Trends of Use of Technology in Engineering Education

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***Abstract*—This paper analyzes new trends on the use of technology in engineering education having as main source the Horizon Report. We discuss and analyze the predictions of this source and also other different views of the current situation in the use of technology based in the previous forecasts and the experience in distance, on-line and on-class engineering education.**

Keywords: Technology enhanced learning; engineering education; service-oriented learning.

I. INTRODUCTION

Everyday technology is having a more important role inside the engineering education just as new technologies are part of the day-to-day learning. And those technologies are implied in the learning process everywhere and in every different learning model (in the traditional on-class system as well as in on-line or distance models, which have everyday more in common in their evolution).

In the last 10 years we have had an impressive new use of technologies inside the learning process as well as communication and Internet technologies impacted previously in the last part of the 20th century. The Horizon Report (HR) [1], a work from The New Media Consortium and the EDUCAUSE Learning Initiative (ELI), has been foreseeing since 2004 the impact of the technologies inside the learning process along the world having three temporary scopes: the year of the report (short-term), the next two years (mid-term) and finally, the four years following the report (long-term).

II. OBJECTIVES

We will use these predictions from 2004 to 2009 (six Horizon reports) that will cover the period 2004-2013 to analyze the technologies that will have a higher impact in education.

We will also discuss about the technologies not covered in the report and that we believe will also have a great impact in the engineering learning near future. In this process we will keep in mind the expertise from previous engineering technology projects as well as the knowledge shared in different technical conferences that provides a guide of the most used technologies around the class-rooms.

With all this information together we will develop a structured view of the foreseen technologies that will have an active role inside the engineering education process, providing our agreement or not with these predictions. On the other hand, the study will include the not forecasted technologies in the past that have been really used in the practice today. Finally we will analyze the technologies that currently and in a near future could have a great impact in our engineering education.

III. METHODOLOGY

The first stage on this research is to gather the technologies identified in each one of the six existing Horizon Reports. These technologies are structured according with the three adoption horizons: short-term, mid-term and long-term.

This work provides information about the technologies that have been identified as the more likely to impact since 2005 to 2014, but with the benefit of a temporal perspective.

The second stage is to create a visual representation of the results, using different colours to differentiate the technologies obtained from the different reports. This work provides an overview of all the technologies involved in the educational environment during the last years and also the most promising technology for the near future.

The third stage is aimed to group technologies according with their similarities and create particular views of each technology group. This work will help to detect where the technology flows are going to and what technologies have finally impacted on the educational environment and on contrast, what others have postponed their implantation or just have never arrived.

Finally, the fourth stage has as main objective to provide comments about what technologies have impacted in the educational environment and do not appear in the research.

IV. MOST LIKELY TECHNOLOGIES TO HAVE AN IMPACT ON EDUCATION

According with the stage 1 of the proposed methodology, the following temporal diagram (Figure 1) represents the technologies that Horizon Reports considered as the most promising to have impact on education.

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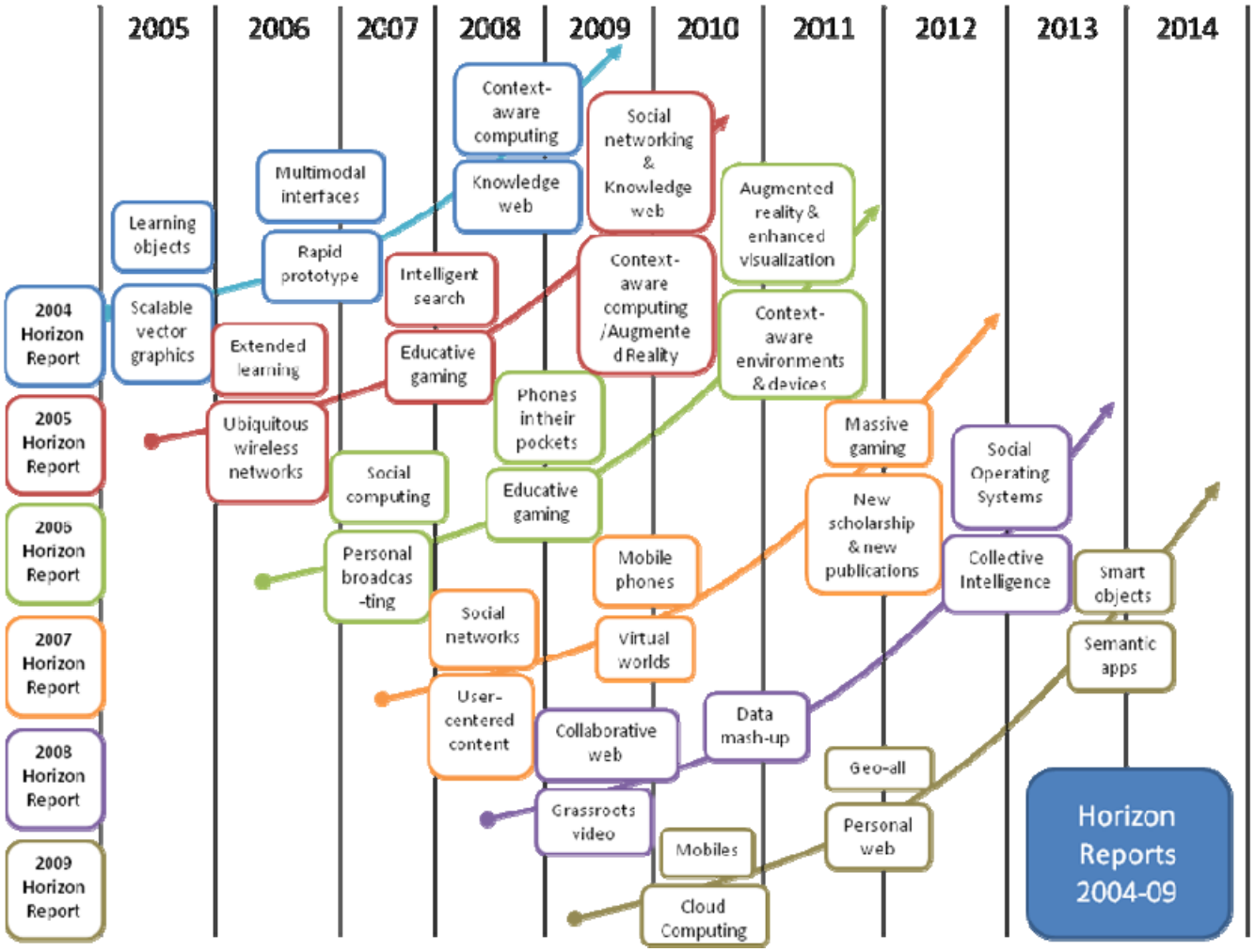

