



New technology trends in education: Seven years of forecasts and convergence

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ARTICLE INFO

Article history:

Received 24 November 2010

Received in revised form

1 April 2011

Accepted 11 April 2011

Keywords:

Technology trends

Education

Forecasts

Social web

Mobile and ubiquitous devices

Augmented reality

Semantic web

Immersive environments

Learning objects

ABSTRACT

Each year since 2004, a new Horizon Report has been released. Each edition attempts to forecast the most promising technologies likely to impact on education along three horizons: the short term (the year of the report), the mid-term (the next 2 years) and the long term (the next 4 years). This paper analyzes the evolution of technology trends from 2004 to 2014 that correspond to the long-term predictions of the most recent Horizon Report. The study analyzes through bibliometric analysis which technologies were successful and became a regular part of education systems, which ones failed to have the predicted impact and why, and the shape of technology flows in recent years. The study also shows how the evolution and maturity of some technologies allowed the revival of expectations for others. The analysis here, which focuses on educational applications, offers guidelines that may be helpful to those seeking to invest in new research areas.

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1. Introduction

New technologies have a powerful influence on all aspects of our society, from commerce and business to health and entertainment. Obviously, education is not an exception. Many technologies have an impact on the way we teach and learn. For example, new mobile devices (e.g., smartphones and tablets) raise student engagement in both indoor and outdoor activities with applications such as mobile augmented reality. New motion sensors and image-recognition technologies are giving rise to applications with more natural interaction methods, helping non-technical users to interact with computer-based systems, as in the case of new-generation video consoles. In addition, social networks and web 2.0 tools give students a more active role in their own education, allowing them to become educational “prosumers” (i.e., both producers and consumers).

Education improvements do not necessarily have to be driven by technological developments. However, there is an increasing interest of researchers on using new technologies to improve education. This paper analyzes the technologies most likely to impact education in the near future, by looking at technology metatrends from 2004 to 2014. This work is designed to provide a tool for researchers in education technologies, identifying the most important technologies in this arena in the past, present and near future. As such, it may help them to decide where to focus their research efforts.

There are various references and bibliographic sources in which experts predict which technologies will be the most relevant in future education, such as the *UK e-Learning Market Report* (Patterson, Jung, & Broadhead, 2009), as well as conferences on technology in education, such as Frontiers in Education (<http://fie-conference.org>), the IEEE EDUCON Engineering Conference (www.educon-conference.org), the AACE e-Learn Conference (www.aace.org/conf/elearn), the ISTE Conference (www.iste.org), and the TIE New Frontiers (tiecolorado.org/conference/). Because the aim of this study was to compile predictions made yearly in order to obtain an overview of the evolution of these technologies from a temporal perspective, the Horizon Reports (HRs) (www.nmc.org/horizon) were chosen as they key point of reference. These reports are produced by the New Media Consortium (www.NMC.org) and the EDUCAUSE Learning Initiative (ELI) (www.educase.edu); each year since 2004 they have predicted yearly the impact of emergent technologies on education across the world, using three temporal horizons: the year of the report (i.e., short-term predictions), the next two years (mid-term predictions), and the four years

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following the report (long-term predictions). According to the figures provided by the Horizon Report Project, these reports receive more than 500,000 downloads a year and have an estimate readership of about 1 million in 75 countries. The context that these reports seek to address is training as well as education.

We used the predictions from 2004 to 2010 (i.e., from seven Horizon Reports), which cover the period 2004–2014, to analyze the technologies that have impacted education in the past or are likely to have an impact in the future. The analysis was carried out using these reports, as they are among the most widely used in education, and no other source of similar data has issued annual reports for a longer period of time. As such, these are the only predictions that allow a temporal comparison that reveals technological metatrends. These reports are very referenced and cited, but no previous metatrends analysis has been conducted using the predictions from these reports.

The metatrends obtained from the analysis of these reports were used as hypothesis. Several assessment techniques were evaluated to assess the hypothesis (e.g., technology sales, technology investment, regional implantation reports, patent analysis), but finally bibliometrics was used for being the only reliable method with enough data from all the technologies to support their temporal comparison. Bibliometric analysis allows extracting information from large databases looking for patterns (Norton, 2001). Bibliometrics is widely used to analyze research trends and identify emerging areas of science (Daim, Rueda, Martin, & Gerdri, 2006). According to Morris (2002), bibliometrics can be used to understand the past and even potentially to forecast the future. Bibliometrics investigates information through the use of different indicators such as publications, occurrences of words, citations and related characteristics (Daim, Rueda, Martin, & Gerdri, 2006). Important works in the use of bibliometrics can be found in Morris (2002), Kostoff, Toothman, Eberhart, & Humenik (2001), Watts and Porter (2003), Pilkington (2003). Patent analysis has also been proven to give good results for technology trend analysis. Examples can be found in Liu and Shyu (1997), Abraham & Morita (2001) and Wang, Cockburn, and Puterman (1998). However, this kind of analysis is mostly for commercial purposes, not for education because patents are more common in industry and market than in education-related research. Other method to make and evaluate forecasts around commercial technology was given by Vanston and Hodges (2004). Finally, bibliometric analysis was used to test the hypothesis given by the Horizon Reports because bibliometrics provided a clear picture of the temporal research efforts around education, which is basically what the Horizon Reports forecast.

The paper is structured in five main parts: an introduction; a methodology section, which lists bibliographic sources and describes the stages of the study; a results section, which includes a compilation of the data obtained from the bibliographic sources, a general classification of the main technology clusters and an in-depth analysis of each technology cluster and analysis of technology flows and evolution; a discussion section, which contains critical analysis of the results; and a conclusions section, which provides findings, highlights, constraints, benefits and direction for future research.

