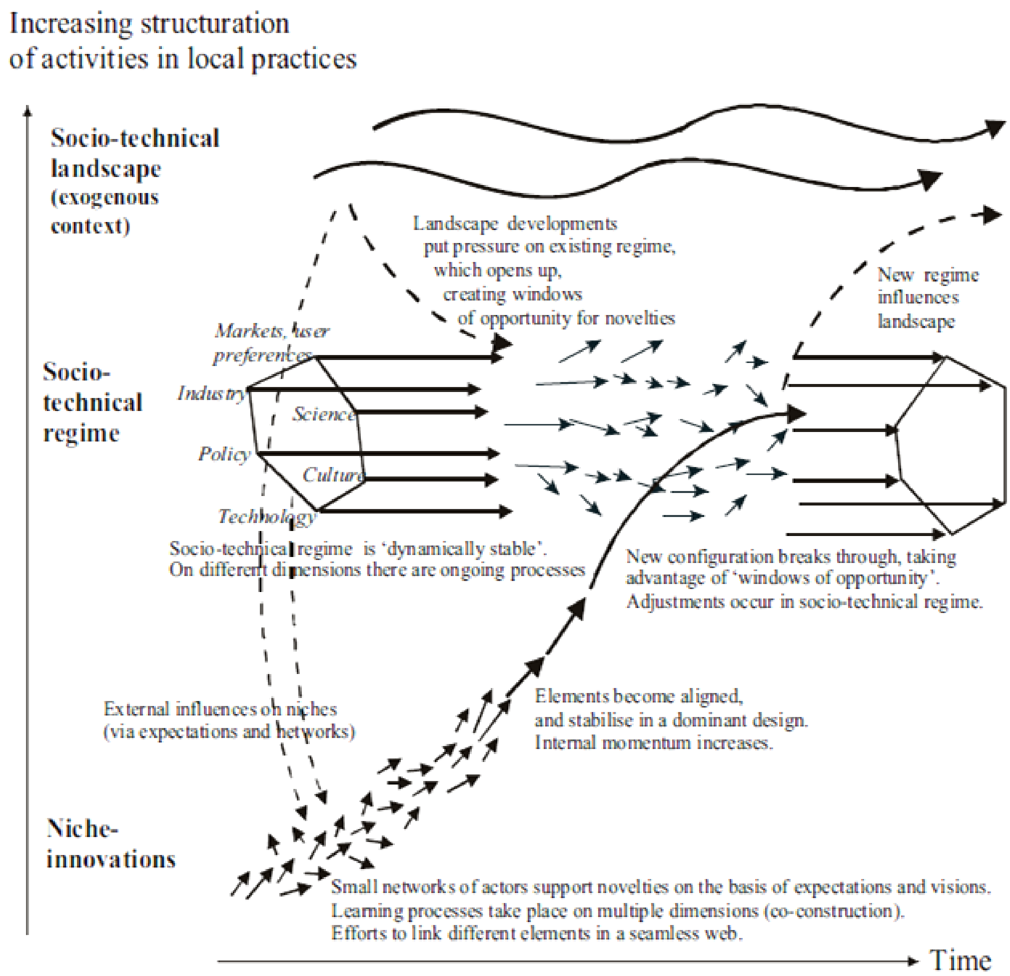

FIG. 3. Multi-level perspective of technological transitions. Reproduced from Geels (2002).

In the third phase, the innovation enters in the meso-level. It becomes part of the regime and it competes against the other current designs and technologies. As it said before, this moment is not really easy to happen since there are many factors involved. Geels (2005b) identifies three basic drivers that may determine if innovation enters to the regime or not:

- Internal drivers of the niche can promote niche actors to improve the design itself or its system. For instance, establishing a proper price/performance ratio of the new design which is a key factor to determine its entrance in the regime. These drivers can be increasing returns to adoption or decreasing investment costs, for example.

- Support of powerful actors of the regime to develop the design and overcome the possible barriers of entry created by companies or social groups. This support is often financial and/or social. Thus, since internal drivers act on the design itself, these drivers have direct relation with the regime and its challenges.
- Pressure and affectation that macro-level does above the regime to create motion and instability which can result in windows of opportunity later. Social, cultural or economic trends at the landscape are the most usual reasons. Specifically, opportunities appear when the different dimensions of the techno-social regime do not go in the same direction and there is stress between actors of different groups.

Overall, the multi-level perspective highlights that dynamics and developments in the three levels are important to determine the success (or not) of an innovation in the regime. Thus, innovation internal characteristics (of the niche), and external (of the regime and the landscape) have high influence in the third phase (when innovation enters to the regime), as well as in the previous two phases since landscape can early interact with the niche level motivating new designs or with the regime level creating instability. All these inter-level processes are reinforced and with no simple direction of affectation. For instance, one change in meso-level may result on a change in the macro-level which may later affect again the macro-level. Thus, all the process is very complex and also non-linear and uncertain. One small innovation with apparent few potential may suddenly rise sharply because of some change in another level. On the other hand, one developed innovation may stay in the second phase during much time (if not forever) waiting for the proper external conditions. In short, multi-level perspective is often useful to explain technological transitions since all the elements, actors, and paradigms are represented. However, each practical case is different because interactions and dynamics occur differently in both space and time.

2.1.5 Applications and challenges of the multi-level perspective

Multi-level perspective has been applied to understand and explain many historical cases of different sectors and industries such as automobiles (Geels 2005b), water supply (Geels 2005a), as well as shipping, aviation, highway systems, and industrial production. On the other hand, there are also some examples where multi-level perspective has been used to model and predict future states of sectors such as power generation systems (Verbong & Geels 2007), pig farming (Elzen et al 2011), electric cars, biogas and co-combustion, and organic food. (Geels 2011). However, the way how multi-level perspective is applied is quite different. In historical cases the goal is to discover why and how technological transitions happened considering the three levels: new innovations, regime evolution and wider trends, while in future cases the specific use of the multi-level perspective is more diverse and depends on the case. Thus, Elzen et al. (2011) focus only on the influences between landscape and regime to analyse future states of the regime. On the other hand, Smith (2007) only works on the relation niche-regime and identifies three kinds of translations that affect the current and future niches and regimes practices. Overall, while in historical cases multi-level perspective is fully used to explain the whole technological transition, in most of predictive cases this framework is only partially used to explain one specific stage or interdependence of a technological transition.

As all the previous cited cases show, the multi-level perspective has become a practically useful tool to analyse technological transitions. However, during the last decade, several authors have identified some problems and weaknesses of this perspective. As an answer, Frank W. Geels who created the current framework had written in 2011 the paper "The multi-level perspective on sustainability transitions: Responses to seven criticisms" in which he discusses all the criticisms and gives his personal opinion. Here, some of them are recalled. Firstly, it has been noticed the multi-level perspective is more about illustration and description that a systematic method of research since each specific case uses its own methodology that complements the multi-level view such as event-sequence analysis, network analysis, even-history methods, and agent-based modelling. Geels argues this is totally true but it does not represent a problem because it is the natural complexity of technological transitions that forces researchers to use this kind of creative and boundaries-less studies instead of working in a closed view. Secondly, the multi-level perspective does not limit the dimension of the empirical topic. Thus, this perspective can be used to study narrow objects such as a specific product in a determined region, as well as wider ones, such as a whole industry sector worldwide. Obviously, the scope of the topic has implications on the functioning of the regime because factors such as number of actors, amount of rules, or interaction between elements can differ notably. Finally, technological transitions are defined as sustainable long-term changes in the social and technical space and since they do not frequently happen, it is difficult (if not impossible) to build large datasets to be applied in new cases. Hence, it is complicated to use hard methods based on numeric and statistical practices instead of softer methods which are more descriptive and probably subjective. As Geels argues, it is easy to understand that since scholars do not still agree about the origins and causes of huge technological transitions and social changes such as the Industrial Revolution or the French revolution.

2.2 Scenario building theory

This chapter aims to explain the reader the other theoretical framework that is used in the analytical part of the thesis, the scenarios theory. The chapter is divided in four main parts, each of them describing different aspects related with scenarios. In the first part, scenario studies are introduced underlying their suitability in subjects with high uncertainty. A brief story as well as some outstanding definitions of scenario is provided. In the second part, some scenario typologies are cited to finally explain in detail one that fits very well with the current situation. Then, considering the wide amount of different types of scenario studies, some general steps and aspects regarding the scenario building process are given. The final part aims to be critic offering an overall vision about the advantages and challenges of scenarios.

2.2.1 Introduction to scenarios

From the beginning, humans have always been interested in trying to figure out what will happen next in order to take decisions in the present that fit better with this expected future. The weather was probably the first thing that humans tried to understand and know since it was a vital environmental factor in the daily life of men of prehistory. Over time, this concern about the future has enormously spread and today the future is aimed to be known in fields such as economics, politics, health, sport, marketing, and demographics, among many others. It is widely recognized that it is not possible to agree many statements about the future but mainly only one; the future is uncertain. (Wilson 2000). Practically, the level of the usefulness of statements about the future differs from case to case. Nevertheless, three main categories of uncertainty are identified:

- Risks: There are enough historical precedents and data to predict the future by estimating probabilities for various possible states.
- Structural uncertainties: It is possible to imagine and identify the possible states that might occur in the future although the states are unique enough not to have historical data to use.
- Unknowable uncertainties: It is not even possible to imagine the possible states that might happen since it is something completely new and unexpected.

Weather forecast and cancer prediction are practical cases containing risks and hence the exact odds for a rain or for a patient to suffer breast cancer can be predicted. The accuracy of these predictions obviously depends on the available data and the model built but in an ideal case, we would be able to calculate the exact probabilities using statistical methods. These examples look promising but unfortunately the most of the cases in planning contain structural uncertainties which cannot be numerically evaluated. Basically, in these cases the possible future can be imagined but the patterns in events that drive to them can be interpreted in several distinct ways. Hence, the question is how we can manage this uncertainty that cannot be estimated. The answer is that not everything about the future is uncertain and hence unpredictable. Thus, what is needed is an approach that allows us to separate what is uncertain from what is not about the future. This is exactly what the scenarios analysis aims to do. “There are many other approaches to discover what the future might hold, but few provide the insights and genuine learning that scenarios analysis can provide. Practically, scenarios can help decision-makers to differentiate between what is truly uncertain and what is more predictable” (Blyth 2005).

There are many different views about what scenarios exactly are. They can be seen as "consistent and coherent description of alternative hypothetical futures that reflect different perspectives on past, present, and future developments, which can serve as a basis for action." (Van Notten 2006). Other scholars consider scenarios not only as the description of the final future state but the path between the actual and that final state (Warfield 1996). The nature of the final scenarios built is also sometimes considered including in the description that "these hypotheses must simultaneously be pertinent, coherent, plausible, important, and transparent" (Godet & Roubelat 1996). Other definitions proposed include terms such as causal coherence, internal consistency, descriptive nature, and qualitative information among others. In short, there are many distinct views but one point is common in all of them: scenarios are not predictions either science fiction but something in the middle (Van Notten 2006).

The word scenario comes from the Latin word "scaena" which means scene (Ringland & Schwartz1998) although the concept scenario related with planning is much more recent. It first emerged during the World War II as method for military planning. In 1950s the American Department of Defense used scenarios for organizational and institutional purposes and during the next decade, Herman Kahn, who was in American Air Force, refined scenarios as a tool for business prognostication. The 1970s can be considered a very fruitful decade for scenario-planning thanks to the successful work of Pierre Wack. He was a planner in the London offices of Royal Dutch/Shell that used scenario-planning to study events that might affect the evolution of the price of oil and provided Shell managers useful information to support strategic decisions. In the following years, Shell moved from a delicate market position to be the second in size and the number one in profitability. Subsequently, "scenario-planning appeared in most management books including Michael Porter's on competitive advantage, Peter Senge's on learning organization or Herny Mintzberg's on strategic planning." (Wilson 2000). Since then, scenarios theory have divided into several different directions as continuing Pierre Wack's view, today better known as "Intuitive Logics" school, like Peter Schwartz (Ringland & Schwartz 1998), van der Heijden (Van der Heijden 1996), and Ringland did, or with the rise of the "French strategic prospective" school promoted by Jacques Lesourne and Hugues de Jouvenel (De Jouvenel 2000). (Bradfield et al. 2005).

Nowadays, the scope of scenario analysis is very wide. It is used in many fields, by a wide range of bodies, using different types of data, designing the scenarios in different ways, and with distinct goals or motivations. However, four main basic purposes of scenario building are identified (Fahey & Randell 1998):

- Better understanding of what possible futures might look like, how they might come about, and why this might happen
- Favour new decisions by providing fresh considerations to surface
- Reframe existing decisions by setting a new context
- Identify contingent decisions

Overall, the outcomes of a scenario analysis can be useful to know the possible future states, and the factors affecting the evolution through them, and to take new decisions as well as modify the current ones according to these hypotheses.

2.2.2 Scenarios typology

Given the extension of scenarios application scope, the need of a scenarios typology has been identified since it provides a common basis to define any practical scenario analysis as well as it makes easier to find out where is the field moving through. In the last two decades several typologies have been done but most of them are not valid nowadays because they are already obsolete or the degree of detail is not enough to recognize all the existent differences. Nevertheless, the typology designed by Philip W.F. van Notten responds really well to the current state of scenarios analysis (Van Notten et al. 2003; Van Notten 2006). It is based on an extensive review of scenario literature as well as an important amount of scenario study cases, and it defines two levels of description of scenario studies; the “macro” and the “micro” level. The former gives a primitive comparison addressing the “why”, “how”, and “what” of a scenario study, while the later gives an in-depth description of several specific aspects which are categorized according to the macro characteristic that are most related with (Table 1. Typology of scenario studies. Adapted from van Notten (2006)Table 1). Both “macro” and “micro” characteristics are described next:

A. Goals of scenario study: There are two poles in relation with the kind of goals the study aims: Exploration that means learning, stimulation of creative thinking, and investigating interactions in order to find something previously unknown; and pre-policy research that means studying possible paths or states but presetting factors such as specific events to happen or even final states to occur. However, practical studies are often hybrids of these two extremes.

   I. Function of scenario study: It refers to what is interesting of the study. A study can be process-oriented what means that the focus in on how the output comes and hence the important is the affectations and interactions that occur during the process, or it can be product-oriented what means that the concern is about the nature and quality of the output or final states.

   II. Role of values in the scenario process: It relates to why the study is interesting. In descriptive scenarios, the process is done without any kind of preference or preset condition and the outcomes of the study themselves is what is interesting, while in normative scenarios, apart from the outcomes found, the interest is also on justifying that something desired will happen under certain conditions.

   III. Subject area covered: It refers to the type of subject studied which can be issue-based, area-based, or institution-based. In the first, the subject is a specific societal group, sector, market, product, or any other system. In area-based the subject is a specific region, country, or city. In institution-based, the subject is the spheres of interest of a specific organization or social group. The time scale (long- or short-term) has also to be specified depending on the kind of subject treated.

IV. Nature of the change addressed: It specifies which can of change the subject experiments; evolution or discontinuity. Evolutions are based on gradual progress of an identified pattern or system through space and time while discontinuities are result of the apparition of a new pattern or factor. It can be distinguish between abrupt discontinuities which have a sudden nature and are often connected with underlying processes, and gradual discontinuities which are self-reinforcing processes that include a set of social, economical, and technological developments.

B. Design of the process scenario: This dimension refers to the general type of methodological approach used in the study. Even though there are many different communities with their own methods, they all can be classified into analytical or intuitive. Analytical approaches are the most rigorous and less flexible. The most common techniques are model-based which can involve conceptual relations as well as arithmetic calculations or computer simulations. On the other hand, intuitive approaches rely much more on qualitative knowledge. These can be also divided into deductive if a framework like a two dimensional matrix is created in the beginning of the process that supports the rest of the study, and inductive if the process is much freer without any structure only using coherent stories and patterns. Often, intuitive studies match better with exploratory purposes and analytical studies with pre-policy researches.

V. Inputs into the scenario process: The inputs can be divided into qualitative and quantitative. The formers are suitable when the study contains much uncertainty and the information needed is too complex to be quantified. On the other side, quantitative inputs are often used in analytical approaches, mostly in computer models. Using both inputs at the same time can make outputs much more robust although their treatment together still remains challenging.

VI. Methods employed in the scenario process: The two extremes in this dimension are participatory and model-based approaches. The first ones call for the contribution of ideas from different experts or stakeholders and the later process and structuring of the data collected. On the other hand, model-based approaches often support analytical methods which can be computational and using quantitative data, or conceptual and using qualitative data such as cross-impact or “la prospective” analyses. A third group of methods between the both extremes is called desk research which is an analytical approach often developed by a small team of researchers through documental analysis or archival research. However, desk research is not exclusive of any method and hence it varies a lot depending on the study case.

VII. Groups involved in the scenario process: It refers to the amount of different types of people that participate in the process. Inclusive groups are composed of people from different areas in order to get more different views while exclusive groups are designed to be small without outsiders.

C. Content of the scenarios: The last macro characteristic has relation with the content that the scenarios have. It is mainly distinguished between complex and simple scenarios. The firsts have a complicated net of interactions between elements or casually-related events while simple scenarios can be result of the extrapolation of isolated trends. It is important to highlight that simple does not mean weak since simple scenarios often are more effective and less costly.

I. The role of time in the scenario: The content of the scenarios can mean a chain of events or a snapshot (of the final state) without explicitly describing the processes that result in that final state.

II. Issues covered by the scenario: This dimension does not represent which kinds of issues (political, technological…) are treated but if they all belong to the same type or not. Thus, a heterogeneous scenario study may include variables from demographics, economics, and technology, while a homogeneous study would include variables from only one issue such as economy.

III. Level of integration: It refers to the degree of interaction between all the variables. Thus, in an integrated scenario study, the end state is result of an analysis where putting with all the variables (or most of them), while in an isolated study, factors are studied independently.

"Macro" characteristic		"Micro" characteristic	
A.	**Goals of scenario study** Exploration/Pre-policy research	**I.**	**Function of scenario study** Process/Product
		II.	**Role of values in the scenario process** Descriptive/Normative
		III.	**Subject area covered** Issue-based/Area-based/Institutional-based
		IV.	**Nature of change addressed** Evolutionary/Abrupt or gradual discontinuity
B.	**Design of the scenario process** Intuitive/Analytical	**V.**	**Inputs into the scenario process** Qualitative/Quantitative
		VI.	**Methods employed in the scenario process** Participatory/Model-based
		VII.	**Groups involved in the scenario process** Inclusive/Exclusive

C.	**Content of the scenarios** Complex/Simple	**VIII.**	**The role of time in the scenario** Chain/Snapshot
		IX.	**Issues covered by the scenario** Heterogeneous/Homogeneous
		X.	**Level of integration** Integration/Fragmented

TABLE 1. Typology of scenario studies. Adapted from van Notten (2006).

2.2.3 Scenarios building process

Considering the previous section, it can be said that the possible nature of a scenario study is very wide. The same happens with the methods that can be used to develop the study. Nevertheless, there is set of general steps that has to be often followed, mainly in intuitive scenario studies where there is not any preset model to carry out (van Notten 2006; Wilson 2000; Blyth 2005):

- Identification and description of the scope, issue(s), and subject of the study as specifically as possible.
- Identification of the variables that may act as driving forces of change being as open and creative as possible not to forget any important variable.
- Clustering the variables previously identified in order to obtain a smaller set of key variables more meaningful and manageable.
- Rank the key variables according to two aspects; their importance or impact on the topic, and their uncertainty. The variables with highest scores in both aspects are likely to be added as dimensions of the final scenario.
- Creation of scenarios. Usually, the dimensions are first defined and then the scenarios are located and described.
- Evaluation of the scenarios obtained, and description of the possible decisions required or suggested. This step is only needed if the study aims to support decision-making.

In last steps, when creating the set of scenarios, some points have to be taken into account. First, "the golden rule in deciding the number of scenarios is no less than two, and no more than four" (Wilson 1998). Obviously, less than two scenarios means that there is no alternative hypothesis what is the basis of scenarios analysis. On the other side, if the number of scenarios is too large, two problems may appear. First, the scenarios may be overlapped and second, it may result difficult to describe in detail all of them. In any case, a set of five criteria for selecting scenarios have been defined (Wilson 1998, Wilson 2000):

- Plausibility: The scenarios have to be possible to occur.
- Differentiation: The scenarios have to be structurally different.
- Consistency: The scenarios have to be internally built in a consistent way.
- Decision-making utility: Each scenario has to provide specific insights to decision-makers about the future.

- Challenge: The scenarios have to outface the current beliefs and provide new ideas about the future.

2.2.4 Scenarios strengths and challenges

Nowadays, scenario studies are considered to have several strengths that make them useful by themselves as well as over other methods (Mietzner & Reger 2004; Wilson 2000):

- Scenarios move away from forecasting one unique future to foresight several hypothetical futures what makes scenarios very suitable for complex subjects impossible to predict.
- Scenarios can offer ideas and possible states difficult to think about without them. During the building process as well as in the final decision-making step, people are force to think out of box what can result on outstanding improvements.
- Scenarios are an appropriate manner to identify weaknesses as well as technological discontinuities and market disruptions what is vital for companies in highly changing markets.
- During the scenario building process, conversation, coordination, and organizational learning can be improved what is very important for companies in general.

In contrast to these four strengths, scenario studies also have some weaknesses or challenges (Mietzner & Reger 2004; Wilson 2000):

- Scenarios require a lot of time to be built what can be difficult to manage in private companies.
- Qualitative approaches basically rely on the proper amount and suitability of participants what in practice is often difficult to manage.
- Scenario studies also require a deep understanding of the field and hence scenario builders often have to do an extra previous task of collecting data and information.
- Given their usual intuitive nature, scenarios can easily represent the most likely scenarios or only the worst and best scenarios, instead of some states more unknown and balanced.

Overall, scenarios studies are very useful and have advantages above other methods for both researchers and companies since they can handle with problems with high levels of uncertainty and they force developers to think “out of the box”. On the other hand, this potential is offset by the considerable amount of resources that scenario studies needed in terms of time, people, and knowledge.