Figure 1. Most likely technologies to have an impact on Education according with Horizon Reports from 2004 to 2009.

In figure 1, each one of the six Horizon Reports is represented in a different colour. And also everyone provides two technologies in each term (short, mid and far) placed in their suitable temporal range.

These technologies can be structured in six technological groups that will simplify next stages. These groups are the following ones:

- Knowledge-Web. It includes cloud computing, which is based on the use of educative services on the cloud. It also includes the called Personal web, which is aimed to reorganize and customize the web according with the preferences of the students. Besides other technologies, in this group it is possible to find technologies that support knowledge representation (learning objects). These technologies are the basis for the arrival of others such as intelligent search engines and semantic-aware applications (understanding of the meaning of the web content); etc.
- Augmented reality. This technology provides additional information to the real world with interactive features. It can be used on both desktop-based computers and mobile devices.
- Social networking. It is aimed to enhance the collaboration and communication among students through moving the social networks phenomenon.
- Ubiquity. It includes smart objects (the Internet of Things within the education environment. It involves technologies such as RFID, QR codes, NFC or smartcards);
- Educative games (both on desktop or mobile computers, helping learners to be immersed in a virtual world that offer them a deeper understanding of the concepts).
- Mobile devices (thanks to new interfaces, location-awareness, broadband connectivity, etc.) and Geo-everything (mainly related to mobile devices);

These technologies will be studied in more detail in the following points, providing a temporal graphic for each one, which will help to analyze the technology flows.

V. KNOWLEDGE WEB

The use of Web-based technologies in education does not suppose any innovative approach. However this research focuses on the arrival of technologies that will support the development of the called 'Knowledge Web' [2]. It is based on three key trends: knowledge representation, mainly through some kind of meta-data or structure language; knowledge generation through collaboration; and personalization of the gathered knowledge (Figure 2).

The first trend was forecasted in the reports for the first time in the 2004 HR, with the arrival of learning objects (forecasted for 2005) and knowledge-web, basically based on technologies such as RDF or RSS (forecasted for 2008-09). The 2005 HR also forecasted it as an important technology to have into consideration, but in this case closely related with social networking (implantation in 2009-10). These technologies are today totally implanted.

The second trend is related with collaboratively creating and sharing knowledge, using the representation schemas previously created. Within this concept we can also find the personal broadcasting, forecasted in the 2006 HR for its arrival in 2007, and based on the idea of a user that will create its own multimedia content that will deliver to others through the Internet (e.g. YouTube-like tools). In addition, regarding also this trend, the 2007 HR included as key technologies for 2008 the creation of user-centred content (the user actively becomes author of the content, not just a listener, as in the case of blogs, wikis or video-web creation). In fact, as this technology was rightly a fact, the 2008 HR saw the impact of more advanced collaborative technologies, as data mash-ups (forecasted for 2010-11). These technologies merge knowledge from different sources (pictures; real state; entertainment, academic or corporate information) into other tools (e.g. maps and social networks) getting an added value from the raw knowledge. The impact of this technology will be considerably more important when the knowledge sources used to mash-up were based in a collective work (as Wikipedia is). This kind of applications are not far to be a reality. In fact, the 2008 HR forecasted its impact on education for 2012-13 (long-term horizon).

And finally, the technologies from the third trend are related to searching and getting personalized knowledge, based on the previous knowledge representation. Regarding the searching, the 2005 HR provided details of the implantation of intelligent search engines (e.g. federated searches, such as Blinkx and Google Scholar or Desktop) in a mid-term horizon (2007-08), which is a totally implanted technology today in the educational environment. This concept is the basis of semantic applications, forecasted in the 2009 HR to impact in a long-term horizon (2013-14). It is based on the idea of systems able to extract meaning from the information in the Web and giving personalized services and information more according with the user's needs.

On the other hand, regarding the personalization, trends seem to tend towards the personalization of the content, services and knowledge that the user receives. It specially reflected in the 2009 HR, which forecasted the impact of the personal web (self reorganization of Web content, using technologies such as RSS or Widgets) for 2011-12.