2. Methodology

The aim of this work was to get a clear idea of the technologies that will be most important for supporting education in the future. As no previous work was done using predictions from these or similar reports, authors have developed their own methodology to analyze them. The main stages involved are the following:

1. The first stage was to record the technologies listed in the seven Horizon Reports. Information was gathered about the technologies identified as likely to have an impact from 2004 to 2014, with the benefit of a temporal perspective.
2. The second stage was to create a visual representation of the results using different colors to differentiate the technologies of each report. The Horizon Reports forecasts two technologies in a short term, two in a mid-term and two more in a long term. For each report, the different technologies were represented in the figure according to the moment in which they are likely to impact. This representation provided an overview of all the technologies involved in education over the previous 7 years as well as the most promising technologies for the near future.
3. The third stage was to group technologies according to their similarities and to create detailed views for each group. This approach helped to determine the direction in which educational technology is progressing. The results of this stage were used as hypothesis.
4. The fourth stage was to study the evolution of technologies within each group. This stage was in charge of analyzing metatrends and evolution flows of the technologies involved according to the predictions given by the Horizon Reports.
5. The fifth stage was bibliometric analysis. The HR predictions should be objectively evaluated using some assessment method to corroborate whether they were successful or not. This stage was based on searching in bibliographic databases the number of paper published from 2004 to 2010. The Horizon Reports forecasts technologies to impact education in a near future. This impact was measured through the number of articles published every year around the predicted technologies. This search was conducted through Google Scholar (i.e., scholar.google.com) because it allowed to search in many multidisciplinary academic repositories, such as “Springer”, “IEEE Explorer”, “Wiley Online Library”, “JStor”, “Education Resource Information Center – ERIC” (i.e., www.eric.ed.gov), Questia – Trusted On-line Research (i.e., www.questia.com), as well as in libraries of many world-wide Universities and even academic social networks such as Mendeley (mendeley.com). The main steps and conditions involved in the searches are the following:
 - 5.1. Keywords selection. Several keywords were selected for each technology group to be used in the searches. For example, the keywords “mobile”, “ubiquitous” and “context-aware” were selected for the mobile technology group.
 - 5.2. Year of publication. Seven searches (one per year from 2004 to 2010) were conducted for each keyword, so that the historic of publications for each keyword was obtained.
 - 5.3. Publication title. The search was narrowed to only education-related publications searching only in publications with the keywords “learning” or “education” in the title.
 - 5.4. Results weighting. The number of papers available in Google Scholar in education-related publications changes every year. Thus, these results were weighting. A weighting factor (WF) for each year was obtained to be able to compare the publications in different years using the same magnitude. This WF was applied to the results for each technology obtained each year. The equation used to obtain the weighting factors is shown in Eq. (1). Basically, the WF of each year is obtained dividing the mean of number of papers published from 2004 to 2010 between the number of papers published each year.

$$WF_i = \frac{\bar{p}}{p_i} = \frac{\frac{1}{N} \sum_{i=2004}^{2010} p_i}{p_i}, \quad \bar{p} = \text{mean of number of publications from 2004 to 2010}$$

$$p_i = \text{number of publications in the year } i$$

$$i = \{2004, 2005, \dots, 2010\}$$

$$N = \text{Total number of years}$$
(1)

6. The sixth stage was to objectively assess to which extent the predictions given by the Horizon Reports were successful. For this stage, the results obtained in the fourth stage are compared to the ones given by the Horizon Reports. In this stage, it is important to notice that the articles published one year were the result of the research work in the previous year because of the publishing delay. This aspect must be considered when comparing the HR predictions with their effect on publications.

3. Results

3.1. Information compilation and representation

The results of stages 1 and 2 of the study as described above are illustrated in Fig. 1, a temporal diagram that represents the technologies that the Horizon Reports considered the most promising in terms of impact on education. Each of the seven Horizon Reports is represented as a colored line. Two technologies are shown for each horizon (i.e., short term, mid-term and long term) per temporal range, represented by a box.

3.2. Technology clustering

According to stage 3, these technologies can be structured in several technological clusters that simplify analysis. These clusters that we used are as follows.

Social Web: These technologies aim to enhance collaboration and communication among students via the use of Web 2.0 and social networks for educational purposes.

Semantic Web: These technologies propose a collaborative environment in which the information has a machine-readable meaning. The achievement of this goal requires the addition of metadata (e.g., XML, RDF, Ontologies, or RSS) and information rules. Related technologies include the so-called Personal Web, which is aimed at reorganizing and customizing the Web according to the preferences of the students. These technologies are the basis for others, such as intelligent search engines and semantic-aware applications, which require an understanding of the meaning of Web content.

Learning Objects and Open content. A digital learning object (Smith, 2004) consists of content (e.g., images, text, videos, and simulations) and an interface (e.g., metadata) to allow user access. These objects are reusable, manageable, and discoverable, and they represent the basis for content delivery and exchange in an educational environment. Metadata enable the discovery of these objects by search engines and online repositories such as E-Spacio UNED (www.e-spacio.uned.es) and MERLOT (www.merlot.org).

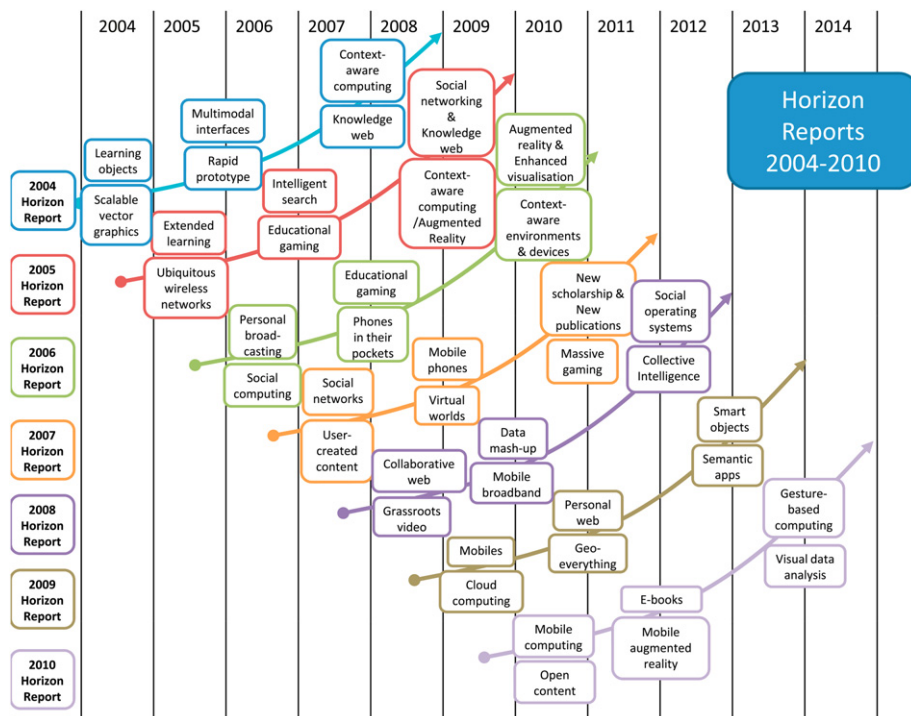


Fig. 1. Technologies most likely to have an impact on education according to the Horizon Reports from 2004 to 2010.