3. THE CONTEXT: THE CATALAN HIGHER EDUCATION

This chapter pursues three different objectives. Firstly, to introduce the reader in the study case what means Catalonia and its higher education system. The second goal is to draw out how the actual system is, paying special attention to the methods and activities that are used in the learning process in order to compare it later with the future states resulting from the analysis. Finally, the last aim is to describe the action plan that the Catalan government has defined and planned for the university system underlying the lack of any study or action of technological nature on it.

Concretely, the chapter is divided in four main parts. The first one contains an introduction about Catalonia in order to locate the place where the study case is done in the map and to give the reader some characteristics about this region underlying the special political organisation that the country has. The second part focuses on the Catalan higher education and it gives a description of the whole system including information about amount and types of universities, structure of the studies, staff categories, and amount of students, among others. The third part is about the specific way how students learn in the Catalan system using the concepts “teaching paradigm” and “learning paradigm”. Finally, the focus in on the future of the Catalan university system where information about the action plan of the Catalan government is provided highlighting its managerial nature and the lack of any kind of technological novelty.

3.1 Introducing Catalonia

Catalonia (*Catalunya* in Catalan) is an autonomous community of Spain, considered as a nation by its Statute of Autonomy. It is located in the north-east cost of the Iberian Peninsula bordered by France and Andorra to the north, the Mediterranean Sea to the east, and the Spanish regions of Aragon and Valencian Community to west and south (Fig. 4). Catalonia is composed by four provinces: Barcelona, Tarragona, Girona, and Lleida. Its capital and largest city is Barcelona which is the second most populated city in Spain and one of the most important metropolitan hubs in the Mediterranean area. The Catalan economy is mostly based on the service sector with a high influence of tourism although the industrial sector has also an important role. In 2008, the regional GDP was the highest in Spain, and Catalan per capita GDP was similar to countries such as United Kingdom or Austria. On the other hand, Catalan estimated population is around 7.550.000 citizens what makes Catalonia the second most populated autonomous community in Spain. About languages, three different ones are considered as official which are Catalan, Spanish, and Occitan.

FIG. 4. Map of Europe denoting the location of Catalonia. Reproduced from ICC (2014).

Nowadays, as a result of the Spanish transition to democracy, Spain is organizationally structured as it is called State of Autonomies resulting in one of the most decentralized countries in Europe. Thus, autonomies communities have their own elected parliaments, governments, public administration, budgets, and resources (*Congreso de los Diputados* 2003). Moreover, health and education systems among others are managed regionally, and even a few autonomies also manage autonomously their own public finances or their own police corps. Furthermore, a "historical nationalities" like Catalonia have some additional powers such as the ability of the regional president to dissolve the parliament and call for election at any time (Agencia Estatal Boletín Oficial del Estado 2013). Specifically, Catalonia is mainly politically organised through the *Generalitat de Catalunya* which is formed by the Parliament, the Presidency of the *Generalitat*, the Government Council and the other institutions created by the Parliament. The actual president of Catalonia is *Artur Mas*, the leader of the Catalan liberal nationalist party.

3.2 Introducing the Catalan higher education

The Catalan university system is composed by 12 universities which offer under-, post-, and graduate programmes in almost all the knowledge fields such as architecture, design, biomedicine, physics, chemistry, mathematics, economy or engineering. Specifically, seven of these universities are public and managed by the Catalan government, four are private, and the last one is online and public. In total, there are 26.300 staff that teach around 225.000 students among an offer of around 1.300 university programmes. Besides the teaching side, Catalan universities are internationally well known for their activity in research, and play an important role in innovation and knowledge transfer. (*Generalitat de Catalunya* 2013). This is proved in studies like the Spanish ranking I-

UGR[1] (Torres-Salinas et al. 2014.) where Catalan universities are leading 10 of the 12 evaluated fields, or in the Times Higher Education 100 Under 50[2] (TSL Education. 2013) where three Catalan universities are present. For all these reasons, Catalan system, and by extension, Catalonia aims to become the knowledge pole in Southern Europe cooperating and competing at the international level.

The actual state of the Catalan university system is result of a process of expansion and consolidation that the system has suffered for the last 30 years. In 1985, the *Generalitat de Catalunya* received the competence on the higher education system when only three universities existed in Catalonia: University of Barcelona, Autonomous University of Barcelona, and Polytechnic University of Catalonia. In 1996, the number of universities was already 8 and during the years after, 4 private universities also started their activity. This evolution has not only been about the amount of institutions, the orientation of these organisations also changed from only teaching to teaching plus research, innovation, and knowledge transfer. (*Generalitat de Catalunya* 2012a).

Today, the structure of the studies that can be taken in Catalan universities follow the European framework. There are three different categories, each of them resulting in the acquiring of their correspondent official diploma of bachelor, degree, and doctorate:

- Bachelor studies are the first studies to do in the university. The goal of them is to obtain a general knowledge about some specific field. They have a total length of 240 ECTS (what is equivalent to a minimum of four years) and they contain both theoretical and practical formation, distributed in the next categories: basic formation, obligatory courses, elective courses, internship, and bachelor thesis.
- Master's degree studies can be begun after getting a bachelor. The goal of these studies is to obtain an advanced knowledge, through specialisation or multidisciplinary, oriented to professional or academic specialisation, as well as, research. They have a total length between 60 and 120 ECTS (what is equivalent of a minimum of 1 or 2 years) and they contain theoretical and practical formation, distributed in the same way as bachelors, plus leaded projects. All the degrees belong to one of these fields: arts and humanities, science, science of health, social science and law, and engineering and architecture.
- Doctoral studies drive students to the obtainment of competences and abilities related with the high quality scientific research. The goal of these programs is that students acquire different formative aspects related with procedures and research lines in order to be able to develop properly a doctoral thesis. The mini-

[1] The Ranking I-UGR of Spanish Universities according to Fields and Scientific Disciplines is based on research production on international journals with high impact and visibility.
[2] The Times Higher Education 100 Under 50 is a ranking of the top 100 universities under 50 years old. It provides a glimpse into the future, showcasing not those institutions with centuries of history, but the rising stars which show great potential.

mum length between the doctoral admission and the thesis presentation is three years at full time, or five years at half time.

The different existent categories of teaching and research staff are regulated by a state law called LOMLOU[3] which provides information of each category about qualifications required, functions, and general content of remunerations. The eight categories defined are:

- Professor: It is the highest position in the academic career, with a permanent contract, and very high professional requirements.
- Aggregate professor: It has also a permanent contract but the professional requirements are softer since its research tasks are not as advanced as a professor.
- Lecturer: It is the first stage in the academic career and it is a fixed-term contract with a maximum of four years. The main difference is that it only composes teaching tasks, no research.
- Associate professor: It is a specialist in some specific field that is currently working also outside the university system. It has only teaching tasks and the contract is fixed-term.
- Visitant professor: It is also a specialist in some specific field but it does not have to be currently working. The contract is fixed-term and its tasks (teaching or research) can vary depending on the specific case.
- Emeritus professor: It is a retired professor with an outstanding career and its tasks can vary depending on the specific case.
- Assistant: It is a doctoral student with fixed-term contract and with teaching and research tasks.
- Doctor assistant: It is a doctor with fixed-term and full-time contract.

Overall, there is an important amount of categories depending on the kind of contract, the tasks to develop, and the professional requirements. Nevertheless, what is important to underline is the distinction between staff with indefinite contracts (professors and aggregate professors) and staff with temporal contracts (the rest). As it is argued next, the proportion between these two groups is an important characteristic of a university system.

Using the data of Table 2, it results that the Catalan systems have around 51,26% of indefinite staff which are considered to be definer and responsible of teaching and research functions, while the rest 48,74% of staff which have temporal contracts give more flexibility and variety to the system. The Catalan government considers that a proper ratio of indefinite staff per temporal staff is from 1:3 to 1:1 depending on the importance of teaching over research. Thus, the Catalan system is theoretically over-

[3] LOMLOU is the abbreviation of "Organic law of modification of the organic law of universities". Further information in: http://www.boe.es/boe/dias/2007/04/13/pdfs/A16241-16260.pdf

crowded of indefinite staff resulting in a rigid system, not able to respond fast to environmental changes.

Type of staff	Quantity
Professors	5.848
Aggregate professors	1.536
Lecturers	493
Associate professors	6.655
Other temporary full time staff	346
Emeritus professors	498
TOTAL	15.376

TABLE 2. Staff of the Catalan university system on the date 1/1/2014. Adapted from *Generalitat de Catalunya* (2014a).

Considering the data of Table 3, it can be stated that the Catalan higher education is mostly based on a public system which is managed in general by the Catalan government although universities have a high degree of autonomy regarding staff hiring, or study programs and research topics selection, among others. On the other hand, considering both previous tables, the ratio students per staff is around 15:1[4] which is quite higher compared with other European systems where this ratio is around 10:1 (*Generalitat de Catalunya* 2012b).

Type of university system	Number of students	% of students
Public system	203.246	90,17
Private system	22.153	9,83
TOTAL	225.399	100

TABLE 3. Number of students in the Catalan university system in the course 2011-2012 (IDESCAT 2013).

Due to the multi-lingual reality that Catalonia presents, it is also interesting to comment how this is managed in the university system. In bachelor studies which are only almost taken by native students, Catalan is the main language with a use percentage of around 80% and Spanish is used in the 20% left. On the other side, in master's degree studies, where the percentage of international students is approximately 35%, the configuration is different (Fig. 5). Catalan is still the most used language but with less than a 60% of presence. Thus, Spanish and English have each one a 20% of presence. Nevertheless, the trend is to increase the master's degree studies taught in English to the detriment of ones in Catalan in order to favour the entry of more international students.

[4] This ratio is not very accurate since it is calculated using data from different years for students (2011) and staff (2013). However, the resulting value using the proper data may be very similar since variation over years is low.

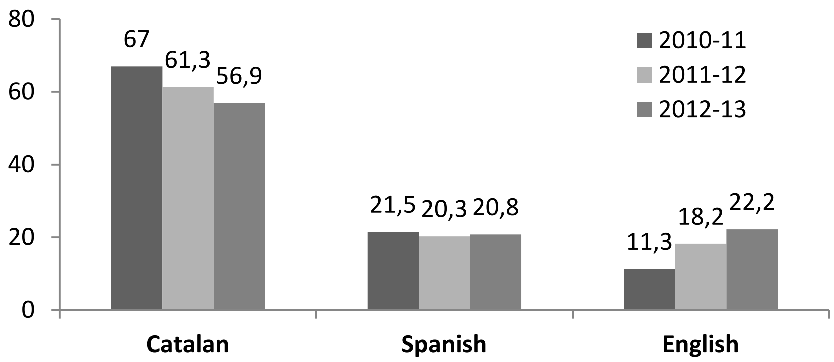

FIG. 5. Evolution of the percentage of master's degrees taught in a certain language in the period 2010-2013 for the public university system (*Generalitat de Catalunya* 2014b).

3.3 Teaching paradigm of the Catalan university system

The paradigm can be understood as the set of rules that are established around a specific system as the higher education. One basic function of these rules is to define the boundaries of the system and its domain of possibilities. Thus, the paradigm of the university system is composed by the processes and methods that are usually employed and that result on the qualitative and quantitative possibilities than students can perform in their learning process. (Barr & Tagg 1995).

Regarding the usual processes and methods used to teach students, the Catalan system is not different to the vast majority of higher education systems. Hence, the paradigm used is the dominant worldwide. Specifically, new theoretical content, practice of this content, and final assessment are performed as follows. Theory is provided in face-to-face classes where one teacher explains the content often to a group of between 50 and 200 students during one or two hours. Thus, this process is characterised by several main structures: Scheduled classes; one teacher, one room; covering material goal; and attendance obligatory. Later, depending on the specific field and topic, this theoretical content can be put into practice in face-to-face classes with smaller groups of students in diverse places such as normal classrooms, computer rooms, or labs with specific material. Finally, this content is assessed in the middle or end of the course on-line or in an attendance class using several different formats. Mainly, three distinct assessment formats exists; multiple-choice tests, essay tests, and problem-solving test (Biggs & Tang 2011), which are more or less suitable depending on several factors such as the qualitative or quantitative, as well as the contextualized nature of the content, the time constrained, or the outcomes desired.

In the higher education context, it is widely spread the distinction between two main paradigms; the teaching paradigm and the learning paradigm. The teaching paradigm is the one traditionally used and it primarily conceives teaching as delivering 50-minuts-lectures (or more) with the final mission of providing instruction. Practically, in this paradigm, a preset specific methodology determines the boundaries of what universities and students can do in the learning process. On the other hand, the learning paradigm establish the production of learning (not of teaching) as a main goal which can be achieved using structures that support the student as a centre and controller of the learning process without only fixed schedules, linear contents, or non-cooperative methods. Specifically, there are some important differences between both paradigms. While one mission of the teaching paradigm is to offer courses and programs, the learning paradigms aims to create powerful learning environments that allow students to learn by their own. Moreover, in the traditional paradigm, the classroom and learning are competitive and individualistic, whereas in learning paradigm, learning environments are cooperative, collaborative, and supportive. Furthermore, in the learning paradigm, staffs are not primarily lecturers but designers of learning methods and environments although lectures are also an option if it suits. Nowadays, it is by in large recognised that the teaching paradigm mistakes a means for an end since truly teaching is only a way to achieved learning, the real purpose of an education system. Moreover, it is noticed that "the passive lecture-discussion format which is the primary learning environment of the teaching paradigm, is contrary to almost every principle of optimal setting for student learning." (Barr & Tagg 1995).

Considering the previous paragraph describing the actual processes used in Catalan university system, and the one defining both teaching and learning paradigm, it is easy to conclude that the current paradigm used in Catalonia, as well as in the vast majority of systems, is the teaching paradigm. It is important to highlight that this study revealing the weaknesses of the current paradigm and the opportunities of the new one, was released in 1995. Nevertheless, it resulted very difficult to undertake this change and hence the traditional paradigm still remains dominant. This difficulty can be result of many different factors but one that has likely affected is the lack of certain technology developments.

3.4 The future of Catalan higher education

It is known that knowledge is in the base of growth and development of societies and economies and hence universities have high social and economical responsibilities. Thus, for the last several years, the specific role that higher education has to play in the social and economical development of societies has been widely discussed. One conclusive text was provided in 2008 by the OECD defining four main missions for any higher education system (Tremblay 2008):

- Human capital formation (teaching)
- Knowledge bases building (research and knowledge development)
- Dissemination and use of knowledge (knowledge spread)
- Knowledge maintenance

This concern regarding the social responsibilities of universities have also been discussed in Catalonia where the government finally defined a list of objectives through learning, teaching, and research that aim to be achieved which is reproduced next (*Generalitat de Catalunya* 2012b):

- The creation, transmission and dissemination of culture and knowledge in scientific, technical and professional fields and the humanities.
- The promotion of critical thought; the culture of freedom, solidarity and pluralism; and the transmission of the civic and social values that underpin a democratic society.
- Enriching Catalonia's intellectual, cultural and scientific heritage with the aim of furthering general, social and economic progress and the sustainable development of the region.
- The incorporation of the Catalan language into every area of knowledge and contributing to the process of making the scientific, cultural and social use of Catalan standard.

The first objective covers the second and third points given by the OECD which are related with knowledge creation and spread. The second one makes reference to the human capital formation in the personal side, while the third objective focuses on the academic human formation which must have result on the social and economic evolution of Catalonia. The last goal has relation with the Catalan culture underlying the important protection of the language in any field. Moreover, the government releases periodically an action plan in order to move towards the main goals previously identified taking into account the actual situation of the system and the environmental factors and trends that are affecting it. In the period 2011-2014, two main goals have been defined:

- To develop a high education model that favour quality, attracting, and retention of talent.
- To internationalise the high education institutions, their academic offer, and the research and development that they produce.

In short, these objectives try to place the Catalan higher education in the international map offering efficiency and quality, and hence being highly competitive. In order to reach these two main points, many specific activities and tasks related with curricula design, staff hiring, construction of common services, or university-industry interaction have been listed. For instance, a growth of the inter-university degree courses offered and the construction of a set of excellent master's degrees in order to improve the international competitiveness; the improvement of the staff selection criteria so as to have a permanent staff of excellence; the creation of a common information, mobility, and staff system among universities to make it more efficient; or the fostering of start-ups, spin-offs, and a whole education system with more interaction with the industry.

Reviewing all the previous specific activities programmed, it is easy to notice that none of them has a technical nature but managerial. This is not a negative point in itself but the possible outcomes and limitations must be argued. First, managerial reforms can easily improve issues related with systems efficiency or actors communication. Thus, costs can be reduced resulting on efficiency improvement, and better mobility and information sharing systems are likely to enhance the degree of internationalization of the system. However, these actions will hardly change how students learn, or in other words, the actual teaching paradigm. Consequently, to truly reach a substantial improvement in the daily students' learning, learning and teaching processes must be changed through technological developments, among other possible reforms.

Overall, new technologies may be the solution to improve the actual teaching and learning methods, and even to revolutionize the current system towards a new paradigm, the learning paradigm where the important is what is mastered, not taught, and where students are the centre, not teachers. In this direction, students may learn new theoretical content on-line using specifically-designed environments, instead of being listening a lecturer, or they may use new devices or environments where cooperation and collaboration become a reality instead of studying alone the most of the time.

4. RECENT AND FORESEEABLE SOCIO-ECONOMICAL TRENDS AFFECTING THE UNIVERSITY SYSTEM

The goal of this chapter is to identify the current social, economical, and demographical trends that are affecting the Catalan higher education nowadays in order to use them later as an input for the analytical part of the thesis. In other words, in terms of the multi-level perspective, this chapter aims to define the landscape of the case study.

In the first part, several studies about current trends of different higher education systems are reviewed in order to create a more inclusive and updated list of trends affecting globally the higher education. Thus, a summary of each of the three studies is included which are later used to develop a unique list of global trends affecting the higher education. The second part focuses specifically on Catalonia and aims to define the trends that are affecting specifically the Catalan system using two different kinds of sources; the list of global trends previously identified, and selected studies developed by the Spanish government. Thus, a description in detail, a justification of its inclusion, and its concrete affectations on the higher education of each trend are provided.

The three studies considered are "The University of the Future" (Heinegard 2005), "Higher education and research for the ERA: Current trends and challenges for the near future" (Bourgeois 2002), and "The brains business: A survey of higher education" (Wooldridge 2005). Most of these studies also include a set of solutions proposed to face the current trends and challenges of the higher education. However, these solutions are not point of interest for two reasons. First, the input necessary for the analysis of the thesis are only the current trends identified, not possible actions to overcome them. Second, all the solutions proposed have a managerial or organizational nature, what moves away from the technological focus of this thesis.

4.1 Recent and foreseeable socio-economical trends affecting the university system globally

First of all, the three studies previously cited are partially summarized including the information needed in order to later develop a common and general list of trends affecting the university system globally. It has to be highlighted that the first study only identifies challenges of the university systems while the other two mention specifically higher education trends. In any way, distinct concepts from all the studies are used in the development of the final list of global trends.

The first study revised is “The University of the Future”, a study developed by IVA (The Royal Swedish Academy of Engineering Sciences) with the goal of supporting and strengthening Swedish universities through the identification of important future considerations. The work of the project is mainly divided in three blocks with different well-defined area and topics, and carried out by different expert panels of between 15 and 20 members.

Panel 1 focuses on “Funding instruments and sources” and identifies changing conditions that are related with. Firstly, the likely increase of number of higher education students due to the government expectations as well as a growing students’ interest. Secondly, the most likely stagnation of public funding what may drive to co-financing with students and private contributions. Thirdly, the insufficient funding of research activities, mainly in big research projects with strategic goals. This may drive governing-boards to a centralized management system of public grants. Finally, the likely lack of funding for the “third mission” which represents the popularization and commercialization of research results. Overall, resources are insufficient compared with the volume of activities that universities must offer (education, research, and “third mission”), and the degree of control of resources and organization that universities have is not enough either.

Panel 2, titled “Organization and specialization”, identifies some challenges that are leading higher education to more specialization and efficiency in both educational and managerial level. These challenges are the increasing number of students what asks for higher efficiency, the increasing need of international coordination between universities and other actors, the tougher competition among universities, and the existence of complex and inefficient structures of authority.

Panel 3 focuses on “Mobility, qualifications and recruitments” and it identifies five main challenges related with these subjects. First, while mobility ratio of students is suitable, the mobility ratio of staff is very low. Second, certain programs are not much attractive for students what shows the wrong design of some programs. In this direction, the increasing unemployment rates among graduates also demonstrate that knowledge mastered does not match with the needs of the working world. Finally, about recruitments, the trend of more and more students per professor, and the lower wages of professor compared with the industry are identified.

The second study reviewed, called “Higher education and research for the ERA”, is a report ordered by the European Commission “to better understand the development in the relation between higher education and research”, and developed by an expert group composed by 21 members coming from a wide variety of countries and disciplines. The study has three main parts. Firstly, current trends in European higher education are identified. Then considering these trends, some major challenges are identified. Finally, several possible global scenarios of the future of higher education and research are provided.

Regarding the current trends of European higher education, the study divides them into three different issues; globalization and market forces, rise of knowledge society, and trends in demography. About the first issue, educational systems are losing their function as central agents of national integration what may result in transnational convergence of higher education systems, competition among universities for students, staff and resources, and mobility of students, researchers and staff. Moreover, the relative reduction of public funding and hence the role of the state over universities may result in the entrance of neo-liberal practices in higher education.

Three main demographical trends are identified. First, a massification of education that resulted on the idea that higher education is almost universal for youth now. Second, European population is substantially ageing what might mean that in the future higher education will have to provide education to many elderly people what does not happen today. Finally, contrary to European situation, the world population is very young what means that in the future European universities may provide education to many foreign young students.