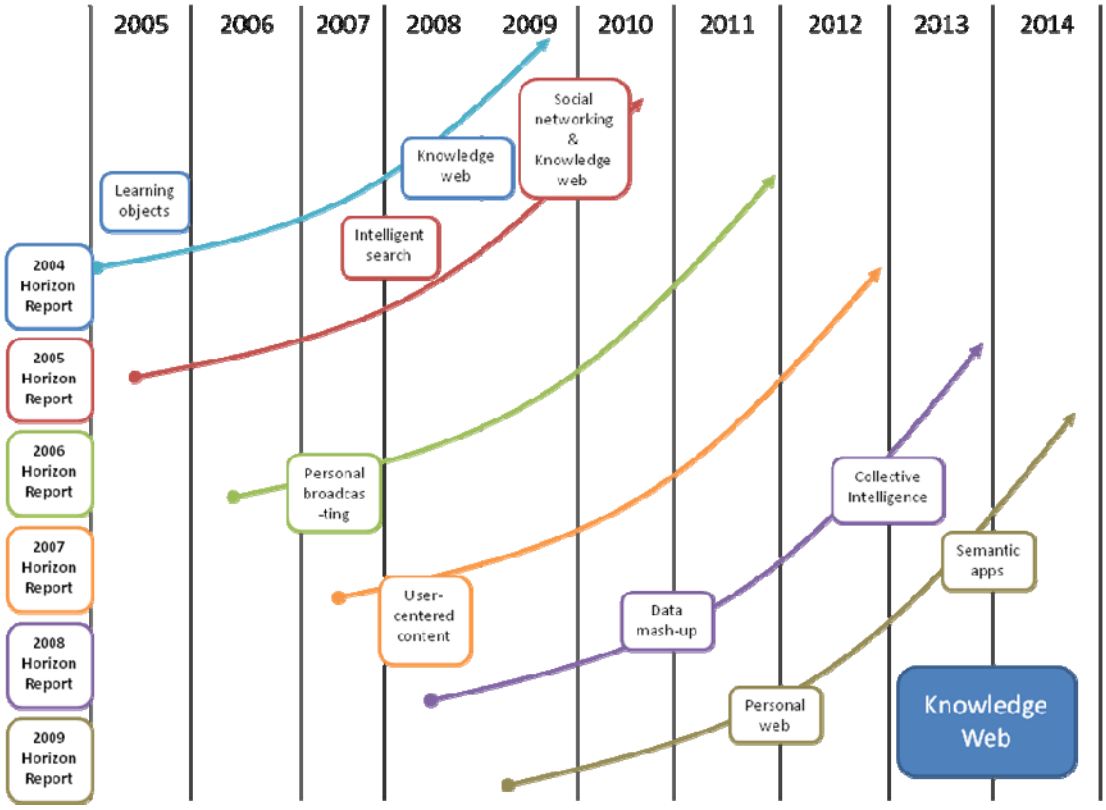

Figure 2. Most likely Knowledge-Web technologies to have an impact on Education according with 2004-09 HR.

VI. AUGMENTED REALITY

Augmented Reality (AR) is a technology that basically merges information or images with video-streaming from a Web-cam [3]. The result is similar to virtual reality but using real-world images in real-time. Some of the many potential revolutionary applications in education are related for example with the study of architecture, art, anatomy, decoration, or in general anything that a graphic, a simulation or a 3D model could improve the comprehension of the concepts. The forecast (Figure 3) in this field started in the 2005 HR, as a long-term promising technology (placed on 2009-10), and the next HR (2006 HR) delayed its arrival one more year (2010-11). Today, it still seems to be far from real implantation. Nevertheless, although any other HR has made any mention to this technology, it is still a promising technology. The proof is that some other technologies, apparently unconnected, are being developed and successfully implanted. As an example, the 2004 HR forecasted the implantation of Multimodal interfaces (i.e. the use of not only keyboard and mouse as input methods, but also others such as motion sensor, location, etc) and Rapid prototypes (i.e. creation of 3D models through CAD, CAT or even X-ray). These technologies are also related to AR, as 3D is one of the basic pieces of information provided, and the use of multimodal interfaces support the interactivity with the simulation just moving around it (motion and location sensors).

Reports also show other examples, such as mobile devices, that were forecasted in the 2007 and 2009 HR to have its arrival along 2009 and 2010.

2007 HR was also focused on user-centred content (forecasted for 2008). This technology is based on the concept that the user is no longer a mere listener, he/she will participate in the creation of any kind of material: videos, wikis, 3D model, etc to be mashed-up in geographical systems. This technology matches the conception of AR, as it is based on providing valuable material over real world images. Therefore, the experience will be more enriching as long as the user has more accessible contents. These two technologies specially converge when we talk about 3D models or information to be placed over a particular location. Along these lines, reports also show that other technologies such data mash-up and geo-all (2008 and 2009 HR respectively) will make its arrival between 2010 and 2012, when in fact, they are quite extended technologies. These technologies are closely related with the previous one because of the need of mashing-up content with location capabilities. Finally, other technology that apparently is not related to AR is Smart Objects, which is partially based on the concept of tags (RFID or QR). This tags support the tagging of our surrounding environment, helping us to provide it some kind of intelligence. This tags are also one of the key factors for AR, due to the fact usually the matching between real world images and computer-based information is through this tags. It means that when the AR system finds one of these tags, it changes it for the desired simulation or information.