Augmented reality: This technology provides additional information on the real world through interactive features. It can be used on both desktop-based computers and mobile devices.

Immersive environments: This technology includes games and virtual worlds. These environments helps learners become immersed and engaged in a virtual environment that offers them a deeper understanding of learning concepts.

Mobile devices, Geo-everything and ubiquitous technologies: This group includes mobile devices, context awareness, Geo-everything, and smart objects.

3.3. Metatrends analysis and technology flows

This section includes the work proposed in stage 4, analyzing the predictions of the Horizon Reports, studying metatrends and evolution flows of the predicted technologies.

3.3.1. Social Web

Social interaction puts the user at the center of attention as an active player. This notion naturally extends from the Web 2.0 philosophy, in which content is the key driver of new media applications and collaboration and social interaction are the driving forces behind opinions (e.g., through blogs), knowledge (e.g., on wikis) or the sharing of digital artifacts (e.g., presentations, photos, audio, and video). These processes inevitably lead to the emergence of virtual communities that enable social networking. Today's audiences have shifted from a niche of masses to a mass of niches (Jarvis, 2009), in which service personalization, content creation, and knowledge acquisition are driven by social interaction. In short, the one-size-fits-all paradigm no longer fits. The user is the center of the educational process and thus requires adequate technological support to create, communicate, collaborate on and access personalized services.

The 2005 HR (Johnson, Laurence, & Smith, 2005) forecasted the importance of the Social Web (Fig. 2) through the arrival of collaborative tools for communication among students (known as extended learning) over the short term (2005). This report also predicted its importance by forecasting the use of more advanced tools in education, such as social networking, over the long term (2008–2009).

The 2006 HR (Johnson, Laurence, & Smith, 2006) also reflected this role of the Social Web, focusing on virtual collaboration tools known as social computing (Wang, 2010) and the broadcasting of user-created content known as personal broadcasting, such as blogs, wikis, and audio/video-based tools. Note that both types of tools were forecasted to have an impact in 2006. Moreover, the 2007 report predicted the imminent arrival (in that same year) of social networks into the educational environment. This phenomenon is based on the idea of

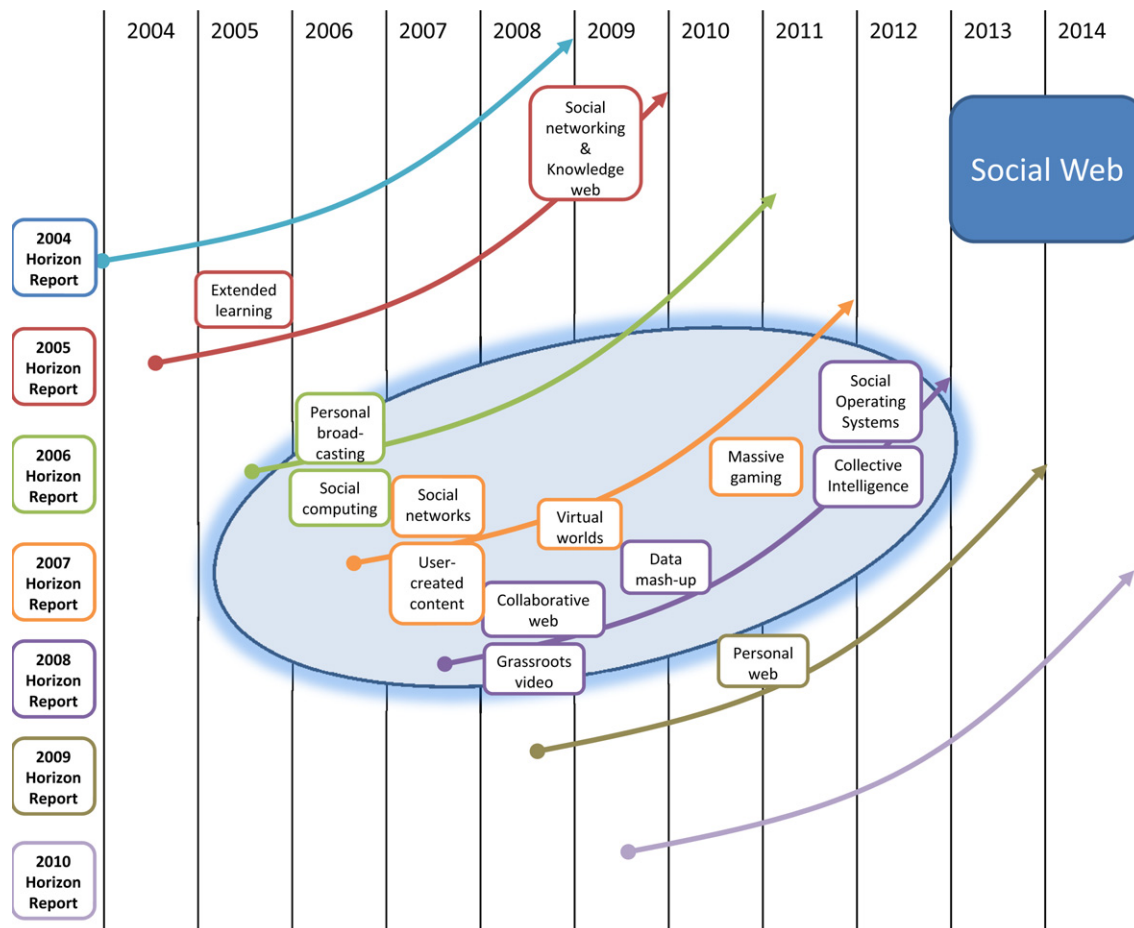


Fig. 2. Social web technologies most likely to have an impact on education according to the Horizon Reports from 2004 to 2010.

providing students and educators with advanced communication and collaboration tools and the creation of a network of contacts to support a highly engaging environment. The 2007 report also focuses on the mid-term horizon (2009–2010) with respect to virtual worlds, which are the evolution of social networks toward totally immersive environments in which the user plays a role inside a virtual world.

The 2007 report also predicted that massive multiplayer online games (MMOGs) would have an impact in the long-term horizon (2011–2012). Within these technologies, users play engaging online games with thousands of other players; the game is active 24 h per day and it proceeds regardless of whether the user is connected. In these games, each player has a specific role. The games usually involve complex tasks and relationships, such as a pharmacist who creates pills to sell to doctors who will then use these pills to heal warriors in battle. The tasks entail the development of a wide variety of skills and a great deal of knowledge in a very engaging environment (Traphagan et al., 2010). Therefore, MMOGs should not be omitted from the academic environment.