The last study considered, “Brains business”, is a survey published in The Economist in 2005 by Adrian Wooldridge (Wooldridge 2005). It mostly states that higher education is currently suffering many fundamental changes due to four main reasons. Firstly, the massification of the higher education that means the growing amount of students that reaches the tertiary education. Secondly, the rise of the knowledge economy understood as the shift from physical resources to knowledge resources as a main driver of economic growth. Thirdly, the globalization of the higher education represented in terms of mobility of students and staff, coordination of institutions, and exchange of information. Finally, the increasing degree of competition that traditional universities face against themselves as well as new private entries to compete for students, staff, and research grants.

As a result of these trends, Wooldridge added that universities have a complicated challenge to handle with the rising volume of students enrolled and activities to perform considering the limited (and often insufficient) amount of public funding. He differentiates between two opposed views regarding how to solve the current situation; techno-utopians who believe higher education will experiment a technological revolution, like this thesis aims to justify, and cultural conservatives who believe the solution is not allowing the massification of university systems. Nevertheless, he adopts a position between both previous views and gives two advices to decision-makers; diversify sources of income, and favour the entry of as many students as possible.

Considering the results of the studies above, five social, economical, and demographical general trends are identified to be affecting the higher education worldwide:

- Massification: In most of the countries worldwide, the amount of students that universities have enrolled is increasing and this trend will probably continue in the future due to three components: The belief of young national population in higher education as a key factor to succeed in the working world, the increasing need of people already in the working world to extend their current knowledge, and the apparition of a huge market of young people from Asian countries such as China or India.
- Stagnation of public funding: University systems traditionally funded with public money like the most of European systems are experiencing a paralysation of their funding as a consequence of the deceleration of the whole economy and after decrease of the state budget. Considering this fact and the growing number of students enrolled, some systems are increasing their enrolment fees, while others are trying to build more efficient systems or finding new private investors.
- Globalisation: Globalisation is a trend affecting all the university systems worldwide in the same manner that is affecting many other sectors. Thus, a process of international integration is arising from the interchange of views, ideas and information. Specifically, both students and staff are interested in making use of the actual technologies to collaborate and share information with international mates, or even travel more frequently. Moreover, universities may also improve their communication and coordination with other institutions easily.
- Rise of the knowledge economy: This trend is also present in every system worldwide since, as well as globalisation, it has an interstate and inter-sector nature. It means the emergence of knowledge and information as main drivers of economic growth. The consequence for the university sector is that high-level education both traditional and new knowledge more related with cognitive and social abilities are much more necessary for everyone and for lifetime.
- Increasing competition: This trend is considered result of the globalisation and hence it is also present in every university system worldwide. Particularly, due to the current open market situation of the higher education where students and staff can move without many restrictions, there is an increasing trend within universities (or university systems) to compete for both students and staff with prominent achievements.

4.2 Recent and foreseeable socio-economical trends affecting the university system in Catalonia

Due to the general nature of the trends that are affecting the higher education globally previously identified, they are also applicable in a specific geographical area such as Catalonia. Specifically, globalisation, rise of the knowledge economy, and increasing competition are present in Catalonia since they are completely global. Regarding massification, Catalan system has not been as affected as other systems but it will probably be in the future. Finally, due to the public nature of the Catalan system, stagnation of public funding is also a very present trend, probably the most noticeable.

Thus, all five trends are also affecting the Catalan higher education system although some adjustments have to be commented. To justify that these trends are also applicable in this geographical area, some data regarding them in the whole Spanish university system which behaves very similar to the Catalan system independently is provided in the next section. Moreover, in the last section, these trends are analysed more in detail identifying a list of specific novel challenges that the Catalan university system has to face as a result of them.

4.2.1 The socio-economical trends in the Catalan higher education with numbers

Firstly, massification of education is also a reality in Catalonia since there have been a considerable increase of the number of students enrolled for the last 20 years. However, this trend has been quite lighter than in other countries up to now with an increase of approximately only 20% as it is represented in the next page (Table 4). Indeed, the percentage of youth between 18 and 24 years old that are today enrolled in higher education institutions is only the 27,9%[5]. This means that more autochthon youth are likely to go to higher education. Thus, considering these facts as well as the possible entrance of foreign students, the massification trend will probably continue.

	Academic course		
	1991-92	**2001-02**	**2011-12**
Number of students enrolled	1.208.369	1.525.545	1.425.018
Variation rate of students enrolled[6]	-	21,6%	-3,7%

TABLE 4. Evolution of the number of university students enrolled in the period 1991-2012. Adapted from *Secretaría General de Universidades (2012).*

Due to the nature of globalization, it is a trend affecting also the Catalan higher education system. Institutions as well as students are more and more interested in collaborat-

[5] This data corresponds specifically to the academic year 2011-12.
[6] The percentage of variation of course 2001-02 is respect to the course 1991-92, and the percentage of variation of course 2011-12 is respect to the course 2001-02.

ing, communicating, or sharing information with foreign agents. One fact that represents perfectly this trend is the evolution of the Spanish tertiary students that are taking Erasmus programs, represented in the next page (Fig. 6).

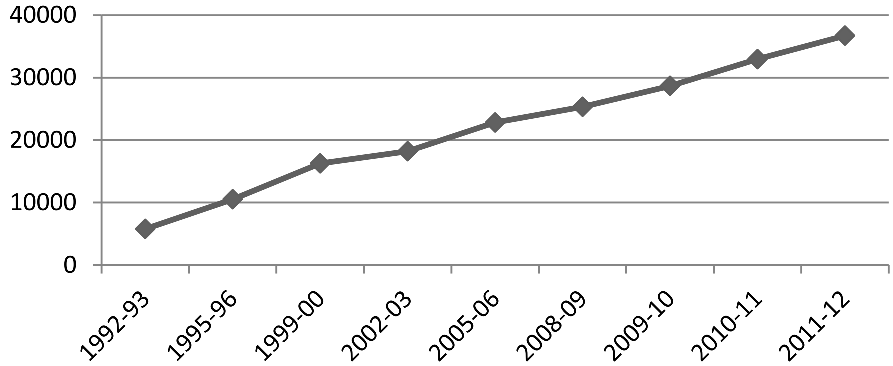

FIG. 6. . Evolution of Spanish students in an Erasmus program.
Adapted from *Secretaría General de Universidades (2012).*

In Catalonia, as well as in the whole country, the stagnation of public funding has not resulted in an increase of the contribution of the private sector but a growth of the enrolment fees. Thus, in order to handle the increasing number of students with the same amount of funding, Catalan universities are increasing the enrolment fees of both bachelor and master's degrees. In some cases, the price has doubled in less than ten years (Fig. 7). Indeed, today common enrolment fees of one year of bachelor are around 3.000€ which can extremely increase, even paying the full theoretic cost, if ones repeats courses. Overall, the paralysation of the public funding is probably representing the issue in higher education with more social repercussion.

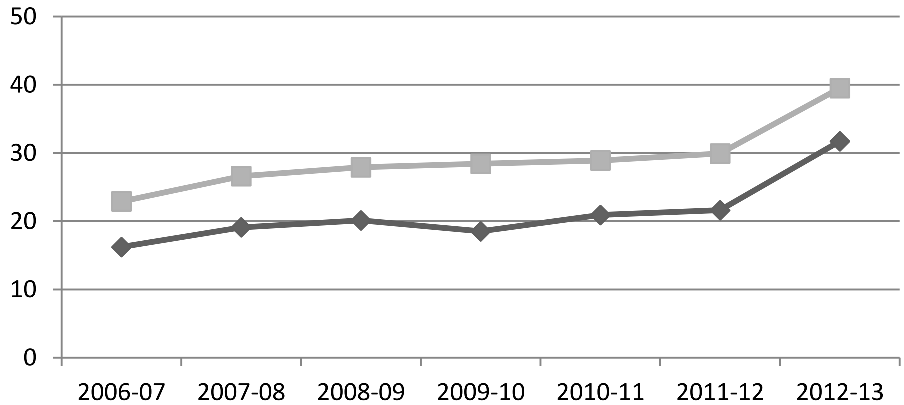

FIG. 7. Evolution of the maximum and minimum price of the credit enrolled for first time in master's degree in Spain (€/credit) *(Secretaría General de Universidades* 2012).

The rise of the knowledge economy is not as appreciable with number as other trends. Nevertheless, in the evolution of the unemployment rates it can be noticed that today having a higher education diploma is not equal to being prepared enough for the working world (Fig. 8). Thus, it can be stated that universities could make two changes in their education activity. First, teach new types of knowledge that are highly required nowadays in many professions. Second, use new kinds of tools and methods which enhance some personal abilities such as communication or coordination skills which are very valued today.

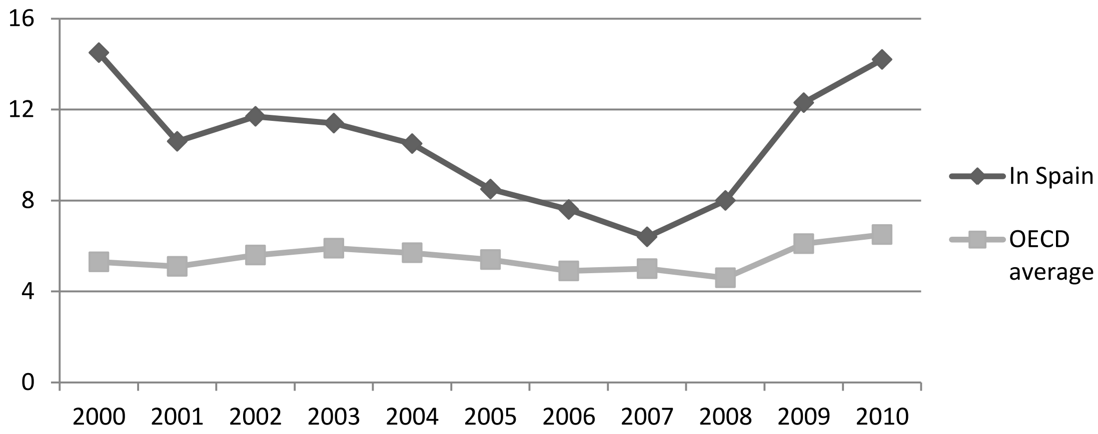

FIG. 8. Evolution of the unemployment rates of population with higher education (%) *(Secretaría General de Universidades* 2012).

Increasing competition is also difficult to represent with numbers. However, there have been some recent decisions taken by the Catalan government that evidence the existence of this trend in the Catalan space. One is the firm commitment to Massive Open Online Courses with an investment of 200.000€ for the academic year 2013-14. Another is the "Serra Húnter Program" that the Catalan government started to find and hire international staff of excellence.

4.2.2 Specific affectations of these trends on the Catalan university system

Practically, these five trends are creating a new environment for the university system and it is its mission to be responsive and give solution to the new challenges appeared. Thus, first of all, it is important to indentify which are these specific novel challenges that the system has to face and give solution to. In this direction, the list of trends and their resulting "natural" challenges is provided next (Table 5). The term "natural" is used to refer to the idea that there is no speculation on these cause-effect relations between trends and challenges since they are very intuitive.

Massification directly results in only one challenge for the Catalan system, the need of higher enrolment capacity. Evidently, if one university wants to have more students, it has to increase its places offered. Regarding the stagnation of public funding, due to massification is a reality and universities have to balance their accounts, there are only three main solutions; improve the education or managerial efficiency of the university, or find new sources of funding. Globalisation results in three natural challenges for universities which represent the main basis of a global economy; easy mobility and communication between people, and easy coordination between organisations. The rise of the knowledge economy means that universities have to make some adjustments in their offer including new types of necessary knowledge and also enlarging the total amount of programs. Finally, due to the increase of competition, universities will only succeed hiring useful and profitable staff if their wages are suitable, and getting students if their programs offered are good and attractive enough. Thus, these two conditions are the natural challenges resulting of increasing competition that universities have to face.

Socio-economical trend	Novel challenges of the system
Massification	Higher enrolment capacity
Stagnation of public funding	Higher educational efficiency Higher managerial efficiency New sources of funding
Globalisation	Easier mobility of students and staff More communication between international students and staff More coordination between universities
Rise of knowledge economy	Offer new kinds of knowledge (cognitive, social...) Offer a wider range of programs
Increasing competition	Higher staff wages Offer better and more attractive programs

TABLE 5. Trends and their resulting challenges of the Catalan higher education system.

5. THE FIVE SELECTED TECHNOLOGIES: OVERVIEW AND FORESEEABLE DEVELOPMENTS

These five selected technologies are those with high potential in changing the actual configuration of the Catalan higher university, specifically as regards the education ambit. In other words, these technologies may have an important future role regarding how, what, where, and with whom students learn. One determinant issue that has to be clarified is why these set of technologies and not other ones. Indeed, the amount of possible sets of technologies that could have been considered is quite significant and hence this final group is result of an important researching work. The first step was to explore all the possible technologies that may have some potential using different sources such as several distinguished studies of public organisations about technologies in higher education as well as many papers about specific technologies. After this, the number of technologies considered was rather large. Thus, the next step aimed to reduce the amount of technologies using two manners: Discarding the technologies least promising, and jointing some technologies that were similar which was an important task since many of them were multidisciplinary and hence they were somehow related.

Overall, the manner and considerations that have been taken to select the final group of technologies have been rather subjective although a lot of secondary information has been taken into account. Thus, it is not proved that these five technologies are the ones with more potential in higher education but they do have some kind of future potential. Indeed, this statement is methodologically corroborated in the first part of the analysis, before proceeding with any other analysis.

5.1 Social Media and social networks

This chapter aims to give information enough to understand all what Social Media represents to later analyse its interactions and possible co-evolutions with the higher education sector. Thus, this chapter is divided in five different parts, all of them with Social Media as a main focus. In the first section, Social Media is defined using the most common and valid definition nowadays. Then, several studies are reviewed to finally give a general classification of Social Media applications. In the third section, all the classes previously identified are deeply described. The next section aims to draw out the current situation of Social Media worldwide and also specifically in Spain underlying several trending characteristics of the sector. Finally, considering the current state and its trends, the three most probable future scenarios are explained.

It is interesting to notice that Social Media is different than all the other technologies considered in the thesis since it is a mature technology, already in mainstream markets worldwide, and characterised by the existence of a dominant design (Suarez & Utterback 1995; Anderson & Tushman 1990) perfectly defined. This fact has consequences in the best way how Social Media has to be described and hence how the chapter is developed. Firstly, over time, Social Media has adopted many different forms resulting in a very wide nature today. For this reason, there is a higher necessity and difficulty to define what Social Media is and means. Secondly, given that there is already a consolidated dominant design, the main way that the sector may evolve is not through a lineal improvement but a disruption. Therefore, the future of Social Media is described using three different scenarios to handle uncertainty that there is present.

5.1.1 Introduction to Social Media

The most used and widespread definition of Social Media is the one introduced by Kaplan and Haenlein in their publication of 2010. They define Social Media as "a group of Internet-based applications that build on the ideological and technological foundations of Web 2.0 allow the creation and exchange of user-generated content" (Kaplan & Haenlein 2010). Thus, there are two primary terms in this description; Web 2.0 and User-Generated Content (UGC) which are explained next.

Web 2.0 is a term that was first used in 2004 to describe a new way in which software developers and end-users started to utilize the World Wide Web. Thus, in this platform, all users are able to modify content and applications at any moment in a participatory and collaborative way, instead of Web 1.0 where content was created and published by individual users. Web 2.0 has been possible due to the total development of a set of functionalities that allows this continuous interaction which are Adobe Flash, Really Simple Syndication (RSS), and Asynchronous Java Script (AJAX).

While Web 2.0 is somehow the technological foundation and it establishes the boundaries of the world, User-Generated Content (UGC) defines how users can operate in this world to truly create and make use of Social Media. Thus, according to the Organisation for Economic Cooperation and Development (OECD 2007), UGC needs to fulfil three primary conditions in order to be considered as such; "it needs to be published either on a publicly accessible website or on a social networking site accessible to a selected group of people, it needs to show a certain amount of creative effort, and it needs to have been created outside of professional routines and practices." Overall, to consider content such a user-generated it has to meet three conditions. First, the site where the content is exposed has to be accessible for anyone and hence sites which require a high level of personal information as a identification are not UGC. Second, content has to offer something creative and new, never done before. Finally, content's motivation or purpose cannot be exclusively professional.

5.1.2 Social Media classification

The definition of Social Media is not very strict or specific and hence many different applications can be considered as such. For this reason, it is interesting to make some kind of classification or categorisation to indentify more precisely all the possibilities and potential of Social Media. Some practically useful categorizations have been done by Fred Cavazza, a French consultant in new media, in his annual *Social Media Landscape* for the last five years. He started in 2008 breaking down Social Media applications into ten groups: Publication tools, sharing tools, discussion tools, social networks, micro-publication tools, social aggregation tools, livecast, virtual worlds, social gaming platforms and massively multiplayer online gaming (Cavazza 2008). After five years, the model of 2013 evolved substantially from this initial publication. There, he places *Twitter*, *Google+* and *Facebook* in the centre of the landscape, and he reduces the segmentation into only four groups: Publishing platforms, sharing services, discussing and chat applications, and networking for B2C audiences (Cavazza 2013).

The weakness of these studies is that only contemporary applications are considered in the creation process and hence the model changes every year. In this direction, Kaplan and Haenlein (2009) offer a more interesting categorization since it is based on the primary meanings of Social Media. Thus, the same categories (with few modifications) will be theoretically valid for both current and future applications. Their model relies on a set of theories related with media research and social processes.

The theoretical foundations of their categorization related with the Social Media side come from two theories: The Social Presence Theory of Short, Williams and Christie (1976) and the Media Richness Theory of Draft and Lengel (1986). The first theory states that media differ in the degree of social presence (which is influenced by intimacy and immediacy of the medium) that they allow between two communication partners. "The higher the social presence, the larger the social influence that the communication partners have on each other's behaviour". The Media Richness Theory is based on the assumption that "the goal of any communication is the resolution of ambiguity and the reduction of uncertainty". It states that media differ in the degree of richness they possess what is considered as the amount of information that media allow to be transmitted in a certain time interval. Consequently, some media resolve ambiguity and uncertainty faster and in a more effective way.

Regarding the social dimension of Social Media, its foundation is the concept of self-presentation, introduced by Goffman (1959) which states that in any type of social interaction people has the desire to control the impressions that other people form of them and this depends mainly on the presentation that one does of himself. In any type of interaction (face-to-face, telephonic, online...), some kind of presentation is required and hence presentation is always important. It adds that the most outstanding aspect of presentations is the degree of self-disclosure (or self-presentation) what represents the amount of personal information revealed consciously or unconsciously that the media requires to make an effective use.

		Social presence / Media richness		
		Low	Medium	High
Self-presentation/Self-disclosure	High	Blogs	Social networks	Virtual social worlds
	Low	Collaborative projects	Content communities	Virtual game worlds

TABLE 6. Social media classification. Adapted from Kaplan & Haenlein (2009).

Thus, Kaplan and Haenlein assume that a primary classification of Social Media can be made based on 1) the richness of the medium (or social presence) and 2) the degree of self-disclosure (or self-presentation) it requires. Combining both dimensions, they come out with a classification of Social Media which is represented in the previous table (Table 6).

This study was done in 2009 and therefore today some new applications exist that cannot be included in any of the previous six groups. However, due to the definition of these two primary dimensions of Social Media (Social presence and Self-presentation), it is easy to include new groups on the existing view. Thus, considering the actual relevance of applications like Skype or WhatsApp, chat applications which basically allow users to interact in a synchronous way should also be included. However, the specific place in the table where chat applications must be included is not clear. They often require a high degree of self-presentation since a profile is needed but their degree of Social presence is very diverse because it depends on the medium they use (text, voice or video).

5.1.3 Types of Social Media

In this section, the seven groups of Social Media previously indentified (collaborative projects, blogs, chat applications, content communities, social networking, virtual game worlds, and virtual social worlds) are developed describing what they really mean.

Collaborative projects enable the joint and simultaneous creation of content by many end-users. They are divided in two main groups: wikis, which are websites that allow (usually anonymous) users to add, remove, and change text-based content, and social bookmarking applications, which enable group-based collection and rating of Internet content. It has to be highlight that collaborative projects (mainly wikis) are increasingly becoming the main source of information for many Internet users although the inexistence of any kind of veracity confirmation of the contained information. Despite their important use on the Internet, this kind of applications is also used by private organizations and companies to create internal documents in a collaborative way.

Blogs represent the earliest form of Social Media and they are websites with the main characteristic of displaying date-stamped entries in reverse chronological order (OECD 2007). There is a multitude of examples in the Internet nowadays, from personal diaries, to discussions or summaries of any specific knowledge or content. Blogs are usually managed by one person only but others users (usually registered and with some profile information) can interact by adding comments. Text-based blogs are still by far the most common. Nevertheless, blogs have also begun to take different media formats such as pictures or videos, a trend that may increase in the future.

Chat applications enable real-time (or synchronous) communication between users using text, voice, or video. This communication can be point-to-point as well as multicast what means from one sender to many receivers. When using text, messages tend to be shorter than in blogs and emails in order to enable other participants to respond fast. These applications are not often designed alone but incorporated to other applications and websites.

Content communities, as the name indicates, are created by users with the main goal of sharing some kind of media content. They exist for a wide range of different media, including text, photos, videos, music and digital presentations. Usually, content communities do not require users to create a personal profile page, or if they do, it only contains basic information. This contrast with social networks and blogs where information required is often higher. From a corporate viewpoint, content communities carry the risk of being used as platforms for the sharing of copyright-protected materials like recent episodes with television series.

Social networking sites are applications that enable users to connect between them by creating personal information profiles, inviting friends and colleagues to have access to those profiles, and sending almost any kind of content between each other, like e-mails, instant messages, images or videos. Furthermore, social networks are recently incorporating new features such as creating groups, plan future events, playing games or advertising yourself in the network. Social networks are especially popular among young Internet users but the trend is to increase its presence in every market segment. Indeed, several companies are already using social networking sites to support the creation of brand communities or for marketing research.