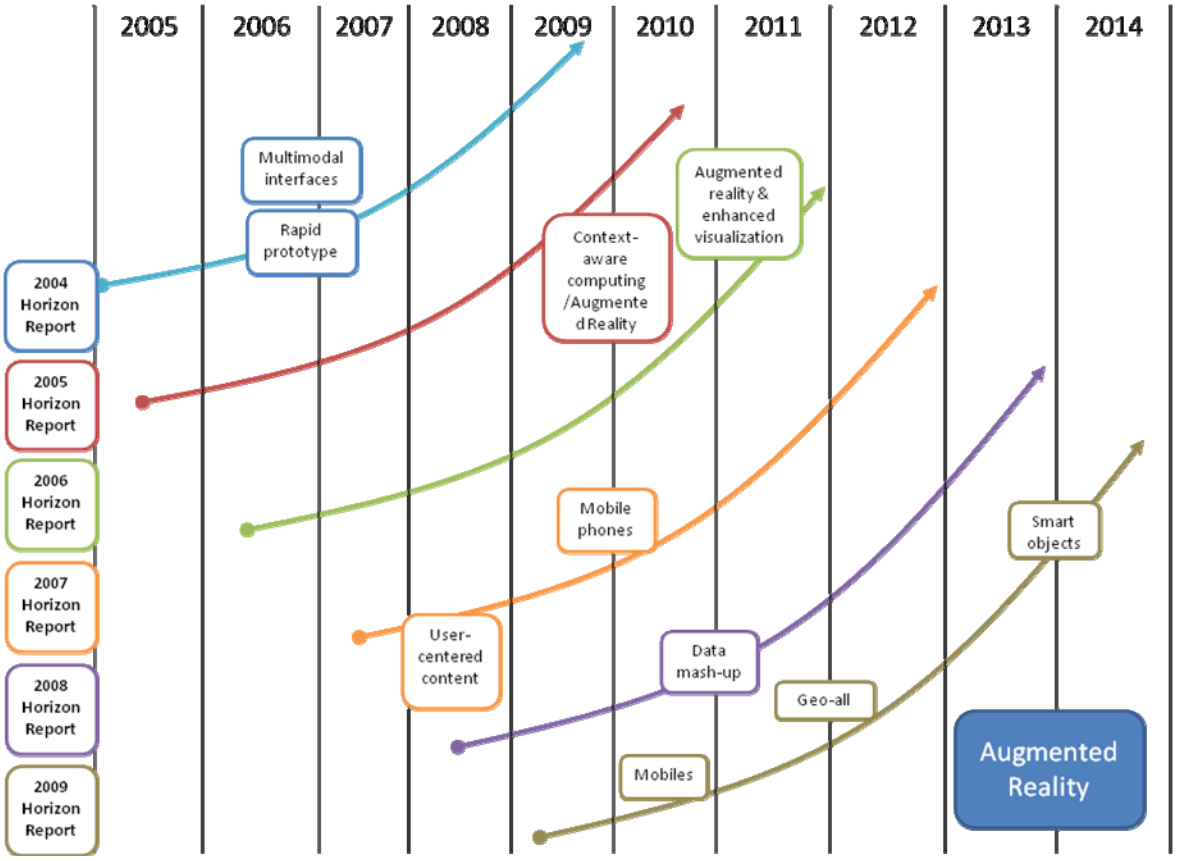

Figure 3. Most likely AR-related technologies to have an impact on Education according with Horizon Reports from 2004-2009.

VII. SOCIAL INTERACTION

The social phenomenon is one of the most promising technologies, as the amounts of technologies of this area that have been forecasted demonstrate (Figure 4).

The 2005 HR already forecasted the importance of the Social Interaction, through the arrival of collaborative tools for communication among students (called extended learning) in a short-term (2006), as it already was a widely implanted technology in other environments. This report also predicted its importance when it forecasted the use of more advanced tools in education, as social networking, in a long-term (2009-10).

The 2006 HR also reflected this fact, focusing on virtual collaboration tools (Social Computing) and broadcasting of user-created content (Personal Broadcasting), such as blogs, wikis, and audio/video based tools (its impact was forecasted for both during the year 2007). This last concept appears in the 2007 HR as user-centred content to have impact in 2008. Moreover this report shows the imminent arrival (2008) of a widely implanted technology in entertainment environments: Social networks. This phenomenon is based on the idea of providing advanced communication tools and the creation of a network of contacts, supporting a totally engaging environment. This report also focuses in a mid-term horizon (2009-10) on virtual worlds, which are the evolution of social networks towards totally immersive environments, where the user plays a role inside a virtual world. This report also describes the impact of Massive Multiplayer On-line Games (MMOG) in a long-term horizon (2011-12). Here the user plays with thousands of other players an engaging on-line game, which is active 24 hours per day. It means that the game goes on, although the user is not connected. In these games, every player has a specific role inside the game. It usually involves the development of complex tasks, such as a pharmacist that has to create pills to sell to doctors, which will use these pills to heal warriors in a battle. These tasks involve the development of many skills and knowledge in a very engaging environment. For that reason, education should not leave it aside of the academic environment.

On the other hand, the 2008 HR is again focused on the use of collaborative systems in a short term (2009), especially those focused on the Web, such as the use of collaborative tools to edit documents in group or sharing videos with a community. In the mid-term horizon (2009-10), data mash-up is introduced as a key technology. It is based on the idea of overlapping information over geographical systems. And finally in the long-term horizon (2012-13) the forecasting focuses on social operating systems, which promulgates the organization of the social networks around people instead around content. The other technology forecasted, in this report and in the same term, is Collective Intelligence based on the knowledge generated from large groups of users, such as Wikipedia or passive search patterns.

In brief, the social networks phenomenon has widely proved its power of engagement, and its capabilities to create collective knowledge [4] from the work of a group, which is more than enough to take it into consideration in education.