The 2008 HR (Johnson, Laurence, Levine, & Smith, 2008) again focused on the use of collaborative systems over the short term (2009), especially that of Web technologies such as collaborative tools to enable a group to edit documents or to enable the sharing of videos within a community. For the mid-term horizon (2009–2010), data mashup was introduced as a key technology. This technology merge knowledge from different sources (i.e., pictures, real estate-related information such as properties location, entertainment, and academic or corporate information) into other tools such as maps and social networks, resulting in added value from the raw knowledge (Okuoka, Takahashi, Deguchi, Ide, & Murase, 2009, Nakayama, Ito, Hara, & Nishio2008).

Based on the number of technologies forecasted by HR, the social Web was the most promising technology from 2005 to 2008. However, this changed in the 2009 HR (Johnson, Laurence, Levine, & Smith, 2009), as only one related technology was forecasted, namely, the personal Web, which is actually not related to experiencing social collaboration as much as using social-based knowledge to build user-centered content. This trend continues in the 2010 HR (Johnson, Laurence, Levine, Smith, & Stone, 2010), which predicts no social Web technology.

Finally, the long-term forecast (2012–2013) focused on social operating systems that organize social networks around people instead of around content. Another technology whose use was forecasted in this report and for the same horizon was collective intelligence, which is based on knowledge generated by large groups of users, such as on Wikipedia or through passive search patterns.

3.3.2. Semantic web

The Semantic Web is based on three key trends: knowledge representation (mainly through some kind of metadata or structural language), knowledge generation through collaboration (Wang & Hsu, 2006), and the personalization of the gathered knowledge (Huang & Yang, 2009). Fig. 3 shows groups of technologies that were analyzed, including the knowledge web, collaboration, learning objects, and semantic applications.

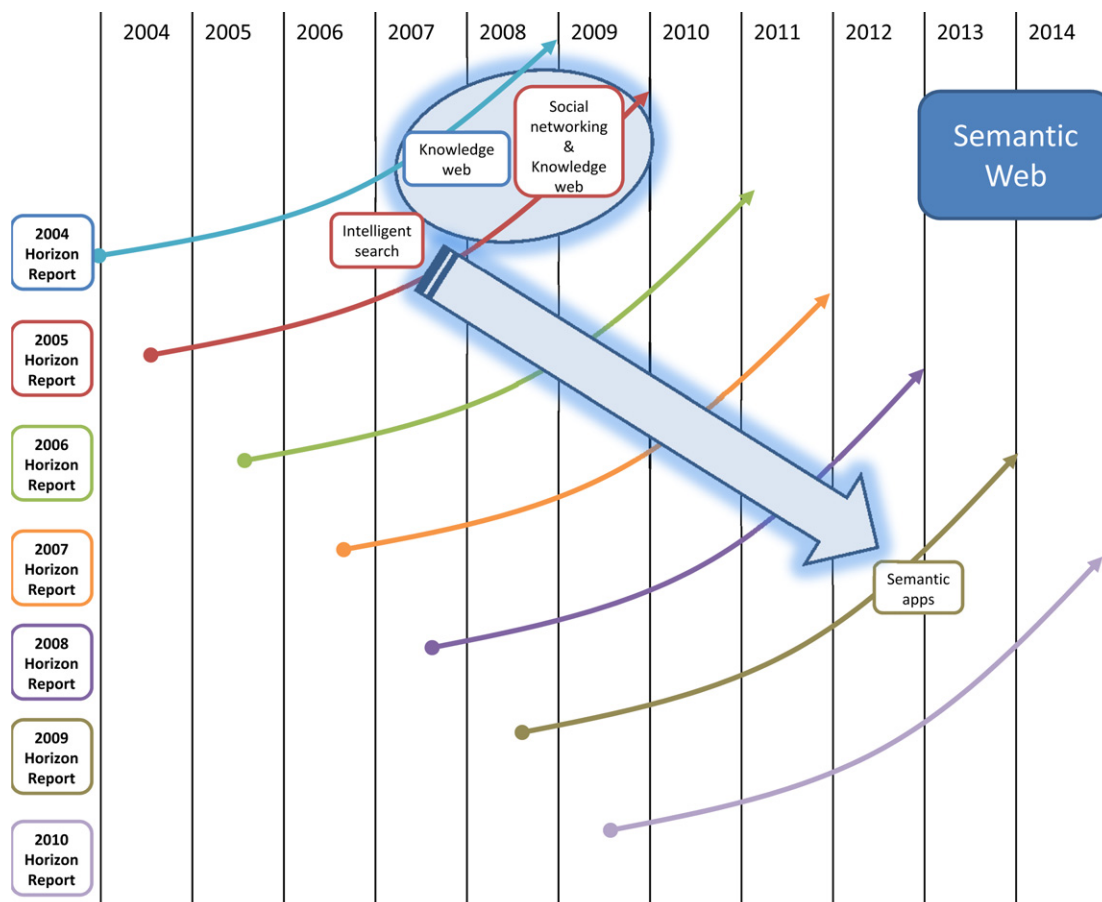


Fig. 3. Semantic web technologies most likely to have an impact on education according to the Horizon Reports from 2004 to 2010.

The knowledge web, first forecasted in the 2004 HR (Johnson & Laurence, 2004), is focused on providing knowledge representation for information based on technologies such as RDF or RSS (forecasted for 2007–2008). The 2005 HR (Johnson et al., 2005) also forecasted this as an important technology, but in this case, it was closely related to social networking. No other mention to it has been made in other HR, as the circle around these technologies shows in Fig. 3.

Related to this group of technologies, intelligent search engines also use knowledge representation to search for and provide personalized knowledge. The 2005 HR (Johnson et al., 2005) provided details on the predicted impact of intelligent search engines in the mid-term horizon (2007–2008).

However, no related concepts appeared in the reports again until 2009, when the experts decided that semantic applications would be impacted over a long-term horizon (2012–2013). This temporal gap is shown in Fig. 5 through an arrow that moves from intelligent search to semantic applications. Semantic applications are based on the idea of systems being able to extract meaning from information on the Web and to provide personalized services and information according to user needs.

3.3.3. Learning objects

There are few mentions to this group among the HR predictions. Learning objects were forecasted in the 2004 HR (Johnson & Laurence, 2004) as arriving in the short term (2004–2005). This technology appears again in the 2010 HR (Johnson et al., 2010) as open content, which was also forecasted to have an impact in the short term because of the current trend of offering open content for free on the Web. This temporal gap is represented in Fig. 4 as an arrow from learning objects to open content. One of the best proponents of this trend is the Open Courseware Initiative (ocw.mit.edu) at the Massachusetts Institute of Technology (MIT).