Virtual game worlds are platforms that replicate a three dimensional environment in which users can appear in the form of personalized avatars and interact with each other under certain specific restrictions or conditions of the world. In this side, virtual worlds are probably the ultimate manifestation of Social Media, as they provide the highest level of social presence and media richness of all applications discussed up to now.

The second group of virtual worlds, often called virtual social worlds, allows users a more freely behaviour than game worlds since there are less rules, limitations, and conditions. Essentially, they try to simulate the real life where “everything” is permitted. Thus, like in virtual game worlds, virtual social world users appear in the form of avatars and interact in a three-dimensional virtual environment. However, there are no rules restricting the degree of interactions, except for basic physical laws.

5.1.4 Actual situation of Social Media

In this section, current examples of each kind of Social Media are given in order to clarify the reader what these applications are exactly about. Then, two important characteristics of the current state of this sector are explained: The social networking services as a core of the Social Media activities, and the centralised paradigm of social networking sites. Finally, the current situation of Social Media in Spain is drawn out underlying the importance that networking sites have also there.

Because of Social Media sites do not offer often only one service but a pack of the features previously described, it is quite difficult classify them inside one only group. However, several studies (Kapla & Haenlein 2009; Grahl 2014) identify the main purpose or feature of the most common Social Media sites worldwide. Thus, considering these studies, the next table (Table 7. Current market leader social media applications.
Adapted from Kaplan & Haenlein (2009), Grahl (2014).
) give a couple of widely common examples for each type of Social Media application.

Type of Social Media application	Actual examples
Collaborative projects	Wikipedia, Delicious
Blogs	WordPress, Bloger, Twitter
Chat applications	WhatsApp, SnapChat, Skype
Content communities	YouTube, Pinterest, Instagram, Spotify
Social networking sites	Facebook, Google+, LinkedIn, Badoo
Virtual social worlds	Second Life, OZ World
Virtual games worlds	World of Warcraft, Entropia Universe

TABLE 7. Current market leader social media applications.
Adapted from Kaplan & Haenlein (2009), Grahl (2014).

After seeing which applications are leading right now the Social Media sector, some conclusions about what the whole sector is characterized by and where it is moving through can be drawn. As it is stated by the FIDIS (Future of Identity in the Information Society) network in its paper “Social Networking 4.0”, “social networking services represent nowadays a phenomenon that is at the core of the main battle of the Internet actors of today". Not only intrinsic Social networking sites like Facebook or LinkedIn offer this service, also other websites specialized in other activities like searching, sharing content or blogging are incorporating this dimension and creating some kind of communities across their users. Thus, some of the most used websites and applications worldwide like Google, YouTube, Twitter or Spotify are developing social networking applications as complement of their main activities in order to improve their business models in terms of communication, branding, or marketing. Overall, social networking is becoming more and more the core of Social Media and the Internet in general as shows the graphic of the next page (Fig. 9) which shows the evolution of the percentage of Internet users (stratified by age group) that use social networking sites in United States in the period 2005-2013.

Another key characteristic of the current Social Media sector that has to be underlined is the centralisation of social networking systems. As Chisari (2009) states, "social networking sites operate as "walled gardens", where content is exclusive to the site, and most importantly, the sites provide very little interaction with the outside internet". The consequences of this business model for social networks users are mainly two, as it is explained in the paper "Decentralisation: The Future of Online Social Networking" (Au Yeung et al. 2009).

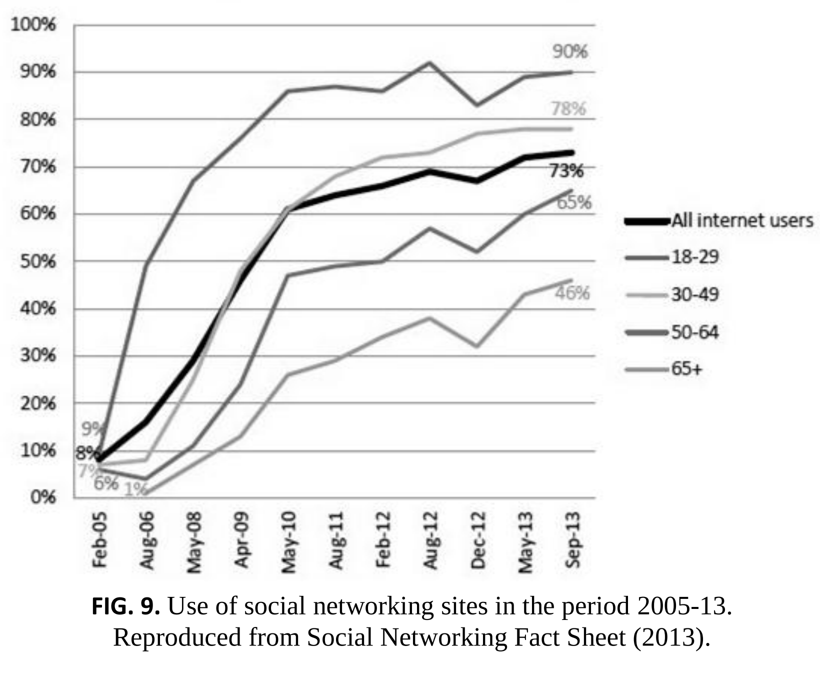

FIG. 9. Use of social networking sites in the period 2005-13. Reproduced from Social Networking Fact Sheet (2013).

The first one is that these sites form information silos what means that information on one site is not usable in the others. Thus, for instance, a Facebook user is not able to add a YouTube user, to share a video with him or even to send him a simple message because there is not any kind of connection between sites. Since networking sites have always operated in a closed way, users see this situation as normal. Nevertheless, this system does not match at all with the nature of the Internet which tends for everything opened. Thus, just as electronic mail system works in an open way (emails can be sent independently of the email platform used), so, too, should do social networking system. The second problem is that such sites do not allow users much control over how their personal information is saved, treated, or shared what results in potential privacy problems. Indeed, users are given the impression that they are in control of their own data but this is not always the case. For instance, Facebook provides users with an option to deactivate their account but it is not possible to completely remove all the personal information from the site and the Internet (Au Yeung et al. 2009).

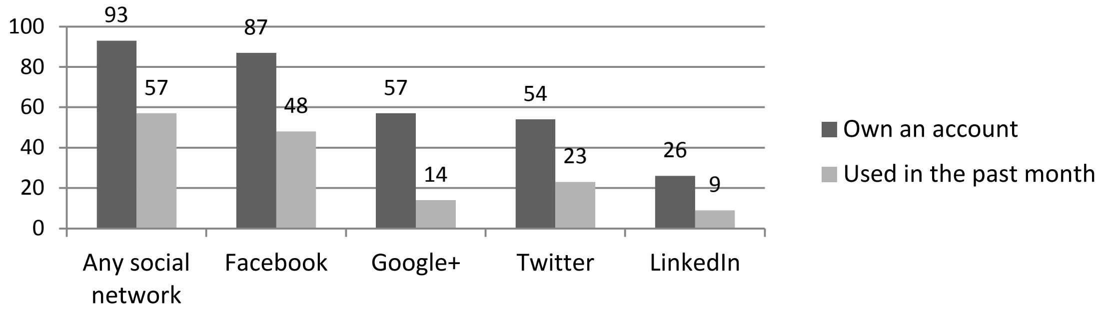

FIG. 10. Percentage of social media users respect to Internet users in Spain (Global Web Index 2014).

Due to the global nature of Internet, there are no notable differences in the Social Media sector between countries. Thus, the whole (worldwide) situation described above is very similar, if not equal, than the Spanish one. Regarding the two main characteristics defined (social networking as a hub of social media, and social networking sites functioning autonomously), the situation is exactly the same. As the Global Web Index data from 2014 shows (Fig. 10), 93 per cent of Internet users own some account in a social networking site, placing social networks on the top of the most used websites. Therefore, the only differences that can be found are regarding the specific applications that are most common. Nevertheless, despite some small gaps, the main trends are the same. Facebook is the evident leader of the market ahead of Google+, Twitter, and LinkedIn. Indeed, Spain is the fifth country with more Facebook users in the world (Global Web Index 2014).

5.1.5 The future of Social Media: social networking

Due to the actual relevance of social networking activities in the Social Media sector, it looks like when talking about the future of Social Media means talking basically about the future of social networking. However, it has to be said that social networking sector is highly volatile and changes happen very fast, and consequently it is difficult to predict how the future state will look like. One clear recent example of this is the case of Facebook overtaking MySpace, the previous biggest social networking site worldwide. Facebook was opened to everyone on end of 2006 and in approximately one year, it had already taken most of MySpace users becoming the biggest social network. Thus, due to the impossibility to predict how this sector will evolve, three different plausible future scenarios are described which differ in the degree of disruption that the sector would experiment. Hence, the first scenario considers that there will not be any major change.

In the second, there is a company that disrupt and becomes market leader, while in the third scenario, the disruption takes place due to a change in the rules of the sector.

Scenario 1

In this scenario, the social networking sites are still centralised and Facebook is used by around 90% of social networks users worldwide. Facebook acts as a hub of the whole Social Media sector and the rest of applications (much more specialised in some specific kind of social media) are like satellites, which can interact more or less with Facebook depending on their activity. Thus, many social websites (like blogs, content communities or virtual worlds) provide their users with the possibility to connect with Facebook somehow. Moreover, Facebook incorporate new features like mobile chat application or music content share, as a result of the acquisition and later development of WhatsApp and Spotify. This situation is highly possible in the short- and mid-term because the weaknesses of the current centralised system or the benefits of a new "open" paradigm are not recognized enough by users.

Scenario 2

In this scenario, the social networking sites are also still centralised but Facebook is not the worldwide leader any more. A disruptive application, which fulfils better the needs of users using the same game rules, has replaced Facebook. This breaker social network may be novel or may come from specific markets such the Chinese one which contains several exclusive networks nowadays. This situation is also quite possible in the mid-term due to the changing nature of this sector, even though it seems that nothing can be better than Facebook now.

Scenario 3

In this scenario, Internet worldwide users realised that the whole situation where the social networking sector was made no sense considering the character and aim of the Internet. The need to communicate and interact with anyone independently of each original networking site, and the higher concern regarding personal data control became key drivers to move through a new paradigm (Chisari 2009). Thus, a sort of SMTP (Simple Mail Transfer Protocol) for social networking, which allows any node to fully connect to any other node, is implanted. The protocol for this decentralized social network uses standards like OpenID, RSS or FOAF (Friend-to-a-friend) which are already used or being researched in the present for other purposes. This scenario will probably occur in the future since it is the theoretical evolution of the current system. Nevertheless, it is hard to predict when it will come but not in the short-term.

5.2 Virtual Learning Environments and Artificial Intelligence

This chapter is focused on two different technologies, Virtual Learning Environments (VLEs) and Artificial Intelligence (AI), which putting them together may provide new solutions to education in terms of teaching and learning. Thus, the final goal of this chapter is to draw out the possible future state of digital learning platforms depending on the degree of AI used on them. Because of the high technical difficulty of AI field, the point is not to describe how AI systems work or how they can be made but what they can do and offer. Thus, only the minimum technical information necessary to understand all the concepts is given.

The structure of the chapter is divided in three main parts. First, VLEs are introduced explaining what they are, the different current types, and what they offer to education. Then, the focus is on the second technology, AI. There, this technology is defined, all the possibilities or goals of AI are listed, the term Artificial Intelligence in Education (AIED) is described, and also how this technology can affect education. The third part is where both technologies are put together in order to show how AI may provide better digital learning platforms in the future. Indeed, it has much sense to combine these two technologies and not other ones since the most prominent improvement regarding VLEs is when using AI.

5.2.1 Virtual Learning Environments

Virtual Leaning Environment (VLE), also known as e-learning platform, is a very used term by educational technologists nowadays because of its rapidly growth as integral part of the teaching and learning process. It includes a wide range of tools and applications, and hence it is quite difficult to find a unique definition that covers all the possible forms. However, one worth definition was already made in 1996 by Brent G. Wilson. He states “VLE is a computer/technology-based environment which is moderately opening systems, allowing communication and information sharing with other participants and instructors, and providing access to a wide range of assets and resources”. In this definition, the three key elements are computer-based, sharing aim, and wide range of assets. Lately, another key element has been included to the definition of VLE, web-based. Thus, VLEs are also considered web-based platforms since today all of them make use of Internet to take advantage of all the possibilities of the net and become more competitive. For instance, Raaij and Schepers (2008) define VLE as a “web-based communications platform that allows students, without limitations of time and place, to access different learning tools, such as program information, course content, teacher assistance, discussion boards, document sharing systems, and learning resources”. Hence, Internet allows students to learn in an asynchronous way without any preset schedule although learning in a synchronous way is also used.

VLEs have entered recently to the mainstream education market and it is considered a new phenomenon for most of universities and higher education institutions. However, the first steps towards VLE were done hundreds years ago. In 1728, a professor called Caleb Phillips wrote an announcement in the Boston Gazette offering art classes to people among the country using post. This was the first example of distance education. After that, some universities started using post to offer education to faraway people (Arslan & Kaysi 2013). However, distance education truly started with the emergence of the Internet in the early 1990s and the use of VLEs. Thus, many educators wanted to take advantage of the benefits that the Internet offered to complement and expand their teaching activities. However, to create efficient and stimulant VLEs requires much time and expertise. For this reason, although universities were starting using them, they did not become a reality so fast for the whole university sector. Later in 1996, International University, the first fully web-based university, was founded and in 2008, YouTube also entered to the higher education market working as a platform for the Open University (O'Leary & Ramsden 2002).

Today, Virtual Learning Environments represent the basis of distance learning although they can also be incorporated in physical learning environments what is called blended learning. In any case, users are usually assigned a teacher ID or a learner ID. Thus, learners have some restrictions while teachers can see all what learners do apart from being able of setting and regulating everything. Furthermore, as it said before, current VLEs can be used in an asynchronous as well as synchronous manner. In the first one, users can virtually meet and learn in “real time” using videoconference or live chats for instance, while in the second one, students can watch lessons, submit assignments or do other tasks whenever they want before the correspondent deadline established by the teacher. Some important and actual VLE software packages are Moodle, Lotus Learning Space, Blackboard, WebCT, or COSE. (Arslan & Kaysi 2013).

The education possibilities of VLEs are enormous and VLEs packages which include several different tools in the same platform are more and more sophisticated and complete. O'Leary & Ramsden gave already in 2002 a worth list of tools and features that VLEs can incorporate and offer which is reviewed below:

- Communication between students and teachers: Different types of tools such as mail, chat, or discussion boards can be used depending on the kind of communication desired (synchronous or not, amount of users...).
- Self-evaluation: Students do exercises which give an immediate feedback or score to evaluate a specific content already studied. The most common types are multiple-choice or fill-in-the-blanks assessments.
- Delivery of learning resources and materials: Teachers can upload on the platform very diverse content such as text files, images, videos, softwares, links, or any other kind of information.
- Students tracking: The assignments undertaken and/or the content viewed by students is recorded and analysed to evaluate the student or to modify its future learning activities in such a way the student learn what he still has not mastered.

- Supporting student tools: Students can make use of several supporting tools that make the VLE more useful and manageable such as cloud folders, calendars, a recent news window, or a personalised platform.

It is very enriching that VLEs can take many different forms. Nevertheless, it is important to define which aspects characterise and define these environments. Dillenburg et al. (2002) noticed the lack of a systematic study about that and elaborated an interesting paper giving some tips about what is a VLE and what is not. For instance, an education web site is not a VLE since it is a static page where interaction in both directions is difficult and personal platforms are impossible. A virtual campus is not a VLE either because it is forced to offer a set of courses while a VLE is not restricted to any scope or level and hence it can be perfectly used for only one course or even a part of a course. On the other side, VLEs are designed information spaces with specific functional requirements such as multi-authoring, maintaining information, or sharing information with the world. Moreover, VLE are considered social spaces which integrate heterogeneous technologies and where students are not only participants but actors.

As it is said before, VLEs are just sets of tools supported by computers and the Internet, and hence many digital teaching or learning tools may be a VLE or be incorporated to a VLE package. Thus, there is much room for improvement in this side since many online learning systems with new features and possibilities are being researched and developed. Some of the most promising are included in the third section of this chapter where VLEs are combined with Artificial Intelligence technology. On the other side, due to this only digital nature, VLEs are less effective when recreating and informing about the real world than physical tools and objects since digital contents are only mere abstractions of the “real things”. In this direction, Chapter 6.4 and Chapter 6.5 show completely different kinds of education tools that move away from the only-digital world and offer a much more “real experience” by interacting with physical objects using your own body.

5.2.2 Artificial Intelligence

Artificial Intelligence (AI) is concerned with creating computational models of human faculties, enabling systems to replicate common-sense tasks and otherwise reproducing intelligent behaviour. Russel and Norvig (1995) develop the term intelligent behaviour. They say it can be defined as “acting rationally what means to do the right thing given the available information”. Another widely used definition of AI is given by John McCarthy who coined the term in 1995. He states “AI is the science and engineering of making intelligent machines, especially intelligent computer programs”. Moreover, he adds that “AI methods do not have to be biologically observable but they can follow new principles and thinking ways created by humans” (McCarthy 2007).

AI field is highly technical and specialised, and is also deeply divided into subfields that often are difficult to relate. Thus, several different divisions exist. One of them is due the field where the specific AI system has to be used such as education, robotics, engineering, or medicine. AI systems are also divided by their specific aim. For instance, one application in medicine or engineering may have the main goal to master some specific knowledge, and to reason and solve a specific problem according to it. However, due to the different characteristics of the problem itself, the tools and techniques needed may probably be not the same. Thus, another division is regarding the particular approaches, tools and techniques used by AI systems.

As it has been said, one possible division of AI systems is regarding the goal they have, or in other words, which kind of human faculty the system can reproduce. Although it is not easy to make one unique list, one worth division considering several relevant AI textbooks (Russel & Norvig 2003; Luger & Stubblefield 2004; Poole et al. 1998; Nilsson 1998) can be as follows:

- Deduction, reasoning and goal-solving: These systems are designed to reason and solve problems and hence they have to decide what to do in a sequential way in order to achieve desired states and goals. Specific systems with this goal are problem-solving systems or search methods-based systems.
- Knowledge representation: These systems are capable of internally representing and keeping available any kind of knowledge like objects, properties, categories, concept relations, situations, events, states and time, or causes and effects. This can be crucial since many problems intelligent systems are expected to solve require extensive knowledge which has to be ready to be processed and manipulated.
- Planning: This type of systems is capable to set goals. Thus, they can visualize the future by representing the current state and making predictions about the future, and finally make choices that maximize the profit regarding the available sources.
- Learning: These systems are able to learn how to perform some task without any “friendly teacher” that provides examples, start states, models or utility functions. The basement is computer algorithms that improve automatically though experience, trying multiple actions and evaluating their result. In chess, for instance, a system could learn how to play without receiving any examples of game situations, just trying random moves and using only as a feedback the final result (victory or defeat).
- Perceiving: These systems have the capacity of getting information about the world they habit. The key component of these systems are sensors which is anything capable of change the computational state of the system in response to a change in the state of its environment. There many types, from simple one-bit-one sensors that distinguish only between two states, to complex sensors like something similar to a human eye’s retina.

- Communicating: These systems have the capacity to exchange information with other intelligent systems or/and humans. The most used way to communicate with humans is by Natural Language Processing (NLP) which systems are able to read and understand the languages that humans speak with. Thus, a advanced NTP system would be able to acquire knowledge directly from human-written sources, like text mining or machine translation applications do.
- Motion: These systems have the capacity to perform tasks as object manipulation and navigation, and hence they can also handle problems like localisation, mapping, and motion planning. The field that better cover this kind of systems is robotics which not only the computer system is designed and built in but also the physical robot itself and the sensory system.
- Other faculties: There are three more faculties that intelligent systems may perform in the future. First, systems may possess social intelligence and hence recognise, interpret, and simulate human affects. Second, systems may be creative what is related to intuition and artificial thinking fields. Finally, intelligent systems may be totally intelligent what means that they may be able to combine most or all of the skills and faculties that humans have.

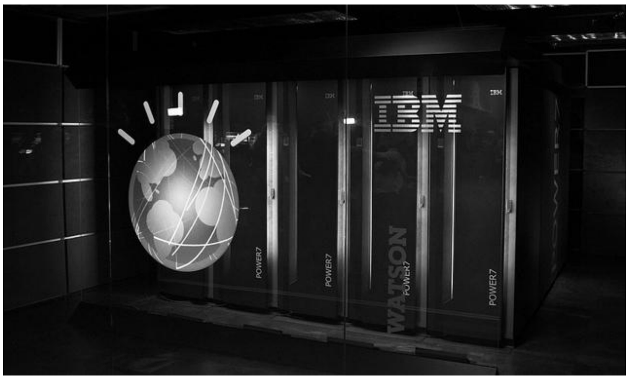

FIG. 11. IBM Watson supercomputer. Reproduced from Newscientist (2013).

Practically, intelligent systems often perform more than only one goal; this makes hard to give clear examples of each type. For instance, a system created with the goal of solving some kind of problem can use a search-based method to work and hence it needs a way to represent all the knowledge it contains and hence this system has also to perform the faculty of knowledge representation. One real example of a system based on Artificial Intelligence is Watson, a supercomputer created by IBM in 2011 (Fig. 11). It was first developed to compete in the quiz show “Jeopardy!” and it achieved to beat the two best “Jeopardy!” human players ever. Its main abilities are knowledge representation of all the data it contains, understanding natural language of the questions, generating hypotheses based on evidences, and learning as it goes.

After seeing the main possibilities of AI, it seems clear that AI is a multidisciplinary technology with different approaches for each of its application fields. For this reason, the rest of the chapter is focus only in Artificial Intelligence in Education (AIED). Notice that AIED is not focus only in HE but in education in general. As it is written in the International AIED Society Report (2010), “Artificial Intelligence in Education (AIED) is an interdisciplinary research at the frontiers of computer science, education and psychology which promotes rigorous research and development of interactive and adaptive learning environments for learners of all ages, across all domains”. Thus, AIED is related with any kind of learning process independently of the place, the students, or the content to teach. AIED research has been done oriented to formal classroom setting as well as outside the classroom and online environments, to K-12 schools as well as universities, and covering content from mathematics to languages. However, since the focus of the chapter is AI related with virtual learning platforms, the most treated AIED applications are digital and web-based and hence online. This should not be surprising since online AIED applications are the ones are growing more.