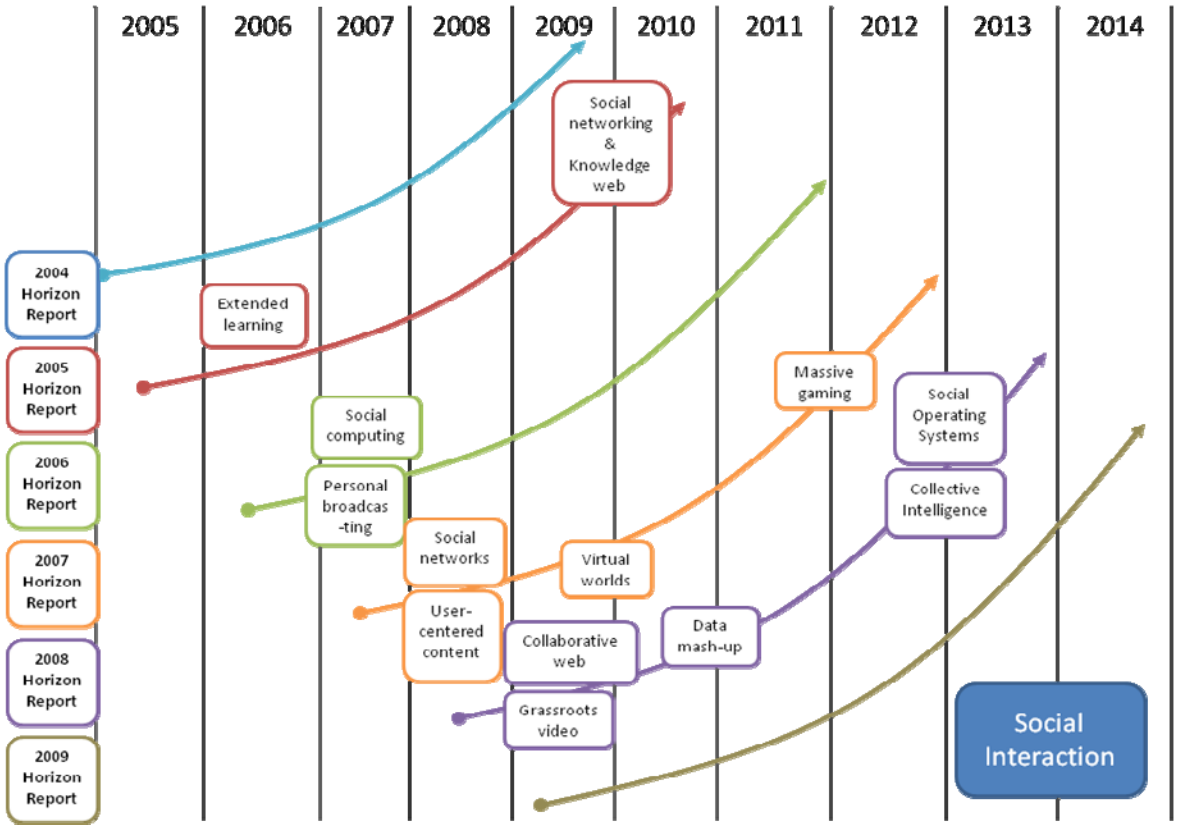

Figure 4. Most likely social technologies to have an impact on Education according with Horizon Reports from 2004 to 2009.

VIII. UBIQUITY

Ubiquitous computing is based on the concept of an invisible computing power embedded in the environment that can act and react according with user's needs. This paradigm involves the most natural possible interaction between user and computer with the final aim that the user will not even realize that is interacting with a system [5].

Ubiquitous computing is not a technology itself, but a group of technologies that will support the arrival of this new paradigm such as: context-aware computing, ubiquitous wireless networks, smart objects, location-based systems and more recently mobile-based technologies. For many years many of these technologies have been considered by experts as some of the most promising technologies to have an impact on all levels of our society (Figure 5). But the truth is that its arrival has been delayed.

In the 2004 HR, context-aware computing was foreseen as a key technology in a long term horizon (2008-09). In the 2005 report, an important technology for this paradigm appeared as implanted or in process of implantation in a short term: Ubiquitous wireless networks. In fact, it is one of the key requirements to support the arrival of ubiquitous computing, but experts again foreseen its implantation in a long term (2009-10). In the 2006 report, the phenomenon of mobile devices in education seemed to be a reality in a mid-term (2008-09). Context-awareness arrival is again delayed until 2010-11, although mobile devices could act as catalyst. Mobile devices were corroborated in the next report, but delaying its arrival one year (2009-10).

In the 2009 HR this paradigm returns as a promising technology. Here, mobile devices appear as a technology to be implanted in a year-term, as probably will happen. Obviously this implantation will not be worldwide, and cannot be seen in all the centres, but it will probably start becoming a reality.

Regarding with the other key-technologies in this report, it is interesting the impact in a mid-term (2011-12) of location-based technologies (geo-all). It is a fundamental piece of the puzzle, due to the fact it allow retrieving a very important part of the context (where the user is) to use it in a great variety of applications (e.g. just giving personalized services and information according with the location or integrating it with data mash-up systems). On the other hand, smart objects (Internet of Things, RFID systems, etc.) are forecasted for a long-term horizon (2013-14), which will allow to provide some intelligence to common objects.

The role of mobile devices in education started just as the basis of a very rudimentary mobile learning, but with the integration of ubiquitous computing and context-awareness paradigms, such as location-based technologies its functionalities are being extended to provide a real improvement on the learning experience [6]. The success of mobile devices in education in a short-term and its integration with ubiquitous technologies will probably foster the arrival of ubiquitous learning in a few years.