3.3.4. Augmented reality

Augmented Reality basically merges information or images with video streamed from a webcam. This can be considered a step beyond data mashup. The result is similar to virtual reality but uses real-world images in real time. This technology can be applied to some of the many potential revolutionary applications in education, including the study of architecture, art, anatomy, languages (Yang, Chen, & Jeng, 2010), decoration, or any other subject in which a graphic, simulation or 3D model could improve comprehension (Zhou, Duh, & Billingham, 2008). Augmented reality could also be used together with QR codes in books to create augmented books in which images or simulations could complement the book content.

The technologies in this field were forecasted beginning in the 2005 HR (Johnson et al., 2005) as a long-term, promising technology forecasted for impact in 2008–2009, but the 2006 HR (Johnson et al., 2006) delayed its predicted arrival by one more year (2009–2010). This technology was then not referenced until the 2010 HR (Johnson et al., 2010), in which mobile devices were again forecasted to play an important role in education; these technologies are now predicted to take effect in the mid-term (Fig. 5). This fact is represented as a circle grouping the 2008–2010 predictions and an arrow toward the prediction on 2011–2012.

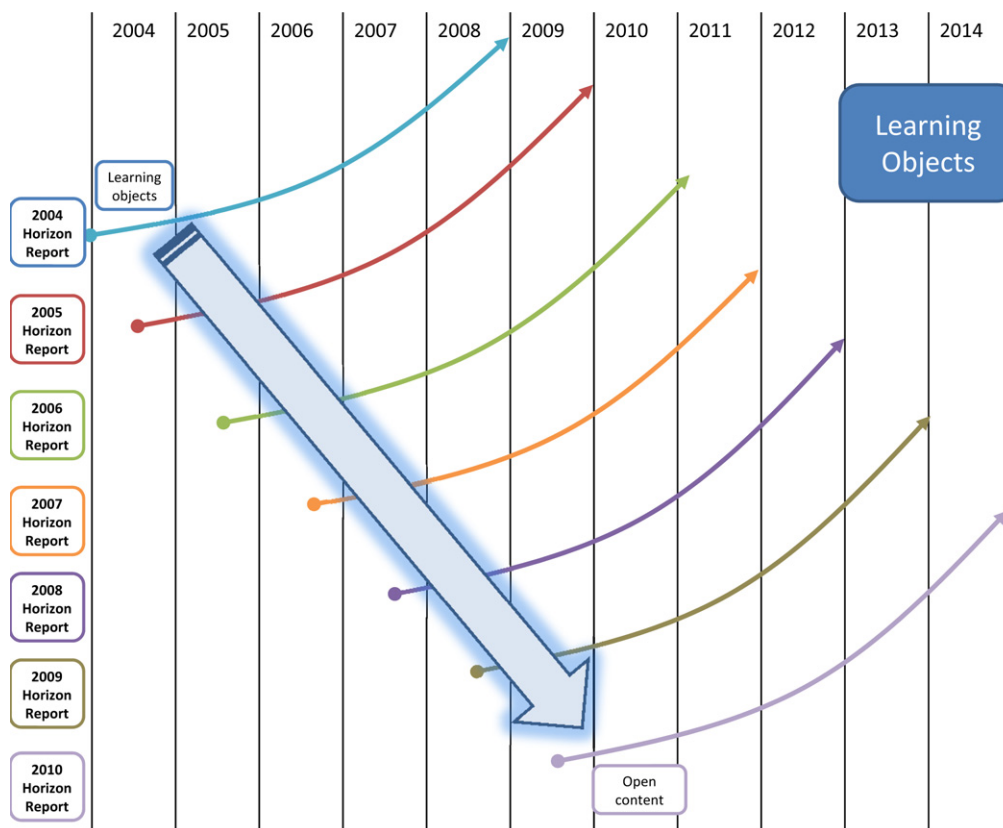


Fig. 4. Learning objects technologies most likely to have an impact on education according to the Horizon Reports from 2004 to 2010.

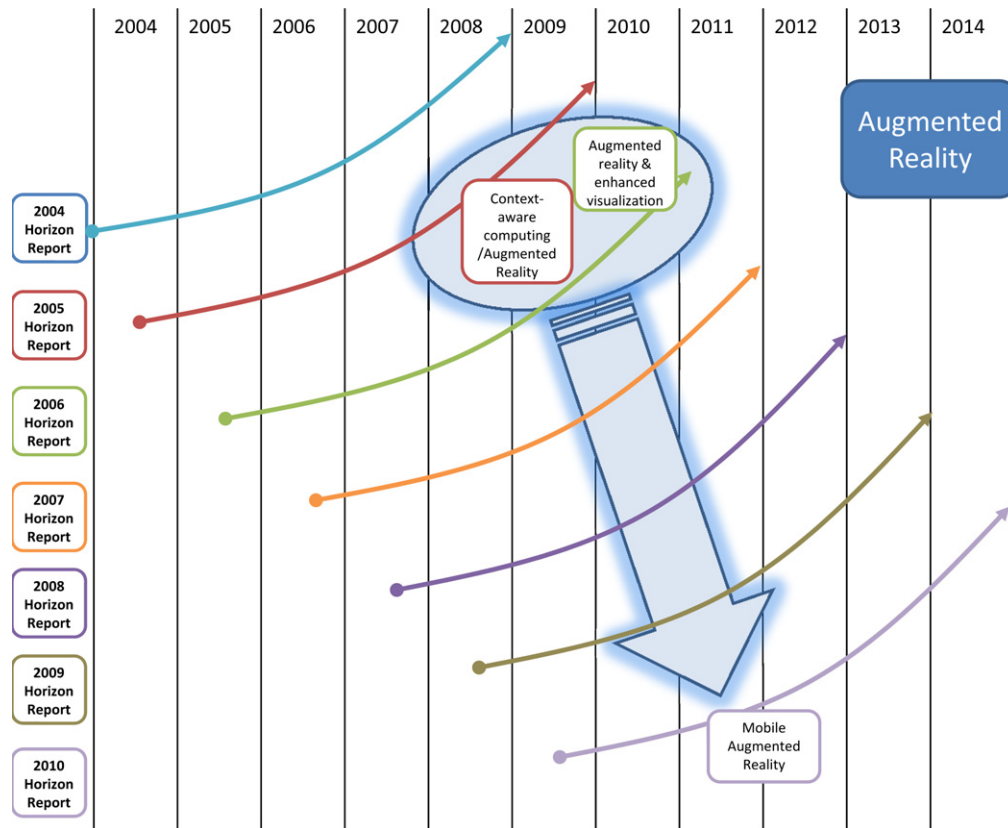


Fig. 5. Augmented reality technologies most likely to have an impact on education according to the Horizon Reports from 2004 to 2010.