So far, it has been shown which the possibilities of AI are and where AI can have affectation in the education sector, but it is important to know why AI is really interesting for education, or in other words, what new AI can offer to teachers and learning. The answer for these issues is discussed by Underwood and Luckin (2011a) who state that “AIED has the potential to deliver more flexible and inclusive personalized, effective and engaging learning experiences through lifetimes and across formal and informal settings”. Thus, AIED tools may offer a personalised teaching as well as teachers can do, using new attractive ways to present the content. Moreover, AIED can enable higher education institutions to lower costs by reducing the ratio of teacher hours per student and hence the total number of teacher hours.

5.2.3 Virtual Learning Environments using Artificial Intelligence

As it is shown in the section 5.2.1, virtual learning environments are already a quite developed technology since they currently provide education institutions several useful features to support their classroom-based teaching method. Nevertheless, there is still much room for improvement, mainly when incorporating artificial intelligence systems to these environments. There are many studies arguing about the possible relevance of these new environments as well as introducing some specific features (Underwood & 2011b; Chaudhri et al. 2013; Conati & Kardan 2013; Lester 2013; de la Monografía 2007; Brusilovsky & Peylo 2003; Brusilovsky & Millán 2007). Some of the most promising virtual learning environment features are described as follows moving from most possible

- Adaptive evaluation systems: These systems mostly aim to evaluate the strength and weaknesses of students through multiple-choice or fill-in-the-blanks tests. It can be considered the evolution of self-evaluation environments since they do not only score and give immediate feedback but also ask questions depending on the answers of the previous questions. Thus, the system is capable of registering which knowledge has been mastered and which has not. (*de la Monografía* 2007).

- Intelligent textbooks: These systems are digital books with special features that allow students to highlight text, take notes in the margin, interact with graphics, or even ask questions. The main contexts where these systems may be applied are active reading in which students read as the same time as ask and connect, and homework support in which quick access to specific content or deconstructive simple questions might be provided. (Chaudhri 2013)
- Collaborative learning supported by computer: These systems are designed to support and facilitate the learning process of students by providing them a set of tools to interact and work in group. Thus, there is a software agent that mediates and makes easy the interaction between students to finally reach the preset goals. (*de la Monografía* 2007).
- Intelligent tutoring systems: It is widely known that the most effective teaching method is one-on-one tutoring. In this direction, intelligent tutoring systems aim to offer personalised instruction to students mainly in problem-solving tasks according to their needs, as good as human tutors do. Specifically, intelligent tutoring systems are able to offer suggestions or tips if the student doubts or gets blocked during the process of solving a problem. Thus, the system guides the learning process instead of only giving a final feedback. (Chaudhri et al. 2013; Conati, C., & Kardan, S. 2013; *de la Monografía* 2007).

Overall, in the future, learning virtual environments may not only offer evaluation systems and several support-learning tools as they do now. Instead, they may have an important role in learning processes such as reading, homework, group work, and problem-solving. The most important advantage respect to traditional teaching systems, or in other words, human teachers, is their much lower cost since they mostly only require the previous programming of the system. However, the main driver that will determinate their development is the teaching quality that they will be able to offer.

5.3 Massive Open Online Courses

This chapter focuses on Massive Open Online Courses (MOOCs) which can be considered a type of virtual learning environments with special characteristics. The reason why one whole chapter is dedicated to MOOCs is because this technology may change the actual paradigm of the higher education by its own, even if the technological improvements described in the section 5.2.3: Virtual Learning Environments using Artificial Intelligence do not occur. Indeed, what makes MOOCs really interesting is mainly their massive and open character.

Nevertheless, considering that they are also virtual learning environments, they may also make use of these intelligent features evolving from their actual state to new ones with more effective tools and applications providing anyone across the globe a customized and efficient way to learn. Indeed, MOOCs are a perfect space for VLEs and AI to disrupt together.

5.3.1 Introduction to Massive Open Online Courses

It may seem clear what MOOCs are and means considering the terms describe themselves: massive, open, and online courses. However, there have been several papers and posts underlying the lack of an exact definition of MOOC. For instance, it is not clear how many students the word massive requires: More than 100, or than 100k? It is also unclear what open exactly means: Open content? Open access for anyone? Or free entrance? In this direction, Dominik Lukes (2012) does not give a definition of MOOCs but develops a list of features related with the four labels (massive, open, online, and course) that all MOOCs should satisfy which is reviewed below:

- About massive: To “give access to a larger group of students than a single class or institutions could”.
- About open: To offer “open access” what means that no prior knowledge or enrolment to other courses is needed.
- About open: To “not require payment for access to content and peers”, but maybe for special support or events.
- About online: To use an online method of content delivery utilising several modes such as video, audio, text, or animation. Content can be offered in a synchronous or asynchronous way.
- About course: “To follow a course of study with time-sensitive elements towards a specified learning outcome or a set of outcomes”.
- About online course: “To facilitate asynchronous interaction between as many participants as possible” using internal forums or external social media websites.

Lukes also identifies several features that are not essential to consider a course as a MOOC but it is believed they are indicators of higher openness. However, courses offered by current most important MOOCs’ suppliers do not meet these aspects. For instance, a MOOC expands the terms open and online when students have to use the open web instead of being restricted to the VLE. Moreover, a MOOC is more open when is only based in open content, without the obligation of buying licenses or paying fees.

One important and concerning issue regarding MOOCs is how it is possible that they are free and if they will continue being free in the future. John Swope (2013) give a worth answer about it. He states MOOCs “must continue being available for free or nearly free because if not, they will lose their two most important features: massiveness and openness”. He adds that this is viable because of two reasons. First, “MOOCs are reusable” since their content can be used and sold over a long period of time. Second, MOOCs suppliers can use a premium model where all the content in free but students can pay for special services or conditions. For instance, today edX is asking a fee to students that want a personal certificate.

5.3.2 Types and evolution of Massive Open Online Courses

George Siemens (2013) identifies three different MOOC models that are present nowadays: xMOOCs, cMOOCs, and quasi-MOOCs. "xMOOCs are offered in a traditional university model" where learners master and practice what the teacher shows. The actors driving xMOOCs are traditional universities, including many elite American institutions such as MIT (Massachusetts Institute of Technology), Harvard and Stanford. The three most successful MOOCs' suppliers nowadays belong to this group which are Coursera, edX and Udacity. These courses are based on "weekly course topics addressed through recorded lectures that range from 2 to 30 minutes in length" which are also weekly evaluated through computer-graded assignments. On the other side, "cMOOCs are based on a connectivist pedagogical model that views knowledge as a networked state and learning as the process of generating those networks and adding and pruning connections". Practically, the themes are also weekly but the exact content, activities pursued, and tools used are open what gives higher autonomy to learners. Unlike in xMOOCs, there is also a schedule for synchronous sessions of guest speakers or live discussions. In short, the core side of cMOOCs is the high social interaction they allow while their weakness it is the difficulty of evaluation. Finally, "quasi-MOOCs provide Web-based tutorials as Open Educational Resources (OER)". They are not courses since there is no schedule to master the content either social interaction between students. Thus, these MOOCS offer theoretical content about learning-specific tasks without any kind of feedback or control.

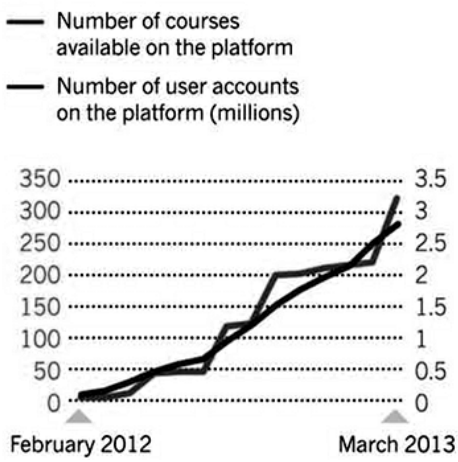

FIG. 12. Supply and demand of Coursera's MOOCs. Reproduced from Waldrop (2013).

The story of MOOCs started in 2008 when George Siemens and Stephen Downes of the University of Manitoba (Canada) created the course Connectivism and Connective Knowledge (CCK08) which was taken by over 2.300 students. Before this, other courses were released but they are not considered MOOCs as defined before. In 2011

MOOCs became a reality in the academic world when Stanford University offered the course Introduction to Artificial Intelligence which was taken by more than 160.000 students across the entire world. Only one year later, Udacity, Coursera and edX, the three most successful MOOCs providers nowadays, were created and MOOCs experimented a sharp rising in terms of amount of courses and users (Fig. 12). Indeed, Andrew Ng who left Stanford to run a new for-profit MOOC provider states that Coursera was growing in 2012 even faster than Facebook (Pappano 2012). To better understand the different types of MOOCs and their evolution over the time see the next figure (Fig. 13).

This fact forced universities and colleges from everywhere to offer MOOCs too if they did not want to be outside of this powerful movement and stay competitive. Thus, in 2013, 24 of the 25 top colleges in United States were offering MOOC courses (Swope 2013). Moreover, this trend also affected Spanish universities which are leading the MOOCs' offer in Europe nowadays with over 100 courses in total. It has to be also underline that most of the universities that offer MOOCs are public and traditional (not online universities).

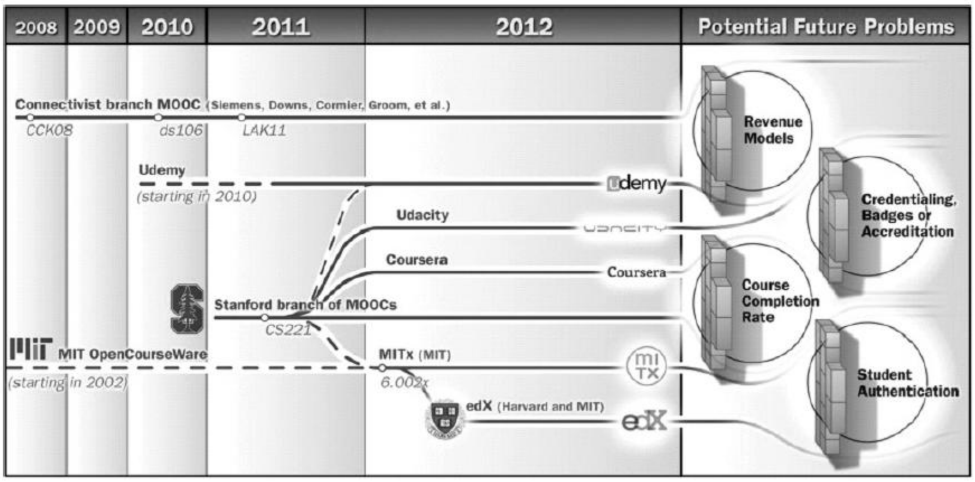

FIG. 13. History of typology of MOOCs. Reproduced from Hill (2012).

Today, the region of Catalonia is only offering over 10 per cent of the total of Spanish courses. However, there are two positive points regarding this region. Firstly, Catalan government is currently funding new MOOCs provided by Catalan institutions. Secondly, *Universitat Autonoma de Barcelona* (UAB) is the only Spanish university that is using really international and prestigious platforms like Coursera what reflects the quality of its courses and also its potential.

5.3.3 Advantages and challenges of Massive Open Online Courses

Considering the recently sharp raising of MOOCs, it seems clear that they have advantages for both students, which are the users, and higher education institutions, which are the suppliers. Chen et al. (2013) compile from several studies three important advantages for students that MOOCs have over traditional teaching: Higher accessibility, higher student engagement, and higher lifelong learning opportunities. Firstly, due to their low cost or free access and their lack of prerequisites, MOOCs are accessible for anyone across the globe, even in countries where higher education was a privilege up to now. Indeed, non-traditional-higher education countries such India or Brazil are the second and third countries with more MOOCs' users in the world (Fig. 14). It is also interesting to underline that Spain is the fifth country with more users what may show the interest for higher education as well as the refuse for traditional universities which are becoming more and more expensive. Secondly, MOOCs were primarily created to allow a higher student engagement that traditional teaching has and consequently to improve student outcomes. Student engagement is defined as the investment of time, effort, and other relevant resources by both students and their institutions. In this side, MOOCs offer a more efficient way than traditional teaching. Finally, due to MOOCs allow students to study only the courses they want independently, people can make use of MOOCs during all they life in a very easy and useful way resulting in an improvement of lifelong learning skills.

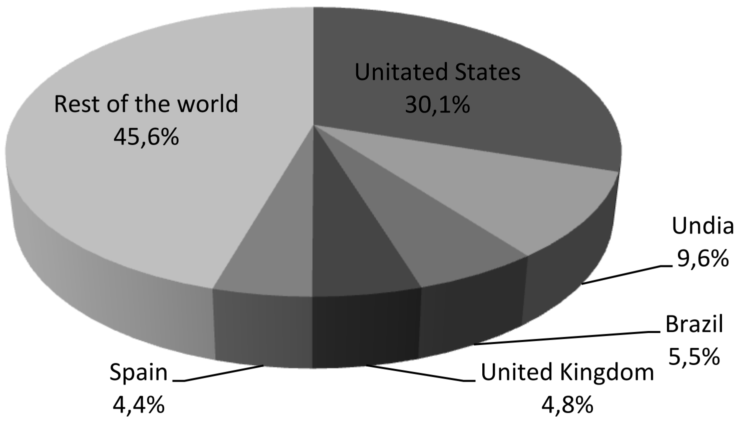

FIG. 14. Origin of Coursera's MOOCs' students. Adapted from Waldrop (2013).

On the other hand, several advantages and interests for higher education institutions are also indentified. One is the possibility of getting more revenues and more scattered across the globe what internationalizes institutions and reduces their risk of a possible national crisis[7]. Another interest is strategic since consolidated institutions consider vital to enter in the virtual world and offer MOOCs in order to maintain their position in the market place. Moreover, offering these new and trendy courses may increase the reputation of universities, as well as, the possibility of finding and capturing outstanding students across the world.

Despite the important advantages that MOOCS have, there are also some challenges that actual MOOCs have to face. Laura Pappano wrote an interesting article talking

---

[7] Further information about the possible American College Crisis in this column of Adam Levin: http://abcnews.go.com/Business/bubble-time-cap-college-tuition/story?id=15987539#.T8-aEtVzp08

about that in the New York Times in 2012. She argues actual MOOCs have three main weaknesses. The first one is grading. In technical and mathematical courses, where the use of multi-choice or fill-in-the-blanks tests are possible, evaluation and grading is effective. However, in courses that involve writing and analysis, autoevaluation is not a possibility. Then, peer review is the most used method but this has important problems in MOOCs since students are very diverse (teenagers to retirees, or from across the globe) and hence grading can vary a lot among students or even be quite unfair, even considering that MOOCs' suppliers use several ways to handle it. The second challenge is regarding course selection. There are many courses offered and all of them have open access. This means that everyone can apply for any course even if it is not appropriated for him at all. Actual suppliers incorporate some recommendations but this is not enough. The solution of that is moving towards crowdsourcing where students and/or courses are evaluated by a huge amount of users. The third and last challenge is what the reward that one gets to accomplish a MOOC is. Today, Coursera or edX give a certificate what is something but it does not fit in the current higher education model at all. Thus, the trend is that universities and higher education institutions give credits for official MOOC certificates and hence MOOCs will be integrated in the higher education sector. George Siemens (2013) also recognizes several important challenges of MOOCs such as the growing concern for university providers regarding cheating and plagiarism, the poor completion rates, or the interest of leader institutions to only favour shareholders, instead of teachers and students.

In short, although the abrupt growths, Massive Open Online Courses are still in a young and low developed stage since there are many weaknesses and challenges to face. Thus, they may evolve in many different ways in the future. However, what is clear is that if they can overcome weaknesses such as personal identification, grading, and equivalence with traditional courses, MOOCs will likely become completely dominant in the higher education sector.

5.4 User Interfaces and Touchscreens

In Chapter 5.2: Virtual Learning Environments and Artificial Intelligence, it is shown that artificial intelligence may improve the way how students learn using digital learning platforms in a traditional device like personal computer, laptop or tablet as a physical platform. In this chapter the focus moves away from these traditional devices towards alternative systems that people may use in the next years to interact with digital information paying special attention to the ones with more potential in the education sector. Thus, the main topic of this chapter is to define and describe the user interfaces that may allow students to learn in a new way, more intuitive and instructive.

The chapter starts introducing the term user interface and citing several important different types of interfaces. Then, the focus is on one specific type of interfaces that have high potential in education in the short- mid-term which is gestural interfaces. There, Touchscreens are described in more detail providing information about what they exactly mean, which types exists, and finally their probable future evolution towards the multi-touching.

5.4.1 Definition and types of User Interfaces

Human-computer interaction is the study of how humans interact with computer systems which many disciplines contribute to, including computer science, psychology, ergonomics, engineering, and graphics design. At the end, the goal of human computer interaction is to design user interfaces that "produce a fit between the user, the machine, and the required services" (Karray et al. 2008). The user interface is that part of the computer system with which a user interacts in order to undertake his tasks and achieve his goals. As it is said below, many different interfaces exist since each device and application requires different features. For instance, watches and telephones often have buttons which can be pressed, sound systems and microwaves also incorporate dials to set up time or volume, and recent tablets can only be manipulated touching the screen. Practically, user interfaces include hardware as well as software components that provide means for two points: Inputs, allowing users to manipulate the system, and outputs, allowing the system to show the effects of the users' manipulation. (Stone et al. 2005).

There are many different types of interfaces depending on how the input and the output are performed. Some of the most important are listed next:

- Graphical User Interfaces (GUIs): These interfaces are characterised by giving the output graphically in a display like a computer monitor or any other kind of screen. The input may be given through different ways like a keyboard, mouse, touching or bottoms. Practically, almost all the devices are equipped with a display since it is the easiest way to give outputs and hence most of the interfaces used nowadays are GUIs.
- WIMPs: These interfaces are a kind of GUIs where the main elements are windows, icons, menus, and a pointer what gives sense to its name (WIMPs). Personal computers and laptops use this interface but not mobile phones or tablets, for instance.
- Command line based interfaces: These interfaces are also GUIs where the user provides the inputs by typing a command string with the computer keyboard and the system provides output by printing text on the display. This system is mainly used by programmers and system administrators, in engineering and scientific environments, and by technically advanced personal computer users.
- Web-based user interfaces: These interfaces are also a kind of GUIs that accept the input and provide output online transmitting the information via the Internet and viewed by the user using a web browser program.
- Gestural interfaces: The main characteristic of these interfaces is that the input must be given using gestures. The mouse is probably the gesture interface most

used nowadays which allows 2 dimensional controls. Other gestural interfaces are based on the movement of other handhold devices like stylus or joysticks, our fingers, our hands or even the whole body using sensors placed in different parts of it. There are two main kinds of gestural interfaces; Touchscreens and free-form systems, which are deeply studied in the next sections.

- Aural and speech recognition user interfaces: These systems are characterised by recognising and/or simulating human voice. Thus, human voice can be used as input and/or input using complementary devices like microphones and earphones. For instance, today some mobile phones are able to recognise human voice and do actions according to it.
- Visual user interfaces: These interfaces are characterised by the type of input that can be given. Using cameras, visual information is provided to the computer. These systems can be used to track fingers, hands, the whole body or gaze movement, for example. Another application is face recognition as well as any other kind of objects, like buildings or streets.
- Tangible User Interfaces (TUIs): In these interfaces, the user interacts with digital information through the physical environment which is used as input, or even as output. The pioneer in this new field is Hiroshi Ishii, a professor in the MIT Media Laboratory who heads the Tangible Media Group. (Ishii 2008).

The rest of the chapter is focused only on gestural interfaces since this branch is the only one that has a high potential to offer new solutions and tools in the education field in the next years. For instance, WIMP interfaces already give many solutions for education but nothing new is coming in this field. On the other hand, tangible user interfaces may also offer some solutions to education but their possible application is much further since today the technological development is still very low.

5.4.2 Gestural interfaces

The first step towards gestural interfaces was done in 1983 when the professor Ben Shneiderman of the University of Maryland coined the term direct manipulation. According to him, “direct manipulation is the ability to manipulate digital objects on a screen without the use of command-line commands” (Shneiderman 1983). When he said this he was thinking in interfaces using pointers and mice as next step. However, then with the apparition of some devices based on gestural interfaces, direct manipulation was taken to another level. Currently, most gestural interfaces can be categorized as either Touchscreen or free-form. A Touchscreen is an electronic visual display that the user can control through simple or multi-touch gestures by touching the screen with a special stylus, pen and/or one or more fingers. On the other hand, free-form gestural interfaces do not require the user to touch or handle the device itself. Sometimes a controller or glove is used as an input device, but even more often the body is the only input device. (Saffer 2008).

Even if many gestural devices with different shapes and forms exist, there are three parts or components that are common in all of them; a sensor, a comparator, and an actuator. Sensors are electrical or electronic components with the function of identifying changes in the environment. Comparators compare the actual state with the previous one and take a certain decision. Then, this decision is sent to an actuator in the form of a command which it finally gives an answer or output. Actuators can mainly be analog or mechanical. (Saffer 2008).

The next section is focused only on Touchscreens, not also about free-form systems, since only the first devices may provide students a new very realistic way to cooperate and interact with more people. On the other hand, free-form systems are still in development in the most of cases and their utility and application in education is still uncertain.

5.4.3 Touchscreens

A Touchscreen is an electronic visual display that the user can control through simple or multi-touch gestures by touching the screen with a special stylus, pen and/or one or more fingers. Thus, by using touch screen technology, the user is able to manipulate a digital environment by only the touch on the screen. The first example of Touchscreen technology came out in 1971 with the invention of the Elograph. This device set up the first stage of a long history. One later important event was the apparition of the HP-150, the first touch screen computer (Hoye & Kozak 2010).