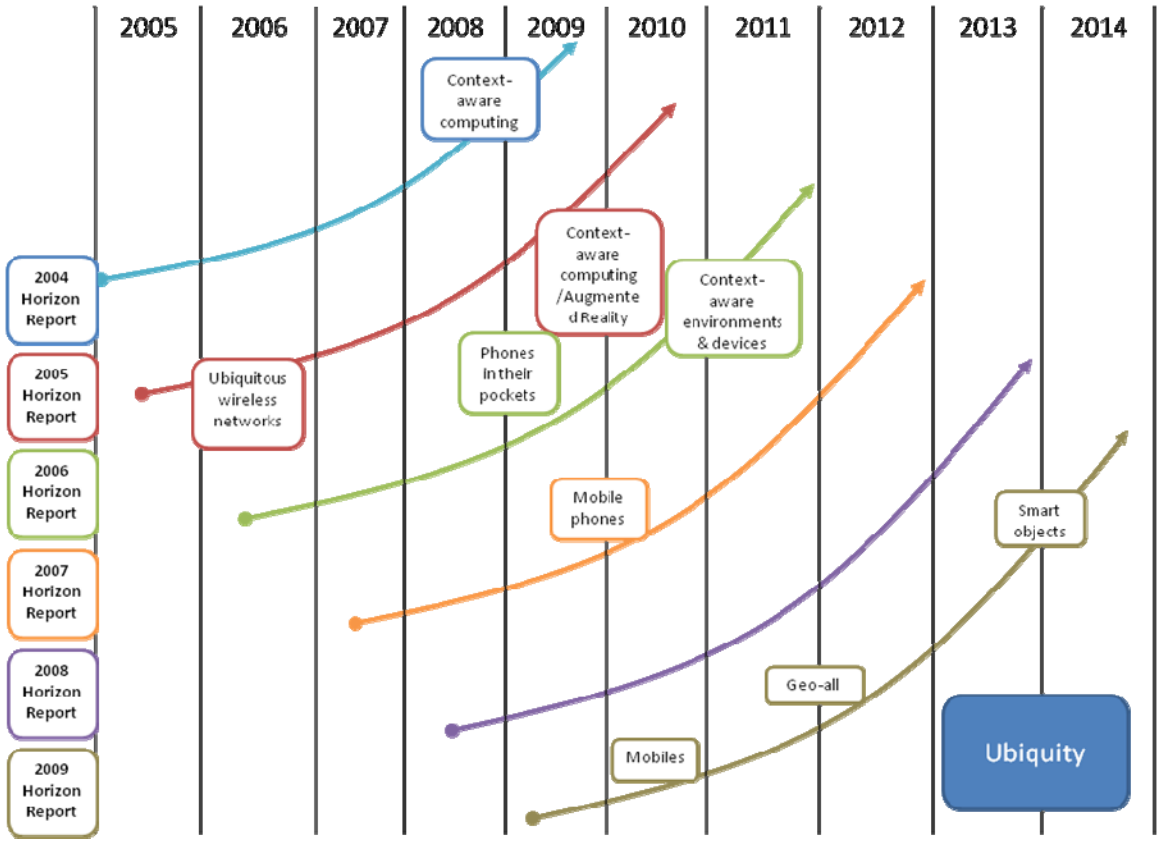

Figure 5. Most likely ubiquitous technologies to have an impact on Education according with Horizon Reports 2004-09.

IX. MOBILE DEVICES

Today's generation has grown with a new kind of technologies that the previous generation might not have imagined: cell phones, Smart-phones, portable video-consoles, GPS navigators, etc. Mobile devices have deeply impacted in our society changing the way we communicate and keep in touch with each others. Nevertheless today mobile devices are not just a communication method as the telephones are [7]. Today mobile devices are also changing the way we work, supporting any kind of applications (further of the typical office apps, Internet, and e-mail); spend our spare time with video games, Internet videos, podcasting, etc; get information, through GPS navigators, augmented reality or just surfing the Web; or even education. This field is where we are most interested in. Currently mobile learning is a promising technology that goes further than the traditional content-delivery by SMS or Web.

According with the studied HR's it is not until 2006 when for the first time experts think phones will have an impact on education. They foresee it in a midterm, it means in the 2008-09 period. This prediction has not been changed like the next report (2007 HR) only postpones it one or two years (until 2009 and 2010). Finally the 2009 HR place its implantation in a short-term horizon, it means for the 2010. Although there are only these references to this technology in the reports, its development has been accompanied by other related technologies such as location-based systems (context-awareness) (2004 and 2005 HR). Thanks to this technology it is possible to provide personalized services to a student according with his/her profile and location, therefore this involves a mobile device. As we have previously studied these ubiquitous technologies were foreseen to impact in education firstly in 2008 but its arrival has been constantly delayed.

Other important related technology is wireless networks. This is a key technology to support the success of mobile devices due to the fact anytime and anywhere connectivity makes the mobile device not being isolated but another part of the environment. Its arrival was foreseen for 2006 (according with the 2005 HR), and currently wireless networks are a reality anywhere (Figure 6).

The only related technology foreseen in the 2006 HR is data-mash-up. It supports merging useful educational information into maps to provide an added value. Its implantation was foreseen for 2010-11 but is today fully implanted (2009). This concept also appears as Geo-everything in the 2009 HR for 2010-11 (mid-term horizon) but with the particularity of the use of data mash-up in mobile devices using the location-based features (context-awareness).

Finally the last related technology is personal web. It is based on the concept of reorganizing the Web instead of just viewing it. It started mainly for desktop computer but thanks to the proliferation of mobile devices it is very likely to have impact in education with both devices at the same time. It was also foreseen in the 2009 HR to impact on a mid-term horizon so its implantation should be around 2011 and 2012.