3.3.5. Immersive environments: games and virtual worlds

Proponents of educational games argue that today's students are used to a different kind of interaction (Sandi & Robinson, 2009) (Crosier, 2002). Students would benefit from more interactive and engaging learning material because this is how they have acquired a great deal of their cultural knowledge (Haieny, Connolly, Stansfield, & Boylea, 2011). Many students spend long periods of time watching TV, surfing personalized content on the Internet or playing engaging games using their desktop computers or mobile phones. This fact requires a change in teaching methods or, more accurately, in learning methods (Prensky, 2001). Today's students find it harder to become absorbed in classroom lectures (Sue, Maton, & Kervin, 2008). Therefore, a great deal of research effort (see games publications in Table 3) has been devoted to creating engaging games to support learning (Papastergiou, 2009; Wishart, 1990) rather than just providing enjoyment. Along these lines, the 2005 HR (Johnson et al., 2005) forecasted educational gaming in the mid-term horizon, i.e., between 2007 and 2008 (Fig. 6). The 2006 HR (Johnson et al., 2006) forecasted its impact one year later.

The 2007 HR (Johnson, Laurence, Levine, & Smith, 2007) focused on two related technologies: virtual worlds (forecasted for 2009–2010) and massive gaming (forecasted for 2011–2012). Virtual worlds have deeply impacted many aspects of our society, giving rise to a parallel world in which people work, communicate, earn and spend money and even receive education (Coller & Scott, 2009, Girvan & Savage, 2010). The difference between these virtual worlds and reality, and the basis of the success of these worlds, may be merely that virtual worlds present the opportunity to carry out these tasks without the fear of failure, as virtual worlds are only games and the player can always start again (Monahan, 2008). Massively multiplayer games are engaging in the same way, as they are also basically virtual worlds, but these games tend to have a clearer objective, for example, to defeat the enemies, save the princess or get the best score (Jarmon & Traphagan, 2009, Lucia, 2009).

However, the HRs from 2008, 2009 and 2010 (Johnson et al., 2008, 2009, 2010) did not mention any technologies related to educational games. Arguments against educational gaming include the high cost of game development (in time as well as money), the difficulty that non-specialists would have in altering the games (which is currently being addressed through open-source engines), and, finally, the creativity required for game creation, as it can be difficult for teachers to learn to teach in a new and unfamiliar way (Moreno-Ger, Sierra, Martínez-Ortiz, & Fernández-Manjón, 2007). Nevertheless, attempts are being made to apply the power of games and virtual worlds to companies (Reeves & Reed, 2009), not only for training but also for a company's work owing to the power of games in engaging employees in repetitive jobs (e.g., call centers).

3.3.6. Ubiquity and mobile devices

Ubiquity and mobile devices can be analyzed separately but are studied together here to demonstrate their interconnection, as we believe that mobile devices are currently the most successful example of ubiquitous technologies, although the HRs consider other technologies such as smart objects to be promising as well. Ubiquitous computing is based on the concept of an invisible computing power embedded in the environment that can act and react according to the user's needs (Weiser, 1991). This paradigm involves the most natural possible interaction between a user and a computer, with the final aim being that the user will not even realize that he is interacting with

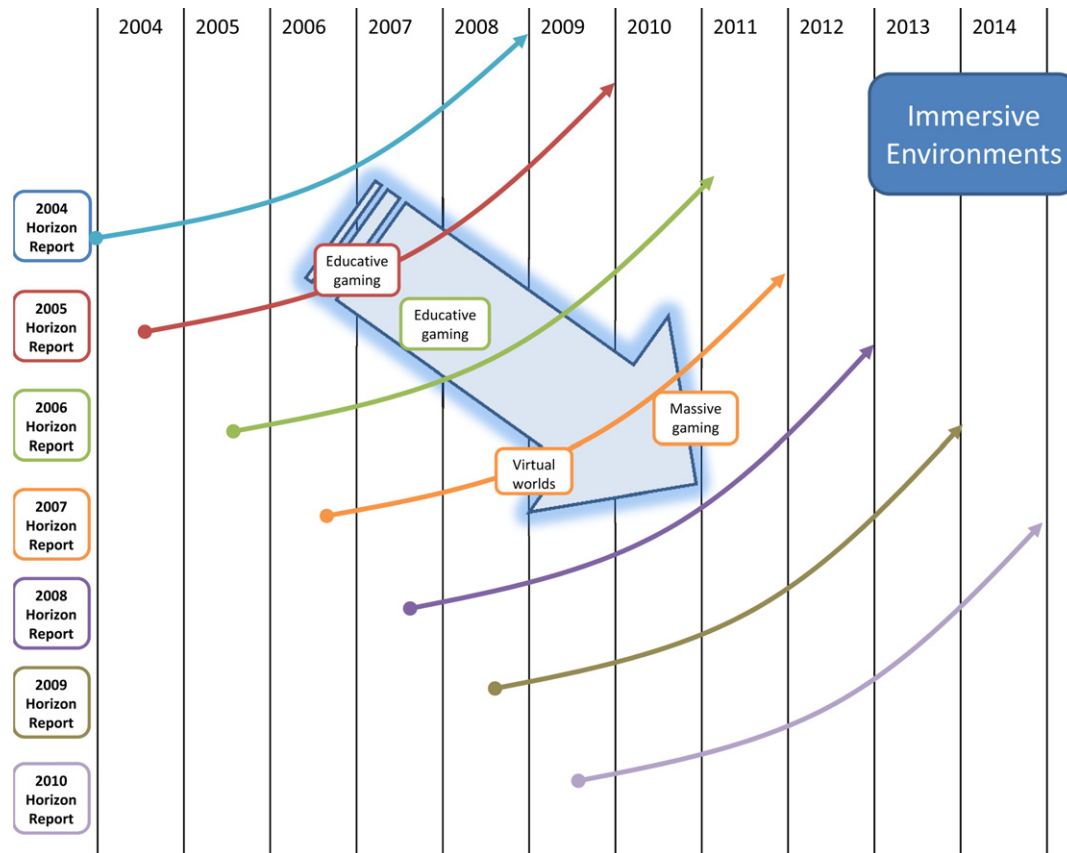


Fig. 6. Immersive environments-oriented technologies most likely to have an impact on education according to the Horizon Reports from 2004 to 2010.

a system (Kwok et al., 2011). Ubiquitous computing is not a technology itself but rather a group of technologies that support the arrival of this new paradigm, including context-aware computing, ubiquitous wireless networks, smart objects, location-based systems and, more recently, mobile-based technologies.