Since then, touch screen devices have become more complex and sustainable what has enabled the entry of this technology in our daily life through Smartphones, tablets or other multimedia players. However, there is still much more room for improvement. In 2006, most of commercially available touch screen devices were only capable of tracking a single point on the surface on the device (Benko et al. 2006). Today, this has changed and multi-touch screens are entering in mainstream markets such as Smartphones and they have high potential in some sectors where collaboration, multi-user interaction and public representation are important like in business, medicine or education.

Touch screen devices are usually divided depending on the technology that they use. Traditionally, Touchscreens have been divided in three different groups; resistive systems, capacitive systems, and infrared systems (Hoye & Kozak 2010). However, in the last years, a new technology is also being used for touch screens: computer vision technology. Thus, today there are four main types of Touchscreens depending on the technology that allow users to interact with the digital information using their hands or other physical devices. A brief description of each technology and the devices that currently make use of each of them is given next:

- Resistive Touchscreens: These systems use a very simple technology. The screen is built using two layers of the conductive material Indium Tin Oxide (ITO), separated by a small gap of air. When the user presses down on the top ITO layer, it physically curves to make contact with the bottom ITO layer, changing the resistance of the two layers. This is the most common type of Touchscreen technology in today's market because of their low price. These devices are used in many applications, such as some cell phones, handheld games, GPS navigation devices, and some digital cameras. However, due to its low precision and its low compatibility with multi-touching, it is being less used in some devices like Smartphones.
- Capacitive Touchscreens: There are two main techniques to build capacitive systems nowadays; projected capacitive and surface capacity touch screens. Both use ITO surrounded by two layers of glass. An electric field is created on the top layer of glass and when the user touches this glass, the variation of capacitance value is detected. The difference between these two techniques is that projected capacitive use two layers of ITO and surface capacity use only one. The popularity of this technology is growing for the last decade due to the effectiveness of its design, its use of multi-touching, and the utilization of this technology by Apple in high successful devices like iPod Touch, iPhone and iPad.
- Infrared Touchscreens: There are also two main infrared techniques; a standard grid and an internal reflection system. In the first system, there is one layer of infrared LEDs that emit light perpendicularly into another layer composed by sensors. Above this second layer, a glass layer is placed. Thus, when a user makes contact with the glass layer, the sensors read a different strength of the beams. The second system is based on internal reflection and use only one layer composed by LEDs and sensors, and one layer of glass. A beam of infrared light is emitted from within the unit, hits the glass, and part of the beam exits through the lens while the other part goes back into the unit. Thus, when a user makes contact with the surface, the internal-reflection pathways change. These systems can support perfectly multi-touching and are the most precise. However, they require more space than other touch screen systems. That is why they are not used in small devices like Smartphones but in big multi-touching devices like the Samsung SUR40 (Fig. 15).

FIG. 15. Samsung SUR40 with Microsoft PixelSense. Reproduced from Samsung (2014).

- Computer vision based Touchscreens: These systems incorporate a camera placed above or below the screen that recognize the contact of fingers or other objects with the surface of the device using computer vision methods. Computer vision is a field that includes methods for acquiring, processing, and understanding high-dimensional data from the real world in order to produce numerical or symbolic information. One application of computer vision is interaction systems as the input to a device. This system is mainly still in development and hence it is the less used nowadays.

5.4.4 The future of Touchscreens: multi-touching

It has been identified that the next step of Touchscreens is towards multi-touching (Hoye & Kozak 2010). First multi-touch devices, like iPhone or iPod Touch, are based on capacitive systems and use multi-touch technology to perform the function keys (Control, Alt, Option, Command, etc.) of a standard keyboard but with only one hand. Now, with the entry of high precision infrared systems in the real market, the possibilities and features of these multi-touch devices are much wider. Thus, more recent devices like the Table of Samsung SUR40 or the Boards and Tables of the company SMART Technologies incorporate a set of new interesting features. They often allow users to make use of both hands to manipulate the digital information, as well as enable wider collaboration and interaction between people at the same time and in the same device, and even tagged objects recognition (Samsung 2014). Today these big devices are mostly sold to hotels, casinos and big companies due to their high cost. However, their ratio performance/price is likely to improve in the next few years and consequently they will be available for a wider amount of customers such as small companies, public organisations or even personal consumers.

After having seen that the near future of touch screens is multi-touching, the aim is to define which specific devices may take profit of this technology, what features they may incorporate, and in which sectors or markets may have an important impact. About the physical platforms, there are two main multi-touching devices: Tabletops and Boards (or Whiteboards). It could be said that both are the same but placed in different position;

horizontal and vertical. However, practically is much different. "Desktops are personal, tabletops are social, and digital whiteboards are public" (Dillenburg & Evans 2011). Thus, fundamentally, a table is a place where people can easily interact while boards are a great place to address to a large group of people. Often, the performance and utility of these devices can be improved using complementary devices like presence sensors, remote interactive displays or other support hardware. Moreover, the trend of multi-touch screens is to become larger so that in the short- or mid-term future it is likely to see teachers, lecturers or business leaders using interactive screens while performing their activities.

Multi touch screens have several interesting characteristic features. Current devices can already perform most of them. Thus, the future goal is to improve the efficiency of some of these tasks and also reduce the cost of the entire system. Some important features are listed next:

- Touch detection: Clearly the capacity to interact with digital content using ones hands or prosthetic is the main feature of these systems. As it said above, there are 4 different technologies that allow this task. The best choice depends on size, precision required, multi-touching and cost.
- Multi users: They allow two or more people to use the device at the same time (Fig. 16). The trend is to increase the number of touches that can be done simultaneously and hence to increase the number of users that can manipulate the device at the same time. Nowadays, SMART Table can already support up to 40 simultaneous touches (SMART Technologies 2014).
- Object awareness: The position of physical objects on the surface is detected using specifics technologies and markers (or tags). Thus, depending on what is incorporated to the tag, specific content is displayed and easily manipulated.
- Electronic pens: Apart from interact with media content, stylus or other physical objects can be used to write and draw on the device.

FIG. 16. Users interacting with the Smart Board 8000. Reproduced from SMART (2014).

On the other side, Microsoft offers a list of the possibilities that its multi-touch screens can offer (Microsoft 2012). Thus, even though this is specific for the SUR40 hardware (of Samsung) combined with the PixelSense software (of Microsoft), it can be treated as features that this kind of devices are capable to reach.

- Make content more engaging with immersion and collaboration.
- Plan and simulate using “if/then” in real time.
- Make learning more fun with rich visualizations.
- Transform the shopping experience with more recommendations and options.
- Connect with customers with games and pastimes.
- Communicate and connect with people offering them a new way to get the information they are looking for.

In education, although multi-touch screens (like tabletops and whiteboards) do not offer a new teaching and learning paradigm, they provide novelty in two ways. First, as it said above, they can offer features difficult to perform with traditional devices. Second, “while most Computer-Supported Collaborative Learning (CSCL) environments are designed for on-line activities, these devices are designed for co-located teamwork” (Dillenbourg & Evans 2011). Thus, even they can incorporate some on-line features, the main enrichment is the face-to-face integration. However, these advantages do not mean that every multi-touch screen will work in education but when designing these devices, aspects like individual user-system interaction, teamwork, classroom orchestration and socio-cultural context are taking into account, multi-touch screens have a prominent potential in education (Dillenbourg & Evans 2011).

5.5 Augmented Reality and Virtual Reality

This chapter focuses on two emergent technologies that can offer users new 3D realistic experiences based on computer-generated information and imagery; augmented reality (AR) and virtual reality (VR). These technologies are interesting for this thesis because they can help learners by strengthening the motivation for learning and enhancing educational realism-based practices and hence they will probably have an important implication in education. (Chang et al. 2010).

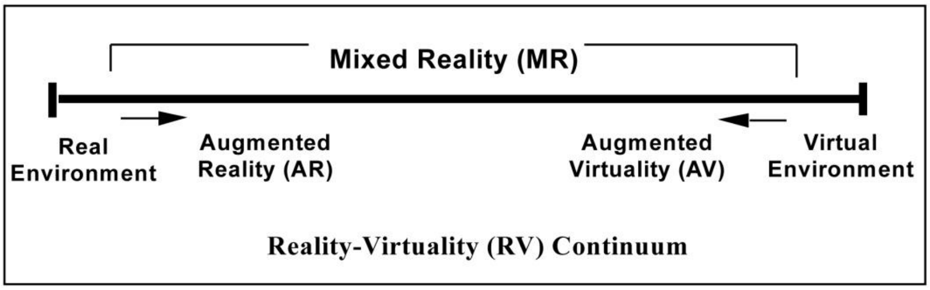

FIG. 17. Reality-virtuality continuum. Reproduced from Milgram & Kishino (2010)

The difference between augmented and virtual reality is the degree of virtuality (and reality) that is used. Virtual reality systems are expected to create a complete computer-generated virtual environment while augmented reality systems generate only local virtuality in the real environment (Lee 2012). This idea is well represented in the reality-virtuality continuum (Fig. 17). There, the term augmented virtuality, in which real objects are added to the virtual environment, is also used. However, these systems are not treated in this chapter since their potential is much more reduced than AR and VR systems.

This chapter could also be a subsection of Chapter 5.4: Non-traditional User Interfaces because in most of the cases, as well as the systems listed there, VR and AR systems does not use the traditional WIMP (windows, icons, menus, and pointing) user interfaces but non-traditional user interfaces which is the main topic of the previous chapter. However, since one of the goals is to study the implications and potential of these technologies in education, it is better to use an independent chapter for these two technologies. The reason is that in the systems introduced in the previous chapter such as multi-touch screens, the user interface was the key element that characterized those applications and their potential in education. On the other hand, the key aspect of the systems presented in this chapter is their 3D and realistic component and hence the user interface is only a complementary technology, although necessary. Anyway, it is useful to have previously seen non-traditional user interfaces in order to follow easier the content of this chapter.

Practically, the chapter is divided in two parts. The first is about augmented reality while the second focuses on virtual reality. In both, the subject is firstly introduced defining the meaning of the technology and giving a typology. Then, some current as well as future practical applications underlying those related with education are described in order to show the potential of these technologies.

5.5.1 Introduction to augmented reality

Augmented reality (AR) is a technology that "allows computer-generated virtual imagery information to be overlaid onto a live direct or indirect real-world environment in real time" (Lee 2012). Thus, it is considered that all AR systems have in common three characteristics (Krevelen & Poelman 2010):

- Combine real and virtual objects in a real environment.
- Register real and virtual objects with each other.
- Run interactively, in three dimensions and in real time.

There are two aspects of this definition that are important to highlight. Firstly, AR is not exclusive to a particular display technology, as it is explained later. Nor AR is limited to the sense of sight, since AR may also mean hearing, touch, and smell (Krevelen & Poelman 2010). Moreover, although the term "augmented reality" is believed to be coined in 1990 by the researcher Tom Caudell, the first AR prototypes (Fig. 18) were already created by computer graphics pioneer Ivan Sutherland and his students at Harvard University and the University of Utah in the 1960s (Johnson et al. 2010).

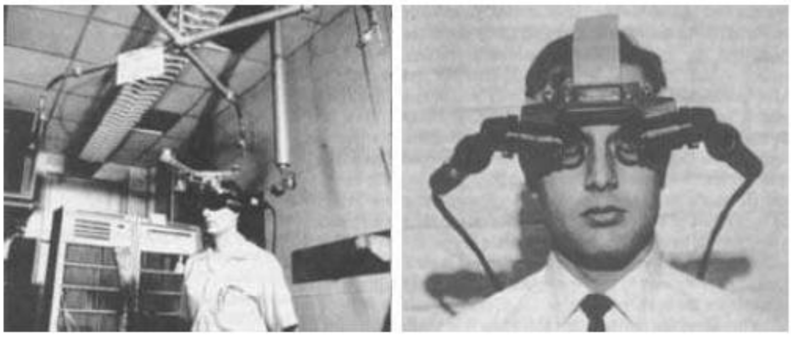

FIG. 18. The first head-mounted display. Reproduced from Tamura (2002)

The technological demands for AR systems are much higher than for virtual environment. The key components needed to build an AR system have not changed since Ivan Sutherland's work of the 1960s (Krevelen and Poelman 2010). There are three, each of them providing a solution for each of the characteristics of an AR system described above.

- Displays to combine real and virtual worlds.
- Trackers and sensors to track user position and orientation for correct registration of the virtual with the real world.
- Software and user interface technologies to allow real-time and 3D interaction.

Thus, there are many possible AR systems depending on the type of displays, trackers and user interfaces used (Krevelen & Poelman 2010). In this chapter, all the systems are listed, paying special attention to visual display systems. Thus, there are basically three ways to visually present an AR:

- Video see-through: The virtual environment is replaced by a video feed of reality and the AR is overlaid upon the digitized images.
- Optical see-through: The real-world perception is alone and only the AR overlay is displayed by means of transparent mirrors or lenses.
- Projected AR: The AR overlay onto real objects themselves resulting projective displays. This group also contains true 3-dimensional displays which are still far off for the masses.

The previous classification divided visual displays according to how the AR is created. AR displays can also be classified based on their position between the viewer and the real environment (Fig. 19**¡Error! No se encuentra el origen de la referencia.**):

- Head-worn: The visual display is attached to the head including the video/optical see-through head-mounted display (HMD), the virtual retinal display (VRD), and the head-mounted projective display (HMPD).
- Hand-held: This category includes hand-held video/optical see-through displays as well as hand-held projectors. These displays are bulkier than the previous ones but it is currently the best work-around to introduce AR to a mass market due to low production costs and ease of use.

- Spatial: These visual displays are placed statically within the environment and include screen-based video see-through, spatial optical see-through and projective displays. These techniques apply well for large presentations and exhibitions with limited interaction.

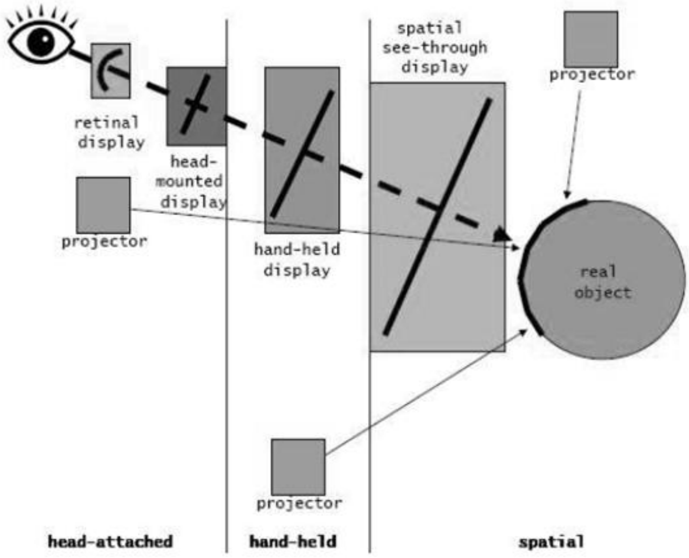

FIG. 19. Visual display techniques and positioning. Reproduced from Krevelen & Poelman (2010).

Before an AR system can display virtual objects into a real environment, the system must be able to solve two issues; sense the environment and track the viewer's (relative) movement preferably with six degrees of freedom (6DOF); 3 rotations and 3 translations. To sense the environment and do a correct AR registration, modelling environment techniques are used. On the other hand, to track the user movement, there are several kinds of techniques such as mechanical or ultrasonic suitable for indoor systems, Global Positioning Systems (GPS) for outdoors, radio techniques, or optical techniques. These last ones constitute the most promising approaches since they can detect scene geometry and camera motion in both 2D and 3D using marked objects in which there is a cue that calls for specific information, or non-marked objects in which the whole object is recognised (Johnson et al. 2010). The last aspect to consider, as said above, it is the user interface that the AR system use. There are several different possibilities although often the best solution is to use a hybrid user interface among tangible user interfaces, haptic user interfaces, visual user interfaces, and aural interfaces.

5.5.2 Applications of Augmented Reality

Augmented reality can be considered a young field since its presence in the market is still very low. Nevertheless, there are some interesting applications that are already a reality (or almost) since they will be available in the next few years:

- Augmented reality mapping: Mobile devices are increasingly driving AR into the mobile space and this application is one prominent example. It allows mobile users to search for information by pointing with the mobile's camera to specific objects, building, or streets. (Johnson et al. 2010).

- One application already available in the market is Google's SkyMap, which overlays information about the stars and constellations as a user views the sky. Some more recent applications are focused on social and commercial purposes like Layar or Squizzd (Fig. 20), which feature content layers of information such as ratings, reviews, or advertising.
- Personal Assistance and Advertisement: The consultancy Accenture developed an interesting device, the "Personal Awareness Assistant", which automatically stores names and faces of people you meet, cued by other information using both visual and aural recognition. Hence, it might be very useful for journalists, police, geographers, or archaeologists. (Krevelen and Poelman 2010).

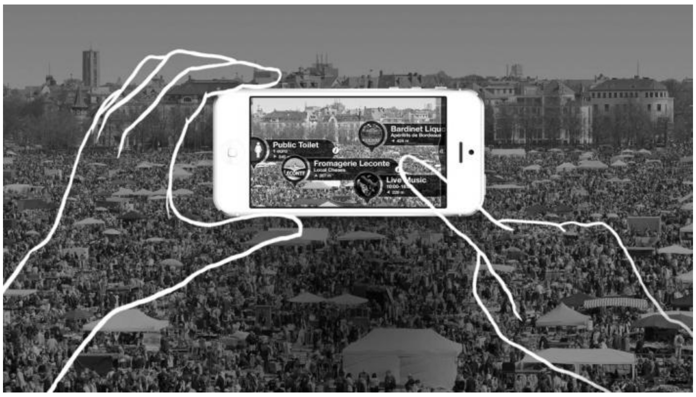

FIG. 20. Squizzd augmented reality application for iOS devices.
Reproduced from Squizzd (2013).

- Touring: Several systems are being developed to offer personalized augmented reality tours of archaeological sites. One of the leaders in this area is ArcheoGuide, which "uses outdoor tracking, mobile computing, 3D visualisation, and augmented reality to enhance information presentation, reconstruct ruined sites, and simulate ancient life" (Vlahakis et al. 2002). In this case, mobile devices and HMD displays are both used as visual displays.
- Maintenance: AR can be highly useful for the industry. Some applications are focus on industrial design or assembly of complex systems. Another important area among industry is maintenance. Complex machinery or structures require a lot of skill from maintenance personnel and AR can provide support to them by recognising possible errors through visual sensors and giving instructions in situ about how to solve a specific problem.

Augmented reality is also highly applicable in education since it can improve the way how complex theories and mechanisms are taught through a more real and interactive manner (Lee 2012). Some possible promising future applications are:

- Creation of 3D models of astronomical, chemical, biological, mathematical or engineering systems using marked objects and head-mounted projective or spatial displays (Fig. 21).
- Projection of 2D models over physical objects to enhance the comprehension about the system such as projections of bones or muscles on real human bodies.

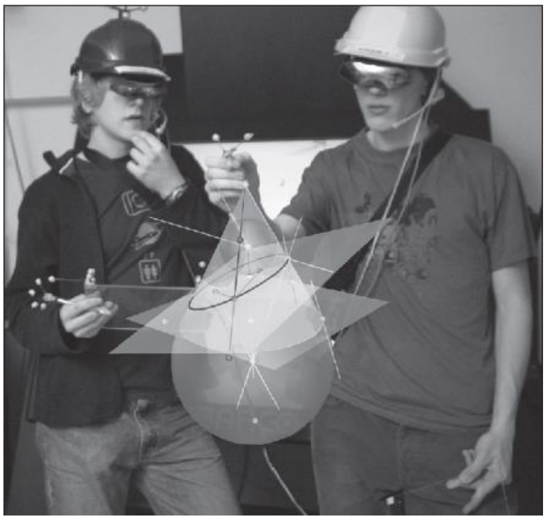

FIG. 21. Augmented reality system with marked objects and HMD displays. Reproduced from Lee (2012)

5.5.3 Introduction to virtual reality

The Encyclopaedia Britannica defines Virtual Reality as "the use of computer modelling and simulation that enables a person to interact with an artificial three-dimensional (3D) visual or other sensory environment" (Lowood 2012). Moreover, it states that "VR applications immerse the user in a computer-generated environment that simulates reality through the use of interactive devices, which send and receive information and are worn as goggles, headsets, gloves, or body suits" (Lowood 2012). Virtual reality systems can also be described considering three primary requirements (Sala 2007):

- Immersion, which requires physically involving the user, both by capturing exclusive visual attention and by transparently responding to three-dimensional input.
- Interaction, through the three-dimensional control device to investigate and control the virtual environment.
- Visual realism, which is an accurate representation of the real world using computer graphics techniques.

Thus, the difference between VR and AR is that in the first one, the whole representation or visualisation is virtual, or in other words, digitally produced. On the other hand, in AR the representation is a mix of real and virtual objects. However, it has to be said that in VR systems, users do not have to be completely isolated from the real world but they can be aware of it. Usually, VR systems are classified according to their method of display (Sala & Sala 2005), considering two main types:

- Immersive VR: Computer simulation is represented on multiple, room-size screen or through a stereoscopic HMD unit. The interaction might be done by special hardware such as gloves or suits.
- Non-immersive VR: Computer simulation is represented on a personal computer or other conventional screen, and the interaction might be done through any kind of interface such as joysticks, touch screens, globes, or mouse.

Another classification divides virtual reality systems weather they deliver virtual representations over the World Wide Web or not (Silva et al 2006):

- VR on-line: It allows more limited multimedia aspects because files are transmitted through internet and hence the size of these files has a limit.
- VR off-line: The software is completely independent of the Internet, and hence it allows more complex simulation and perfect modelling objects in terms of possible textures, materials and animations.