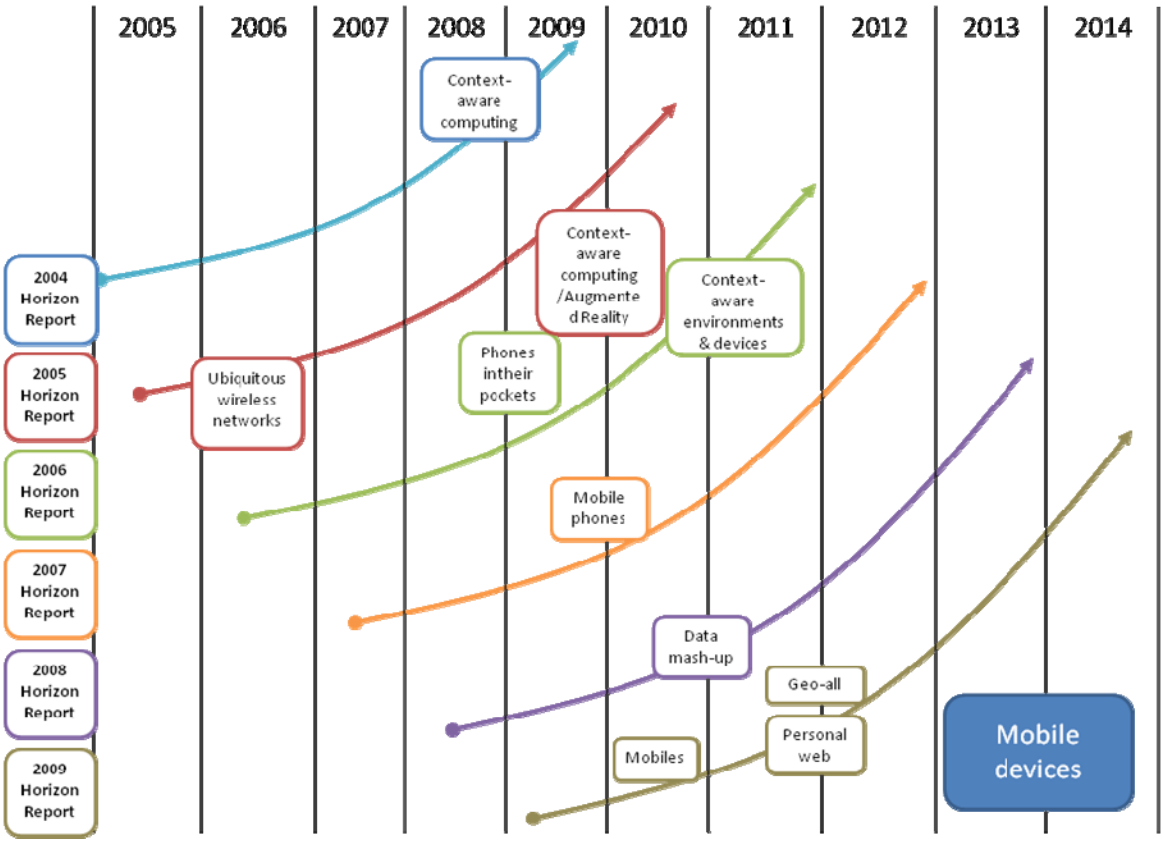

Figure 6. Most likely mobile technologies to have an impact on Education according with Horizon Reports from 2004 to 2009.

X. GAMES

As we discussed in the previous chapter, today's generation are used to other kind of interaction. New generations demand more interactive and engaging materials for learning. Since this is the way they have acquired many of their cultural knowledge. Many students spend many hours watching attractive contents on TV, surfing personalized contents in the Internet or playing engaging games using their desktop computer or their mobile phone.

This fact makes necessary a change in the way of teaching or even better in the way of learning. New generations are not usually engaged with lectures in a classroom. Therefore many research efforts have been accomplished in order to create engaging games to support learning and not just for fun.

Along these lines the 2005 HR (Figure 7) forecasted the implantation of educative gaming in a mid-term horizon, i.e. between 2007 and 2008. Probably, the next report (2006 HR) again forecasted its implantation in a mid-term (2008-09), i.e. one year later, as this learning methodology had still many detractors.

The 2007 HR focused on two related technologies: Virtual worlds (forecasted for 2009-10) and Massive gaming (foresaw for 2011-2012). The reason is that both environments had successfully reached an important part of the society by 2007, so it was very likely also to impact education in a few years. In many aspects of our society Virtual Worlds have deeply impacted, giving rise to a parallel world, where people work, communicate, earn money, spend it and even receive education. Maybe the difference with reality, and the basis of its success, is merely the opportunity to do it without the fear to failure. When all is said and done, virtual worlds are just games and you always can start again. On the other side, massive multiplayer games also own the same engaging component, as they are also basically virtual worlds, but with a clearer objective: to defeat the enemies, to save the princess or to get the best scores.

These both predictions could make to suppose the idea of continuity; therefore this methodology should also appear in the following HR. But in fact, none 2008 and 2009 HR mentioned anything about it again. Maybe the reason is the mentioned doubt of a great part of academics who do not believe it can really contribute to education. Some of the allegations against educative gaming are the high-cost of game development (both economic and timing), its difficulty for non specialist (which is currently being improved through open source engines) and finally the required creativity for its creation. The reason is that it can be difficult to teach in a different way to this you have used to learn.

Nevertheless, some attempts are being done to move the power of games and virtual worlds towards companies [8] but not for training but for serious work due to its engaging power in repetitive jobs (e.g. a call centre). If games finally get to enter into serious companies, it is very likely to assume its final arrival to education.