Fig. 7 represents all the technologies related to ubiquitous computing and mobile devices. During the first years, HR predicted as important technologies for education ubiquitous computing and context-awareness. However, since 2006 no other reference appeared around ubiquitous computing, and the predictions were around mobile devices. These facts are represented with a circle around the ubiquitous computing predictions in the first years, another circle around the mobile device related predictions, and an arrow representing the change of trend, from ubiquitous computing toward mobile devices.

In the 2004 HR (Johnson & Laurence, 2004), context-aware computing was foreseen as a key technology in the long-term horizon (2007–2008). In the 2005 HR (Johnson et al., 2005), ubiquitous wireless networks were reported to impact in the short term. This is one of the key requirements to support the arrival of ubiquitous computing, and experts now foresee its impact as occurring in the long term (2009–2010).

The 2006 HR (Johnson et al., 2006) did not make another mention of context awareness or ubiquitous technologies. Two other groups of technologies appeared instead: mobile smart objects and mobile devices. The concept of a smart object relates to the so-called Internet of Things through technologies such as RFID and QR-Codes, and these technologies aim to instill common objects with some intelligence. The 2009 HR (Johnson et al., 2009) forecasted that these technologies would have an impact on education in the long term (2012–2013).

Regarding mobile devices, today's students have grown up with a new class of technologies that the previous generation might not have imagined, including cell phones, smartphones, portable video consoles, and GPS navigators. Mobile devices have deeply impacted our society, changing the way we communicate with and keep in touch with one another (Liu et al., 2010). Nevertheless, mobile devices are no longer simply a method of communication (Martin, 2009; Naismith, Lonsdale, Vovoula, & Sharples, 2004). They are changing the way we work by supporting a variety of applications (including typical office applications, the Internet, and e-mail); the way we spend our spare time (e.g., with video games, Internet videos, and podcasting); the way we obtain information (including through GPS navigators, Augmented Reality and Web surfing); and even education.

According to the studied reports, 2006 was the first time experts expected phones to have an impact on education. They envisioned this impact as occurring in the mid-term for 2007–2008. This prediction was not changed in the next HR in 2007 (Johnson et al., 2007), delaying its impact one year. Finally, the 2009 HR (Johnson et al., 2009) predicted its impact in the short-term horizon for 2009–2010. Although these are the only references to this technology in the reports, its development has been accompanied by related technologies such as location-based systems (i.e., context-awareness technologies) in the 2004 and 2005 HRs (Johnson & Laurence, 2004; Johnson et al., 2005) and Geo-everything in the 2009 HR (Johnson et al., 2009) over the mid-term horizon of 2010–2011. This is a fundamental piece, as it allows a very important part of the user's context to be retrieved, wherever the user is, enabling its use in a wide variety of applications (e.g., providing personalized services and information according to location or integrating location with data mashup systems).

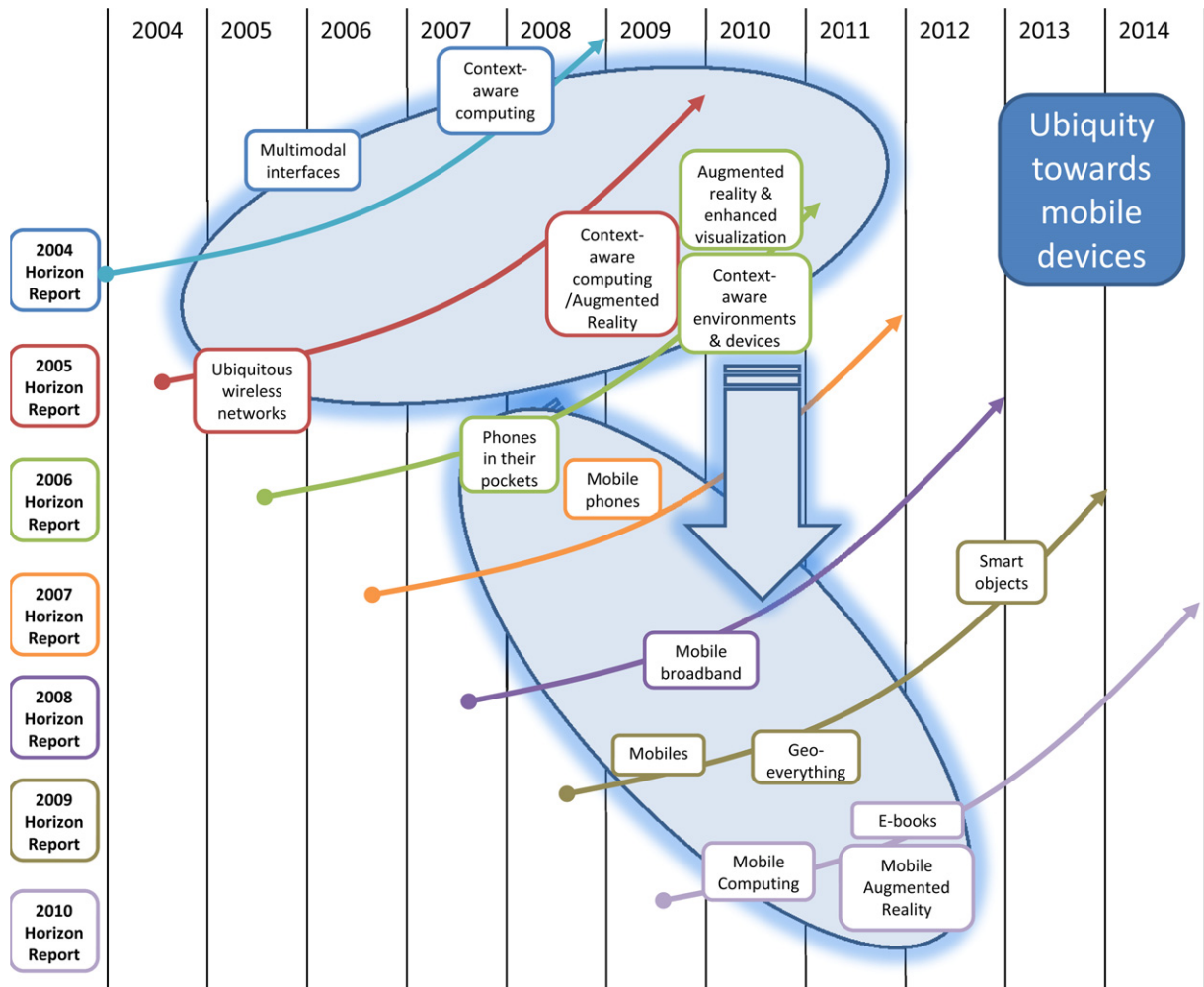


Fig. 7. Ubiquitous and mobile technologies most likely to have an impact on education according to the Horizon Reports from 2004 to 2010.