5.5.4 Applications of virtual reality systems

In this section we talk about some relevant actual and future applications of VR, paying special attention to the education sector. One of the first applications was in the military area, especially in 3D interactive computer graphics and flight simulators (Sala 2007). Other application areas include designing and prototyping, manufacturing, scientific visualisation, engineering, and education. In design, for instance, VR may provide a virtual environment for designers in the conceptual design stage of designing a new product; the designer can produce 3D “sketch”, evaluate functional and mechanical features in a more intuitive way, and modify the design. However, today in design, large companies are mainly the only users of VR. This is because VR devices and software have still a low performance/price ratio (Mujber et al. 2004).

In education, virtual reality is not present mostly although its application in some areas such as science, archaeology, history or architecture is being researched. It is noticed that the advantage of VR over conventional methods of description is that the student is given the opportunity to experience something that would be difficult, if not impossible, to illustrate or describe with conventional methods. Mainly, two types of virtual reality systems might be used in learning (Lee & Wong 2008):

- Virtual worlds that mimic the real world scenario using immersive and off-line features. For instance, a virtual museum to study the history, art and heritage of a place, or a virtual scene that shows how bacteria enter to a human body.
- Computer simulations of 3D models in an interactive multimedia environment such as geometry objects (Fig. 22). These applications are non-immerse and both on-line or off-line, and they constitute the most viable type of applications since they have much lower costs than immersive systems.

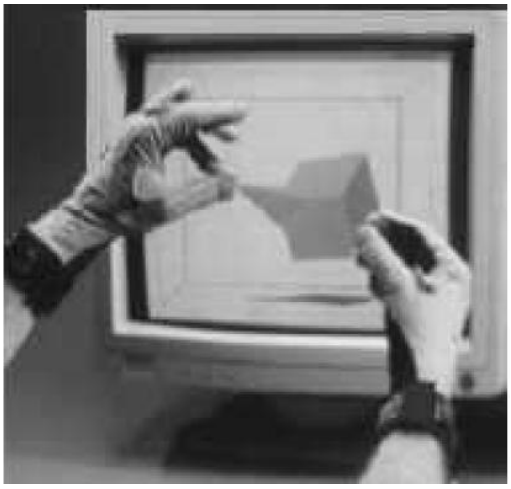

FIG. 22. A virtual object manipulated using data gloves.
Reproduced from Sala & Sala (2005)

6. ANALYSIS OF FUTURE TECHNOLOGICAL TRANSITIONS IN THE CATALAN HIGHER EDUCATION

This chapter contains the analytical part of the thesis and hence it aims to put together all the previous information in order to analyse how the Catalan higher education may evolve as a result of a technological transition. The structure is mainly divided in three parts. In the first one, the Catalan higher education case is connected with the multi-level perspective of technological describing the three different levels, indentifying some peculiarities of the case, and explaining how technological transitions should occur. The other two parts refer to the analysis itself which is divided in two steps. In the first the main method used is a affectation matrix while in the second step, scenarios analysis is applied. However, the concrete approach and methodology followed during the whole analysis is explained in detail in the next section.

6.1 Catalan higher education: A study case of the multi-level perspective

The multi-level perspective is a theory that conceptualizes how transitions from one socio-technical configuration to another one occur. This is exactly what the thesis is about since the main objective is to study how the Catalan higher education may evolve from the actual state (or configuration) to a future one as a result of the entrance of some specific technologies. Consequently, this thesis can be considered a practical case of the multi-level perspective with the Catalan university system as a subject and the five selected technologies as possible novel entries.

In this practical case, the regime is obviously the subject of the study: the Catalan higher education. This level theoretically formed by three different types of factors; socio-technical systems, socio-technical actors, and socio-technical rules. Practically, the socio-technical systems are modelled by the set of teaching tools used such as classrooms, MOOCs, or practical labs, the set of managerial tools, and all the systems that work around the higher education system. This is not going to be more specified since as it is explained later it is not really used in the analysis. On other hand, socio-technical actors are all those actors that are related with the university system such as students, teachers, politicians, leader boards of universities, researchers, or companies. It is important to underline that the most powerful actors of the Catalan university system, those who take the most important decisions about it, are the Catalan government and the leader boards of universities. Finally, the socio-technical rules refer to all those laws, habits, costumes, or beliefs of actors that create the playfield where actors and systems evolve. The macro-level is modelled by the social, economical, and demographical trends identified such as globalisation or rise of knowledge economy which are putting pressure on the current system and creating windows of opportunity that novel technologies may profit. Finally, the micro-level is represented by the five selected technologies such as social media and Touchscreens. Given that these technologies are not in the mainstream higher education market, they remain mostly in niches isolated from the common activities. However, not all the technologies are in the same situation. Thus, while augmented reality is still mostly in technological niches, Touchscreens are already in quite important market niches, and social media is even a consolidated technology in other very important sectors. Thus, according to the multi-level perspective, a technological transition will only occur when the higher university system, the novel trend, and the trends of the system interact together in the same direction.

However, some peculiar aspects of this specific case have to be mentioned. Firstly, unlike the most of the practical cases where the multi-level perspective have been applied (Geels 2005a; Geels 2005b.; Elzen et al. 2011; Geels 2002) which are historical, this study is future-oriented. This means that there is a certain level of uncertainty in the study since how the evolution and what the final situation is going to be are unknown. This fact has an important influence regarding the most suitable methods that can be used to analyse the case. The second peculiarity is that the socio-technical transition analysed is not affected by only one technology, but a group of five ”independent” technologies. The term ”independent” refers to the fact that the evolution and final result of one technology is rather isolated than strongly dependent. Hence, any subgroup of these five technologies may finally enter in the higher education. This complexity is augmented by the fact that the five technologies are not exclusively education-oriented but they may have application in several other sectors and hence their evolution cannot be explained by only considering the education sector. Finally, the last peculiarity is the specific methods used. Event-sequence analysis, event-history analysis, and network analysis are often the selected methods to specifically analyse how the technological transition occurs. Nevertheless, the first two are not appropriate in future-oriented cases while network analysis is very hard, if not impossible, to develop in a case with five non sector-exclusive technologies. Thus, some alternative methods are used in this case.

The general vision adopted is that due to the future nature of the case and the amount of technologies considered, it is very difficult, if not impossible, to analyse in a reliable and realistic way all the specific interactions between actors, systems, and rules. Hence, since the objective of the study is to figure out how the university system would look like after the entry of technologies, the approach used relies on the multi-level perspective not to analyse how everything will happen during the process but only the final result after the entry (or no entry) of the technologies. This approach can be defined as simpler but also as more trustworthy since it relies fewer in conjectures and more in real observable facts.

The multi-level perspective defines that final entry (or not) of a technology in the regime is determinate by three key drivers which are internal drivers of the technology, support of powerful actors of the regime, and landscape trends and technology matching. Thus, the approach used aims to study if these three key drivers are likely to favour the final entry of the technologies or not. Particularly, this is done by analysing each driver separately in the following manner:

- The support of powerful actors of the regime is not considered as an environmental driver that cannot be controlled but a factor of action. This is because the most powerful actors are governments and leader boards of universities which are indeed decision-makers and the final addressees of the study. Consequently, this driver is not considered as something uncertain for decision-makers and hence it is not intrinsically analysed.
- Landscape trends and technology matching is an environmental driver since how much one novel technology fits with the current needs and trends of the whole system cannot be modified by decision-makers easily. Hence, this matching is essentially analysed by creating an affectation matrix between the needs of the higher education, which are result of the landscape trends, and the five technologies. The goal is to find which technologies may provide solution to which needs of the system.
- Internal drivers of the technologies are also considered an environmental driver and hence they are analysed. Practically, internal drivers mean the technical development of technologies and hence this technical evolution is what has to be analysed. Nevertheless, due to the non exclusive education-oriented nature of the technologies it is impossible to make a reliable prediction of their evolution in this study. Consequently, an important degree of uncertainty is considered which is handled using a scenarios analysis. The goal is to find a set of hypothetical scenarios which differ on the degree of optimism regarding the technical evolution of the technologies.

Overall, the approach of the analytical part aims to justify that the technologies have potential to cover the current and future needs of the Catalan higher education, and provide a set of possible future scenarios encouraging decision-makers to support some of them, if not all.

6.2 Interaction between the evolution of the Catalan university system and the selected technologies

In the first part of the analysis, the aim is to figure out which technologies may have potential to provide future solutions to the Catalan university system, if their technical evolution (or internal drivers) is favourable. Thus, following the view of the multi-level perspective, the matching between technologies and trends, which is one of the key drivers that determinates if one technology finally enters or not to the regime, is analysed.

To do this in a reliable manner, with the lowest possible degree of assumption, the analysis is divided in three quite simple and apparent steps. Firstly, the challenges that the system is facing, which have been already previously identified, are listed and argued. Secondly, using all the information collected about the technologies, several specific and plausible future features are provided per each of the five technologies. Finally, both previous steps are put together using an affectation matrix in order to figure out which technologies might give solution to which challenges, and by extension, to the Catalan university system.

6.2.1 List of current challenges of the Catalan university system

In the section 4.2.2: Specific affectations of these trends on the Catalan university system, the social-economical trends have been analysed and a list of novel challenges of the university system have been identified.

- Higher enrolment capacity
- Higher educational efficiency
- Higher managerial efficiency
- New sources of funding
- Easier mobility of students and staff
- More communication between international students and staff
- More coordination between universities
- Offer new kinds of knowledge (cognitive, social...)
- Offer a wider range of programs
- Higher staff wages
- Offer better and more attractive programs

Regarding this list of challenges, it is interesting to underline two aspects. First, as the multi-level perspective proposes, these new needs of the university system are consequence of the affectation of the social and economical trends (or landscape) above the regime which is creating windows of opportunity for novel technologies or solutions. The second point is about the nature of the challenges which can be divided in learning-related challenges such as higher education efficiency or new kinds of knowledge, and non learning-related challenges such as new sources of founding and easier mobility. Moreover, learning-related challenges can also be separated into two groups depending if they are stimulating actions to reduce costs such as higher education efficiency, or action to enhance quality such as more attractive programs.

6.2.2 List of future features of the technologies

In the Chapter 5: The five selected technologies: Overview and foreesable developments, as the title indicates, the five technologies have been by and large described including the plausible and possible features that may incorporate in the future. Thus, the aim of this section is to make explicit the relation between technologies and their most promising features (Table 8).

Technology	Features
Social media	**Enhancing connection between university agents** Global communities by subjects' specialists and students Easy communication and sharing with community members Global communities of higher education institutions
Virtual learning environments	**Enhancing personalized and effective learning** Intelligent textbooks Adaptive evaluation systems Intelligent tutoring systems
Massive Open Online Courses	**Enhancing learning efficiency and accessibility** Accessibility to anyone across the globe Accessibility to anyone independently of his age Online and cost-efficient learning
Touchscreens	**Enhancing immersion and people collaboration** Multi-user participation Object awareness Bigger virtual environments
Augmented and virtual reality	**Providing new manners of understanding of the world** Creation of 3D models of complex systems Creation of interactive environments Projection of 2D models over real objects

TABLE 8. The five selected technologies and their main features.

In the same way that several different types of needs have been identified before, some distinction between technologies can also be done. The first comment is that while most of the technologies are about learning, social media features have no relation with how students learn. However, it may have relation with where students learn since social media may serve as a global connection for the whole university sector what might make easy the mobility of students and staff. On the other hand, the rest four technologies are highly related with the learning process, two in a physical manner (Touchscreens, and augmented and virtual reality), and two in a virtual manner (virtual learning environments and MOOCs). It is also noticeable that given that in online environments teachers are not required (or much less), virtual environments and MOOCs are highly cost efficient. On the other side, Touchscreens and augmented reality tools do not compete for cost but for learning quality improvement.

6.2.3 Affectation matrix between needs of the Catalan university system and the five technologies

		Technology				
		Social media	VLEs	MOOCs	Touch screens	AR & VR
Challenge of the system	Higher enrolment capacity		✓	✓		
	Higher educat. efficiency		✓	✓		
	Higher manag. efficiency					
	New sources of funding					
	Easier mobility	✓				
	More communication	✓		✓		
	More coordination	✓				
	New knowledge				✓	✓
	More programs					
	Higher staff wages					
	More attractive programs		✓	✓	✓	✓

TABLE 9. Affectation matrix between needs of the system and selected technologies.

To finally study which technologies may give solution to which needs of the system in the future, an interaction matrix has been built (Table 9) using the results of the Section 6.2.1: List of current challenges of the Catalan university system in the vertical axis, and the five selected technologies in the horizontal axis. Instead of using the five technologies, the specific features previously identified could have been used but the matrix resultant was inconvenient so that it has been decided to put the technologies and explain the specific relations with text. Indeed, the matrix is very useful to visually recognise the affectations but it does not give any kind of argumentation related.

The main conclusion of this first part of the analysis is that all the technologies have a contrasted potential to provide solutions to the future Catalan university system. Furthermore, some more specific conclusions can be given. Thus, it can be said that there are three different subgroups of technologies with similar characteristics. The first group is only composed by social media which has the potential fill those challenges resulting from globalisation which are easier mobility, more personal communication, and more institutional coordination. On the other side, the second group is composed by virtual learning environments and MOOCs which are mainly characterised by being able to provide higher enrolment capacity and higher education efficiency if their technical development is proper. Finally, the third group is composed by Touchscreens, and augmented and virtual reality systems which are the only ones that may really contribute something new to learning processes in terms of interaction, physical experience, and immersion.

6.3 Scenarios analysis

This chapter constitutes the second and final part of the analysis. Being already justified that all the technologies have a future potential in higher education, what wants to be analysed now is how these technologies may exactly change the actual configuration of the system. Recalling again to the multi-level perspective, at this point of the analysis, the entrance of the technologies in the university system only depends on the technical evolution of themselves, apart from the support of decision-makers.

Nevertheless, as it has already said, it is not possible given the scope of this thesis to predict how these five technologies will technically evolve. Hence, there is an important degree of uncertainty which is handled using a scenarios analysis. The goal of this part of the analysis is to create a set of hypothetical scenarios resulting from the entrance of different subgroups of technologies, and evaluate their outcomes.

6.3.1 Typology of the scenarios used

Considering the typology designed by Philip W.F. van Notten (Van Notten et al. 2003; Van Notten 2006), which has three macro-dimensions and ten micro-dimensions, the scenario analysis can be defined as follows. About the goal of the scenarios which is the first macro-dimension, the study have a product-oriented goal since the outcome that interests is the final nature and quality of the scenario founded, not the way how they were achieved. Moreover, it has a descriptive nature because it explores the future instead of describing a desirable future. The issue can be defined as both issue-based and area-based, since the focus is in the higher education sector but at the same focused in Catalonia. The fourth micro-dimension is the nature of change which is defined in this case as a gradual discontinuity since changes happen as a result of self-reinforcing processes.

The second macro-dimension is about the process design which can be classified as intuitive or analytical. In this case, the process is intuitive since it does not follow any preset methodology. Specifically about the micro-dimensions, these scenarios are qualitative since the inputs are not numerical but conceptual. Moreover, it is not a participatory method since the people participant is only one, nor a model-based since there is no any model. Hence, this study can be considered as a desk research where the work group is small and the research uses a literature analysis on the basis. Finally, the group composition is evidently exclusive since no participants have been invited to enter in the process.

Regarding the third macro-dimension which has relation with the content of the scenarios, it has to be mostly defined as simple scenarios like the micro-dimensions specifies. The temporal nature is not developmental but end-state since it only describes the end state of the university system after the entry of the technologies. They do not specify at all how the technologies have evolved before the entrance. Moreover, the factors are clearly heterogeneous since education is analysed together with several different technologies. Hence, the factors involved are completely heterogeneous. Finally, the variables are treated in an isolated manner. This is an important characteristic since it is result of the approach applied since the beginning in the multi-level perspective where the three key drivers have been analysed separately. In this last part of the analysis, the aim is also to analyse the possible future states in the most simple and reliable possible manner.

6.3.2 Creation of the scenarios

Before creating the scenarios themselves, although the approach is intuitive, some basic steps have to be carried out (van Notten 2006; Wilson 2000; Blyth 2005) which can be generalised as defining the specific subject of the study and identifying the key variables. The first step, which is to define the specific subject, is largely already done since the subject of the scenarios analysis is the Catalan higher education. The exact aim of the scenarios is also quite known; to create several possible and plausible future scenarios of the Catalan higher education resulting of the entrance of different subgroups of technologies.

The second main step is to define the key variables that distinguish the different scenarios. In this case, it is also rather clear as the reason of using scenarios analysis is the uncertainty related with the internal development of the technologies. Hence, the level of uncertainty of the technologies, which is interpreted as the conceptual distance between the actual technical development and the final desired technical development, is the only key driver in this case. Thus, the scenarios are created starting from the entrance of different subgroups of technologies with similar level of uncertainty. Specifically, in the first scenario, only the technologies with lower uncertainty are considered to enter while in the second scenario, the second group of technologies with less uncertainty also enter, and finally in the third scenario, all the technologies enter.

Thus, the next step is to evaluate the technologies according to their degree of uncertainty, interpreted as the conceptual distance between the actual technical development and the final desired technical development of the technologies (Table 10). This evaluation is done conceptually by comparing the actual features of the technologies and the features that are expected to provide. Thus, Touchscreens and MOOCs are the technologies with less uncertainty, since most of their desired features are already available. On the other side, augmented and virtual reality is the technology with more uncertainty since most of the systems are still in researching stages. It has to be mentioned that learning environment and MOOCs are graded with two levels of uncertainty. This is because these technologies may enter in the system before reaching all the considered features. For instance, MOOCs have a low uncertainty to expand in a similar form they currently are, but they have a middle uncertainty to become more powerful tools.

Technology	Degree of uncertainty	Entry to scenario number
Social media	Middle.	2, 3
Virtual environment & AI	Middle/High	2, 3
MOOCs	Low/Middle	1, 2, 3
Touchscreens	Low	1, 2, 3
Augmented reality	High	3

TABLE 10. Evaluation of degree of uncertainty of the technologies.

Overall, each of the scenarios has a different degree of uncertainty which is result of the different subgroup of technologies considered to enter in the university system. Thus, per each scenario, the technologies selected and their specific uses are specified, and the future system configuration and the learning paradigm are also described.

Scenario 1: Better some of pudding than none of a pie

This scenario is the most plausible in terms of lineal technical development since only the technologies with lowest uncertainty which are Massive Open Online Courses and Touchscreens enter in the system. Specifically, many traditional classrooms are equipped with whiteboards that enhance the communication between teacher and students. Moreover, other rooms specially designed for small work groups are equipped with interactive tables where students can work together in a coordinated way to solve problems. On the other hand, MOOCs are continuing growing in terms of number of courses offered and students enrolled, but they still remain as independent courses, not incorporated to any official program. Hence, the teaching paradigm remains equal with the only improvements of higher interaction between students and teachers, and the increasing number of enrolments in MOOCs which are not official courses.

Scenario 2: Union means strength

This scenario is more unlikely than Scenario 1 since the technologies that enter have a higher level of uncertainty. Specifically, Touchscreens are considered to be present in both whiteboards and interactive tables. MOOCs are also present but in an evolved manner. MOOCs are incorporated in official programs and hence they can be changed by credits. Moreover, courses are not offered by universities independently but by groups of universities which share programs, information, staff, and students. All this coordination is also supported by social networks specific of the education sector, as well as LinkedIn is specific of the professional sector. Furthermore, MOOCs as well as traditional online environments incorporate new features such as adaptive evaluation systems. Generally, this scenario represents an important change of the learning paradigm since traditional classroom teaching is combined with learning online. Moreover, this fluent coordination between international universities allows students to take mobility programs much more easily and with validation of the credits taken.

Scenario 3: Futuristic reality or real future?

This scenario is the most uncertain since all the five technologies are considered to enter in the system. Thus, it has to be seen as something highly unlikely to happen in the short-term but more plausible in the mid- or long-term future. Specifically, this scenario embraces all the features included in the Scenario 2 plus mainly two new solutions. First, a higher development of virtual environments including features such as intelligent textbooks and intelligent tutoring systems, which enables students to master new theoretical content at home in an effective and personalised way. Second, the entrance of augmented reality and virtual reality systems in the higher education. Small rooms and labs are equipped with these new devices that offer 2D and 3D models and simulations. Thus, putting all the pieces together, this scenario means a total change in the teaching paradigm. Online environments are so powerful that students can perfectly master the most of the theoretical content in their computer and universities become a place full of studios, labs, and interactive rooms where students can put in practice any type of content using features such as interactive tables, 3D models, or immersive virtual worlds.

7. DISCUSSION

7.1 Scenarios analysis review

This section aims to evaluate the second part of the analysis, the scenarios analysis, which is the conclusive part of the thesis. Thus, several different aspects are point of interest such as the validity of the approach used, the uncertainty present in the scenarios, the needs filled of the university system and the necessary investments in these future states, and some thoughts regarding decision-making.

Regarding the validity of the analysis, it has to be highlighted that the chosen approach is product-oriented and with low integration of variables just to reduce the degree of speculation and uncertainty as much as possible. Nevertheless, the intrinsic uncertainty that technologies have because of their internal future evolution cannot be sorted out. Practically, despite these inconvenient facts, the scenarios analysis serves to show what these technologies might mean for the higher education. Or in other words, the scenarios show the potential of these five technologies. Thus, even though is difficult to give some specific tips or ideas to decision-makers about what is better to do, these scenarios can be useful for them to know where they want to move through.

Specifically, I would say that the most interesting technologies are Massive Open Online Courses and virtual learning environments because of their cost efficiency, and flexible and personalised characteristics, but also because if they incorporate in the future features such as intelligent textbook or intelligent tutoring systems, the actual teaching paradigm of the Catalan higher education may totally change.

7.2 Reflective review of the whole study

First of all, this thesis has been done to pursue two main objectives, and three secondary objectives. Thus, the review has to start by evaluating how well these objectives have been performed. About the secondary objectives, the result is very positive since the three points have been reached. First, the set of five technologies have been corroborated to have a high potential in improving the actual situation of the higher education. Second, an updated literature review of each of these technologies has been done. Indeed, this aspect is a plus for this thesis since there are no many studies about these technologies that joint as much actualized information as this thesis. Third, the multi-level perspective has been properly applied to this case although some challenges regarding the future-oriented nature of the study have been met.