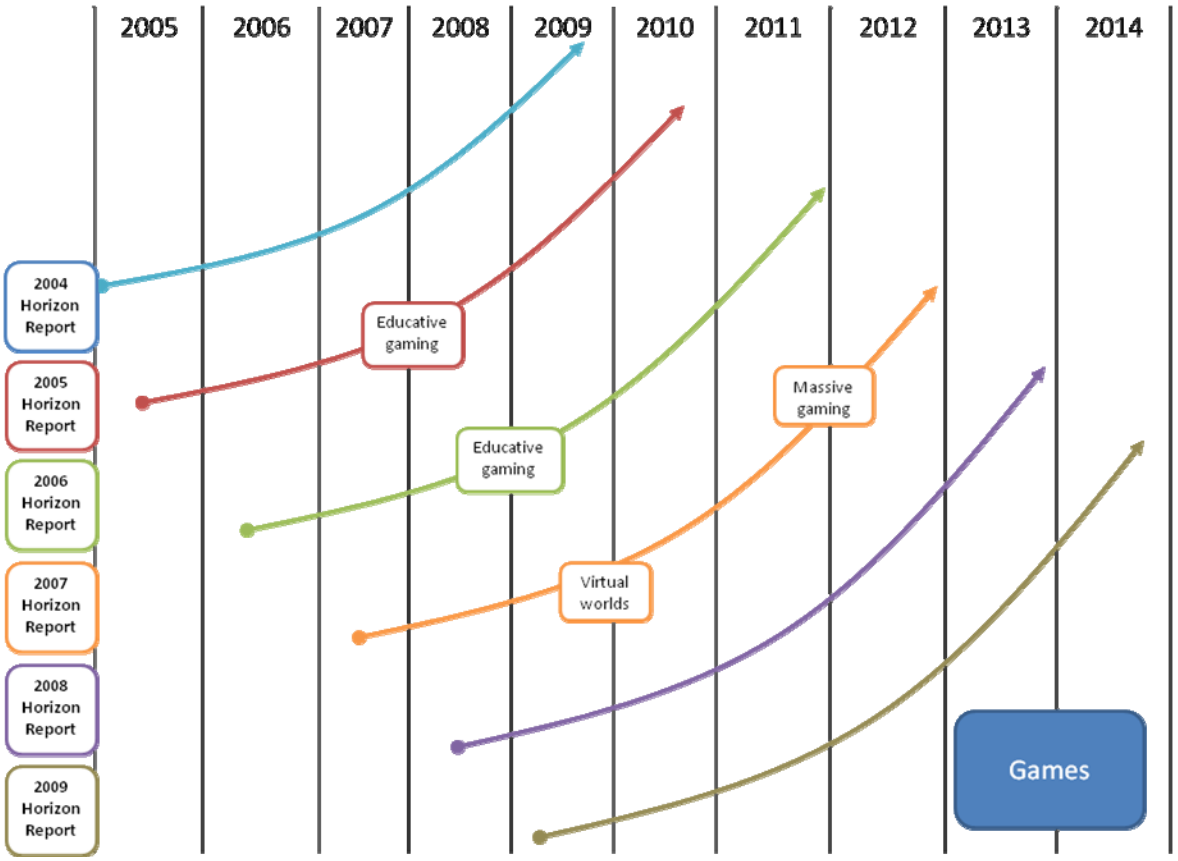

Figure 7. Most likely gaming technologies to have an impact on Education according with Horizon Reports from 2004 to 2009.

XI. OTHER PROMISING TECHNOLOGIES: SERVICES

In addition to those already studied and grouped, there is other technology that will likely have an important impact on education, or better yet, on the way education is going to be built in the coming years. Some authors call this trend 'service-oriented learning', 'service-based learning' or 's-learning' [9].

This technology is related to the concept of learning object already forecasted in the 2004 HR to have impact on 2005, and also to the concept of Cloud Computing, forecasted in the 2009 HR for its impact on 2010. Likewise it is based on the idea of having different services available on the Internet (on the Cloud) that can be used and integrated regardless its physical location.

This service-based trend is based on the concept of modelling the educative services with the objective of providing better interoperability capabilities in different levels: service-services, platform-platform and service-platform. Equally it is based on the encapsulation of services, as the learning objects are, to develop autonomous and self-contained services that can be easily integrated in different environments such as Learning Management Systems, mobile learning environments, remote laboratories or assessing tools. Within this concept, there are many subjacent technologies that are its foundations, such as Web Services and Cloud Computing. Also there is another surrounding concept such as the Digital Ecosystems [10], which is based on the idea of creating environments made of different systems integrated in a plug-and-play way. It is achieved through the use of technologies such as SOA (Service-oriented architecture), ESB (Enterprise Service Bus) or ontologies.

Although emerging, this concept is getting more importance on education, and is becoming one of the key technologies as developers are realizing the necessity of reusing services not only inside the same platform or programming language but also among different platforms and architectures.

XII. TRENDS AND FLOWS: TECHNOLOGIES THAT SEEM NOT TO IMPACT AND CONVERGENCE

During the previous categorization and analysis we have detected some promising technologies that finally have never impacted on education.

As an example we find Ubiquitous Computing. Although this concept was firstly forecasted by the 2004 HR to have impact on education by 2008 it has not even had the expected impact on any of the other aspects of our society. But although slowly is getting a place in the industry; it is still too small to propagate its effects to education. For that reason it seems obvious we will have to wait until it finally takes the important place that seems to belong to see its effects on education.

On the other hand, mobile devices should be observed from a different prism. This technology has deeply affected our society, especially with the new wave of Smartphones, such as the iPhone or those based on the Android or Windows Mobile operating systems. The incorporation of new features such as location or motion sensors are giving rise to a revolution in the way people use these devices.

In fact, partly motivated by this revolution there is a technological trend that is making converge many of the technologies studied here into one. For example, thanks to the appearance of new multimodal interfaces, wireless networks and context-aware technologies (such as those related with location and motion sensors) mobile devices are getting more important. At the same time other promising technologies such as social networks are starting to arrive also to the mobile environment that seems to power even more these devices with never-seen communication capabilities.

Other key-technology for the near future is Augmented Reality, which is becoming also to be implanted in mobile devices providing more flexibility and variety of applications. The new range of environments that can be affected by the combination of both technologies is enormous. For example, in education, this technology in books and magazines could revolutionize the way people study or spend their spear time just providing additional multimedia information over the books through the mobile device. Other relevant example could be for out-of-the-class activities such as those related to agronomy, archaeology, history, natural science, and in general any subject which an in-the-field or challenge-based work that could provide an improvement on the learning experience. At the same time, this is closely related to games because they are based on the concept of challenge. In addition, mobile devices strengthen even more its engaging capabilities because are themselves attractive devices especially with the incorporation of more natural ways of interacting, such as multi-touch screens, motion and light sensors and location capabilities.

Finally, the last key group of technologies studied is also converging with mobile devices as their new operating systems are developed with the idea of simplifying the access to the information and the personalization of services. As an example we find the Google personalized searches depending on the user's location (from cell-tower triangulation or GPS) or the quick access to relevant information of the user through the utilization of Widgets and RSS.

In conclusion, mobile devices are called to be one of the most important technologies on every layer of the society in a near future including of course education. It will be the technology base for the successful arrival of many other promising technologies like:

- Ubiquitous computing
- Social networks
- Augmented reality
- Games
- Personal Web

XIII. CONCLUSIONS

This research is aimed to clarify which of the main technologies are called to have an impact on education according with the history provided by HR. This analysis tries

to provide a perspective on the evolution of some technologies towards others. Having the aim to support a better understanding of the technology flows in the past and to predict what could be the future.

The result is that there are six groups of technologies that are converging into one: mobility. However, it does not mean they are going to disappear and mobile devices are going to be the most important technology. In contrast, these groups of technologies will go on getting more importance, through different branches; and being enforced thanks to the flexibility and synergy power that mobility provides. And at the same time, mobile devices will probably be enforced thanks to the growth of the other convergent technologies, because it will be a tool able to support all of them.

As a conclusion and using the results of this analysis, authors consider important the development of strategies and architectures able to support the forecasted convergence and integration of different technologies into mobile devices. The objective is to provide suitable communication methods and interoperability among these technologies, in order to support their better development.

XIV. Acknowledgements

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