Regarding the two main objectives, the result is a little less positive although some interesting facts have been found. First, due to the presence of some uncertainty, the future state of the higher education could not have been predicted, but different possible situations have been provided using scenarios. Thus, the results are interesting because show what is the potential of these technologies and how the higher education may evolve as a result of them. However, what has not been possible is to explain how these hypothetical situations might occur and how probable they are. Consequently, it is difficult to give specific tips or ideas to decision-makers. Instead, some valuable aspects have been noticed. First, it is rather clear that MOOCs and virtual learning environments might offer important improvements such as more flexible and personalised teaching. But the most important about them is that they are highly cost efficient what means that universities might reduce their cost per student substantially. Another fact that should be noticed to decision-makers is that even augmented and virtual reality have still a low technical development, it might be interesting for universities to invest in researching in these fields what might give them a privileged position in the future.

Regarding the challenges met during the thesis is has to be said first that due to the singularity and novelty of the study developed, it has been quite difficult to define the exact locus of the study as well as the most suitable approaches and methods to do it. Another important challenge has been the large amount of time that I have spent in researching about the five selected technologies as a consequence of two reasons. First, indentifying the most interesting technologies to be studied was not trivial. Indeed, technologies such as big data, cloud computing, or wireless networking were also included in the beginning of the study. Second, developing a quite general and updated description of each of these techs was particularly challenging since they are novel technologies and hence their literature related contains mostly specific aspects of them. Thus, there is no any unique general, reliable and, updated study that combines all the information needed. This time spent in researching has made that the time for the analytical part was quite limited.

7.3 Avenues for future research

Social media, virtual learning environments, Massive Open Online Courses, Touchscreens, and augmented and virtual reality may have much to offer to Catalan higher education in the future. Considering this statement, it would be interesting for future research to develop future-oriented analysis of one specific technology among these five to better evaluate, not their potential, but their real possibilities to become a fact.

On the other hand, it would have also interest to link both managerial and technological perspectives of the future of the higher education. Thus, some short-term future study might be done trying the joint both managerial and technological actions such as the evolution of Massive Open Online Courses supported and complemented by suitable organisational actions.

8. CONCLUSIONS

Nowadays, it is extensively recognised that the higher education does not really match with the needs of the market, the students, and mostly the society. Governments are trying to redirect the situation but they seem to be almost limited to managerial and organisational actions.

This thesis shows that technologies have much to offer to the Catalan higher education in the short- and long-term future. Specifically, all five selected technologies studied (social media, virtual learning environments, MOOCs, Touchscreens, and augmented reality) have contrasted potential to provide solutions to the future Catalan university system. Thus, virtual learning environments and MOOCs might provide higher enrolment capacity and higher education efficiency if their technical development evolve properly and Touchscreens, and augmented and virtual reality systems may really offer something new to learning processes in terms of interaction, physical experience, and immersion.

Besides this, the thesis incorporates a general and updated literature review for each of the five technologies that has been analysed what is an outstanding plus since there are no many studies about these technologies that joint as much actualized information as this thesis.

REFERENCES

Agencia Estatal Boletín Oficial del Estado. 2013. *Estatutos de Autonomía*. Available at: http://www.boe.es/legislacion/codigos/descarga.php?fich=017_Estatutos_de_Autonomia.pdf

Anderson, P., & Tushman, M. L. 1990. Technological discontinuities and dominant designs: A cyclical model of technological change. Administrative science quarterly, pp. 604-633.

Arslan, F., & Kaysi, F. 2013. Virtual learning environments.
Dillenbourg, P. 2000. "Virtual learning environments". EUN Conference 2000: Learning in the new millennium: Building new education strategies for schools.

Au Yeung, C., Liccardi, I., Lu, K., and Berners-Lee, T. 2009. Decentralization: The Future of Online Social Networking. Available at: http://www.w3.org/2008/09/msnws/papers/decentralization.pdf

Barr, R. B., & Tagg, J. (1995). From teaching to learning—A new paradigm for undergraduate education. Change: The magazine of higher learning, 27(6), 12-26.

Benko, H., Wilson, A. D., & Baudisch, P. 2006. Precise selection techniques for multi-touch screens. Proceedings of the SIGCHI conference on Human Factors in computing systems. ACM, 2006.

Biggs, J., & Tang, C. (2011). Teaching for quality learning at university. McGraw-Hill International.

Blyth, M. J. 2005. Learning from the future through scenario planning.

Bourgeois, E. 2002. Higher education and research for the ERA: Current trends and challenges for the near future. Final Report of the STRATA-ETAN expert group. Foresignt for the development of higher education/research relations. Bruxelles: Commission européenne, DG Recherche.

Bradfield, R., Wright, G., Burt, G., Cairns, G., & Van Der Heijden, K. 2005. The origins and evolution of scenario techniques in long range business planning. Futures 37, 8, pp. 795-812.

Brusilovsky, P., & Millán, E. 2007. User models for adaptive hypermedia and adaptive educational systems. In The adaptive web. pp. 3-53. Springer-Verlag.

Brusilovsky, P., & Peylo, C. 2003. Adaptive and intelligent web-based educational systems. International Journal of Artificial Intelligence in Education 13, 2, pp. 159-172.

Caravazza, F. 2008. Social Media Landscape 2008. Available at: http://www.fredcavazza.net/2008/06/09/social-media-landscape/

Caravazza, F. 2013. Social Media Landscape 2013. Available at: http://www.fredcavazza.net/2013/04/17/social-media-landscape-2013/

Chang, G., Morreale, P., & Medicherla, P. 2010. Applications of augmented reality systems in education. Society for Information Technology & Teacher Education International Conference. Vol. 2010. No. 1. 2010.

Chaudhri, V. K., Cheng, B., Overholtzer, A., Roschelle, J., Spaulding, A., Clark, P., Graves, M., & Gunning, D. 2013. Inquire Biology: A Textbook that Answers Questions. AI Magazine 34, 3, pp. 55-72.

Chen, X., Barnett, D. R., & Stephens, C. 2013. Fad or Future: The Advantages and Challenges of Massive Open Online Courses (MOOCs).

Chermack, T., Lynham, S., & Ruona, W. 2001. A review of scenario planning literature. Futures Research Quarterly 17, 2.

Chisari, M. 2009. The Future of Social Networking. W3C Workshop on the Future of Social Networking. Available at: http://www.w3.org/2008/09/msnws/papers/The_Future_Of_Social_Networking.html

Conati, C., & Kardan, S. 2013. Student Modeling: Supporting Personalized Insutrction, from Problem Solving to Exploratory Open-Ended Activities. AI Magazine 34, 4, 13 p.

Congreso de la Diputados. 2003. *La Constitutición española de 1978*. *Título VIII: De la Organización Territorial del Estado*. Available at: http://www.congreso.es/consti/constitucion/indice/titulos/articulos.jsp?ini=137&fin=158&tipo=2

De Jouvenel, H. 2000. A brief methodological guide to scenario building. Technological Forecasting and Social Change 65, 1, pp. 37-48.

De la Monografía, P. 2007. *Técnicas de la inteligencia artificial aplicadas a la educación. Inteligencia Artificial, Revista Iberoamericana de Inteligencia Artificial* 33, pp. 7-12.

Dillenbourg, P., Schneider, D., & Synteta, P. 2002. Virtual learning environments. In Proceedings of the 3rd Hellenic Conference'Information & Communication Technologies in Education', pp. 3-18.

Dillenbourg, Pierre, and Michael Evans. 2011. Interactive tabletops in education. International Journal of Computer-Supported Collaborative Learning 6.4, pp. 491-514.

Dominik Lukes. 2012. What is and what is not a MOOC: A picture of family resemblance (working undefinition) #moocmooc. Researchity – Exploring Open Research and Open Education. Available at: http://researchity.net/2012/08/14/what-is-and-what-is-not-a-mooc-a-picture-of-family-resemblance-working-undefinition-moocmooc/

Elzen, B., Geels, F.W., Leeuwis, C.S., & Van Mierlo, B. 2011. Normative contestation in transitions‘in the making’: animal welfare concerns and system innovation in pig husbandry (1970–2008). Research Policy 40, pp. 263–275.

Fahey, L., Randell, R. 1998: Learning from the Future: Competitive Foresight Scenarios, New York, in: Ratcliffe, J. (ed. 1999).

FIDIS Project. 2009. Social Networking 4.0: Identity in the future of the digital social landscape. Available at: http://www.fidis.net/resources/identity-use-cases-scenarios/social-networking-40-identity-in-the-future-of-the-digital-social-landscape/

Geels, F. W. 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Research policy 31, 8, pp. 1257-1274.

Geels, F. 2005a. Co-evolution of technology and society: The transition in water supply and personal hygiene in the Netherlands (1850–1930)—a case study in multi-level perspective. Technology in society 27, 3, pp. 363-397.

Geels, F. W. 2005b. The dynamics of transitions in socio-technical systems: a multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930). Technology Analysis & Strategic Management 17, 4, pp. 445-476.

Geels, F. W. 2010. Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. Research Policy 39, 4, pp. 495-510.

Geels, F. W. 2011. The multi-level perspective on sustainability transitions: Responses to seven criticisms. Environmental Innovation and Societal Transitions 1, 1, pp. 24-40.

Generalitat de Catalunya. 2012a. The history of the Catalan universities. Ministry Economy and Knowledge. Available at: http://www20.gencat.cat/portal/site/ur/menuitem.c7c5f12f7354d1a9ccf24010b0c0e1a0/?vgnex-toid=8e14fa2156c69310VgnVCM2000009b0c1e0aRCRD&vgnextchannel=8e14fa2156c69310VgnVCM2000009b0c1e0aRCRD&vgnextfmt=default&newLang=en_GB

Generalitat de Catalunya. 2012b. University policy in Catalonia. Available at: http://www20.gencat.cat/portal/site/ur/menuitem.c7c5f12f7354d1a9ccf24010b0c0e1a0/?vgnex-toid=b7c6fa2156c69310VgnVCM2000009b0c1e0aRCRD&vgnextchannel=b7c6fa2156c69310VgnVCM2000009b0c1e0aRCRD&vgnextfmt=default

Generalitat de Catalunya. 2014a. The Catalan University system. Serra Húnter Programme. Available at: http://serrahunter.gencat.cat/en/el_sistema_universitari_catala/index.html

Generalitat de Catalunya. 2014b. Evolution of the percentage of master's degrees taught in a certain language between the 2010-11 and 2012-13 academic years for the whole Catalan public university system. Available at: http://www20.gencat.cat/docs/ur/home/03%20Ambits%20dActuacio/Les%20llengues%20a%20la%20universitat/Dades%20i%20estadistiques%20sociolinguistiques/docs/4.%20Evolution%20MASTERS%20EN.pdf

Genus, A., & Coles, A. M. 2008. Rethinking the multi-level perspective of technological transitions. Research policy 37, 9, pp. 1436-1445.

Georghiou, L., & Harper, J.C. 2006. The Higher Education Sector and its Role in Research: Status and impact of Future-Oriented Technology Analysis. Anchor Paper for Second International Seville Seminar on Future-Oriented Technology Analysis (FTA), 28th- 29th September 2006.

Global Web Index. 2014. Active Usage: Social Platforms.

Heinegard, C. 2005. The University of the Future. IVA, Swedish Royal Academy of Engineering.

Hill, P. 2012. “Four Barriers That MOOCs Must Overcome to Build a Sustainable Model.” Retrieved from: http://mfeldstein.com/four-barriers-that-moocs-must-overcome-to-become-sustainable-model/

Hoye, T., & Kozak, J. 2010. Touch screens: A pressing technology. Tenth Annual Freshman Engineering Sustainability in the New Millennium Conference April, 10.

Ishii, H. 2008. Tangible bits: beyond pixels. In Proceedings of the 2nd international conference on Tangible and embedded interaction (pp. xv-xxv). ACM.

ICC. 2014. Scholar maps. Available at: http://www.icc.cat/cat/Home-ICC/Mapes-escolars-i-divulgacio

IDESCAT. 2013. University education. Students enrolled, by sex and university. Available at: http://www.idescat.cat/pub/?id=aec&n=753&t=2012&x=7&y=4

International Artificial Intelligence in Education Society (IAIED). 2010. International AIED Society [www]. [assessed on 31.01.11]. Available at: http://iaied.org/about/

Johnson, L., Levine, A., Smith, R., & Stone, S. 2010. Simple augmented reality. The 2010 Horizon Report, pp. 21-24. Austin, Texas: The New Media Consortium.

Kaplan, A. M., and Haenlein, M. 2009. Users of the world, unite! The challenges and opportunities of Social Media. Business Horizons 53, pp. 59-68.

Karray, F., Alemzadeh, M., Saleh, J. A., & Arab, M. N. 2008. Human-computer interaction: Overview on state of the art.

Lee, K. 2012. Augmented reality in education and training. Tech Trends 56, 2, pp. 13-21.

Lee, E. A., & Wong, K. W. 2008. A review of using virtual reality for learning. Transactions on edutainment I. Springer Berlin Heidelberg. pp. 231-241.

Lester, J. C., Ha, E. Y., Lee, S. Y., Mott, B. W., Rowe, J. P., & Sabourin, J. L. 2013. Serious Games Get Smart: Intelligent Game-Based Learning Environments. AI Magazine 34, 4, pp. 31-45.

Lowood, H. E. 2012. Virtual reality. Encyclopaedia Britannica. Available at: http://global.britannica.com/EBchecked/topic/630181/virtual-reality-VR

Luján Mora, S. 2012. ¿Qué son los MOOCs? University of Alacant. Available at: http://desarrolloweb.dlsi.ua.es/cursos/2012/que-son-los-moocs/preguntas-respuestas#termino-mooc

Markard, J., & Truffer, B. 2008. Technological innovation systems and the multi-level perspective: Towards an integrated framework. Research policy 37, 4, pp. 596-615.

Meieran, E. S. 2012. 21st Century Innovations. Available at: http://www.engineeringchallenges.org/cms/7126/8275.aspx

Microsoft. 2012. PixelSense. Available at: http://www.microsoft.com/en-us/pixelsense/whatissurface.aspx

Mietzner, D., & Reger, G. 2004. Scenario approaches–history, differences, advantages and disadvantages. In EU-US Seminar: New Technology Foresight, Forecasting and Assessment Methods, Seville, May 2004. pp. 13-14.

Mujber, T. S., Szecsi, T., & Hashmi, M. S. J. 2004. Virtual reality applications in manufacturing process simulation. Journal of materials processing technology 155, pp. 1834-1838.

Nelson, R. R., & Winter, S. G. 1977. In search of useful theory of innovation. Research policy 6, 1, pp. 36-76.

Oliver, M., Hernández-Leo, D., Daza, V., Martín, C., & Albó, L. 2014. MOOCs en España. Cátedra Telefonica-UPF. Available at: http://www.catedratelefonica.upf.edu/wp-content/uploads/2014/02/MOOCs-en-Espa%C3%B1a1.pdf

O'Leary, R., & Ramsden, A. 2002. Virtual learning environments. Learning and Teaching Support Network Generic Centre/ALT Guides, LTSN. Retrieved July,12, 2005.

Pappano, L. 2012. The Year of the MOOC. The New York Times 2, 12.

Psotka, J., Massey, L. D. & Mutter, S. A. 1988. Intelligent Tutoring Systems: Lessons Learned. New Jersey, Lawrence Erlbaum Associates, Inc., Publishers. 555 p.

Ringland, G., & Schwartz, P. P. 1998. Scenario planning: Managing for the future. John Wiley & Sons.

Rip, A., & Kemp, R., 1998. Technological change. In: Rayner, S., Malone, E.J. (Eds.), Human Choice and Climate Change, vol. 2. Resources and Technology. Battelle Press, Columbus, Ohio, pp. 327–399.

Russell, S. & Norvig, P. 1995. Artificial Intelligence: A Modern Approach. Prentice-Hall, Saddle River, NJ.

Saffer, Dan. 2008. Designing gestural interfaces: Touchscreens and interactive devices. O'Reilly Media, Inc.

Sala, N. 2009. Virtual Reality and Virtual Environments in Education. In: Cartelli, A., & Palma, M. Encyclopedia of Information Communication Technology. Volume 2. pp. 838-883.

Sala, N., & Sala, M. 2005. Virtual Reality in Education. In: Carbonara, D. D. 2005. Technology literacy applications in learning environments, IGI Global.

Samsung. 2014. SUR40. Available at: http://www.samsung.com/mx/consumer/monitor-peripherals-printer/visual-solutions/touch-screens/LH40SFWTGC/ZA#

Sawyer, R. Keith. (2006). The Cambridge Handbook of the Learning Sciences. New York: Cambridge University Press.

Secretaría General de Universidades. 2012. *Datos y cifras del sistema universitario español, curso 2012-2013. Ministerio de Educación, Cultura y Deporte.*

Shneiderman, B. 1983. Direct Manipulation: A Step Beyond Programming Languages. IEEE Computer 16, 8, pp. 57–69.

Siemens, G. 2013. Massive Open Online Courses: Innovation in Education?. Open Educational Resources: Innovation, Research and Practice 5.

SMART Technologies. 2014. Available at: http://smarttech.com/

Smith, A. 2007. Translating sustainabilities between green niches and socio-technical regimes. Technology Analysis & Strategic Management 19, 4, pp. 427-450.

Smith, A., Voß, J. P., & Grin, J. 2010. Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. Research policy 39, 4, pp. 435-448.

Smith, A., and Duggan, M. 2013. Social Media Update 2013. Numbers, facts and trends shaping the world. Pew Research Center. Available at: http://www.pewinternet.org/files/2013/12/PIP_Social-Networking-2013.pdf

Social Networking Fact Sheet. 2013. Pew Research. Internet Project. Available at: http://www.pewinternet.org/fact-sheets/social-networking-fact-sheet/

Spiegelhalter, D., Pearson, M., & Short, I. 2011. Visualizing uncertainty about the future. Science 333, 6048, pp. 1393-1400.

Squizzd. 2013. Squizzd Official Website. Available at: http://squizzd.com/

Stone, D., Jarrett, C., Woodroffe, M., & Minocha, S. 2006. User Interface Design and Evaluation. Information Visualization 5, 1, pp. 77-78.

Suarez, F. F., & Utterback, J. M.. 1995. Dominant designs and the survival of firms. Strategic management journal 16, 6, pp. 415-430.

Swope, J. 2013. EDTECH Magazine. How MOOCs Can Be Free and Profitable at the Same Time. Available at: http://www.edtechmagazine.com/higher/article/2013/12/how-moocs-can-be-free-and-profitable-same-time

Torres-Salinas, D., Triguero, I., Moreno-Torres, J.G., Robinson, N., Delgado López-Cózar, E., Herrera, F. 2014. Rankings I-UGR de Universidades Españolas según Campos y Disciplinas Científicas (5ª ed. 2014). Avaiable at: http://www.rankinguniversidades.es/

Tremblay, K., Basri, E., & Arnal, E. 2008. Tertiary education for the knowledge society. Vol. 1. Paris: OECD, 2008.

TSL Education. 2013. The 100 Under 50 universities 2014. Available at: http://www.timeshighereducation.co.uk/world-university-rankings/2014/one-hundred-under-fifty

Underwood, J. & Luckin, R. 2011a. What is AIED and why does Education need it? UK's TLRP Technology Enhanced Learning [electronic report]. Artificial Intelligence in Education Theme. Available at: http://tel.ioe.ac.uk/wp-ontent/uploads/2011/06/telaied_whyaied.pdf

Underwood, J. & Luckin, R. 2011b. Themes and trends in AIED research, 2000 to 2010? UK's TLRP Technology Enhanced Learning [electronic report]. Artificial Intelligence in Education Theme. Available at: http://tel.ioe.ac.uk/wp-content/uploads/2011/06/telaied_part2researchthemes.pdf

Van der Heijden, K. 1996. Scenarios: the art of strategic conversation.

Van Notten, P. 2006. Scenario development: a typology of approaches. Schooling for Tomorrow.

Van Notten, P. W., Rotmans, J., van Asselt, M., & Rothman, D. S. 2003. An updated scenario typology. Futures 35, 5, pp. 423-443.
Van Krevelen, D. W. F., & Poelman, R. 2010. A Survey of Augmented Reality Technologies, Applications and Limitations. The International Journal of Virtual Reality 9, 2, pp. 1-20.

Van Raaij, E. M., & Schepers, J. J. 2008. The acceptance and use of a virtual learning environment in China. Computers & Education 50, 3, pp. 838-852.

Verbong, G., & Geels, F. 2007. The ongoing energy transition: lessons from a socio-technical, multi-level analysis of the Dutch electricity system (1960–2004). Energy Policy 35, 2, pp. 1025-1037.

Vlahakis, V., Tsotros, M., Gounaris, M., Ioannidis, N., Karigiannis, J., Almeida, L., & Gleue, T. 2002. Archeoguide: an augmented reality guide for archaeological sites. IEEE Computer Graphics and Applications 22, 5, pp. 52-60.

Voleti, K. 2013. Squizzd – Create, share and download Augmented Reality maps. Realareal blog. Available at: http://www.realareal.com/squizzd-create-share-and-download-augmented-reality-maps

Waldrop, M. M. 2013. Massive Open Online Courses, aka MOOCs, Transform Higher Education and Science. Scientific American. Available at: http://www.scientificamerican.com/article/massive-open-online-courses-transform-higher-education-and-science/

Warfield, J. 1996. An Overview of Futures Methods. Slaughter, R. (ed), (1996) op cit.

Wilson, B. G. 1996. Constructivist learning environments: Case studies in instructional design. Educational Technology.

Wilson, I. 1998. Mental Maps of the Future. In: Ratcliff, J. (ed. 1999)

Wilson, I. 2000. From scenario thinking to strategic action. Technological forecasting and social change 65, 1, pp. 23-29.

Wooldridge, A. 2005. The brain business: A survey of higher education. The econonomist. September 10th, 2005.