3.4. Bibliometric analysis

According to the work specified in stage 5, a detailed bibliometric research has been carried out to assess whether the defined technology groups had the predicted impact on education or not. Table 1 shows the number of papers published every year along with their WF obtained with the Eq. (1).

Table 2 shows the number of papers available in Google Scholar for each one of the analyzed years in each technology group. WFs from Table 1 are applied to the results in Table 2 to obtain Table 3, with the weighted number of papers published every year in each technology group.

The results from Table 3 are graphically represented in Fig. 8, showing the publishing evolution of each analyzed technology from 2004 to 2010.

Most of the technology groups, such as social web, semantic web, games, ubiquitous computing and mobile devices, are broken down into details in Figs. 9, 10, 11 and 12, showing the evolution of each technology within its group. The augmented reality and learning objects groups are not broken down into more details because they are mainly made of one technology.

Table 1
Relation of number of papers available in education-related publications in Google Scholar from 2004 to 2010, along with their weighting factor.

Year (i)	Number of papers available (p_i)	Weighting factor (WF_i)
2004	164000	0.740243902
2005	158000	0.768354430
2006	146000	0.831506849
2007	130000	0.933846154
2008	108000	1.124074074
2009	81900	1.482295482
2010	61900	1.961227787

Table 2
Number of papers published in Google Scholar in education-related technologies from 2004 to 2010.

Year	Mobile	Games	Augmented Reality	Social Web	Semantic Web	Learning Objects
2004	3366	1588	202	11379	1268	300
2005	4013	1749	214	13162	1426	398
2006	3979	2117	244	15205	1657	429
2007	4155	2336	260	17701	1588	415
2008	5125	2649	282	18392	1854	532
2009	6208	2733	306	19853	1849	461
2010	4855	2633	329	14950	1698	322

4. Discussion

This section evaluates the HR predictions (Section 3.3) by checking their impact on publications (Section 3.4) according to the sixth stage of the methodology. A general analysis comparing Table 3 with the HR predictions indicates that not all the forecasted technologies have had the same impact on education.

Fig. 9 shows the number of publications of the different technologies within the social web group. According to the results, social networks had the deepest impact on education-related research, with a very high rate of academic articles, especially on 2009. It is important to notice that the articles published in 2009 were the result of a research work in 2008, which totally match the HR predictions around this technology.

Although this is the best exponent of this group, the rest of technologies also had an important impact on education research according to the results, especially in recent years, according to HR predictions. For example, user-created content, forecasted by HR for 2007, was an important technology that year because the research efforts in 2007 produced 2952 articles in 2008. This technology continued growing, being the second most important of the group. The impact of other related technologies, such as grassroots videos, forecasted by HR for 2007, and collaborative Web, forecasted for 2008, were delayed one and two years respectively, according to the bibliometric analysis. The research efforts around videos in 2009 produced 3216 articles in 2010 and the research efforts around collaborative Web in 2009 produced 3236 articles in 2010. Finally, other technologies, such as personal Web, did not have the expected impact, since very few articles were published around it.

Table 3
Weighted number of papers published in Google Scholar in education-related technologies from 2004 to 2010.

Year	Mobile	Games	Augmented reality	Social Web	Semantic Web	Learning objects
2004	2492	1176	150	8423	939	222
2005	3083	1344	164	10113	1096	306
2006	3309	1760	203	12643	1378	357
2007	3880	2181	243	16530	1483	388
2008	5761	2978	317	20674	2084	598
2009	9202	4051	454	29428	2741	683
2010	9522	5164	645	29320	3330	632

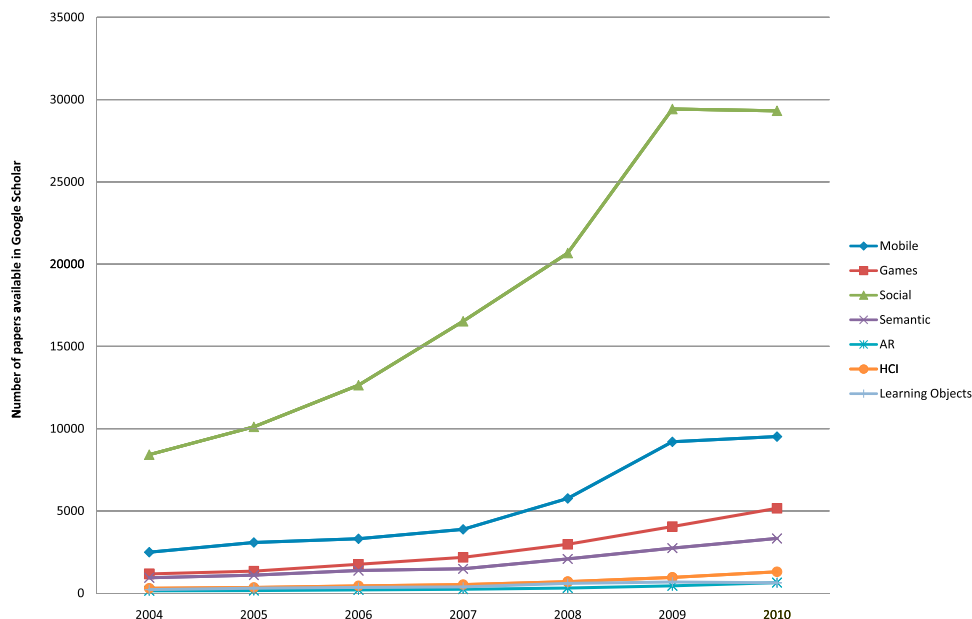


Fig. 8. Publishing evolution of the different technology groups from 2004 to 2010 according to Google Scholar.

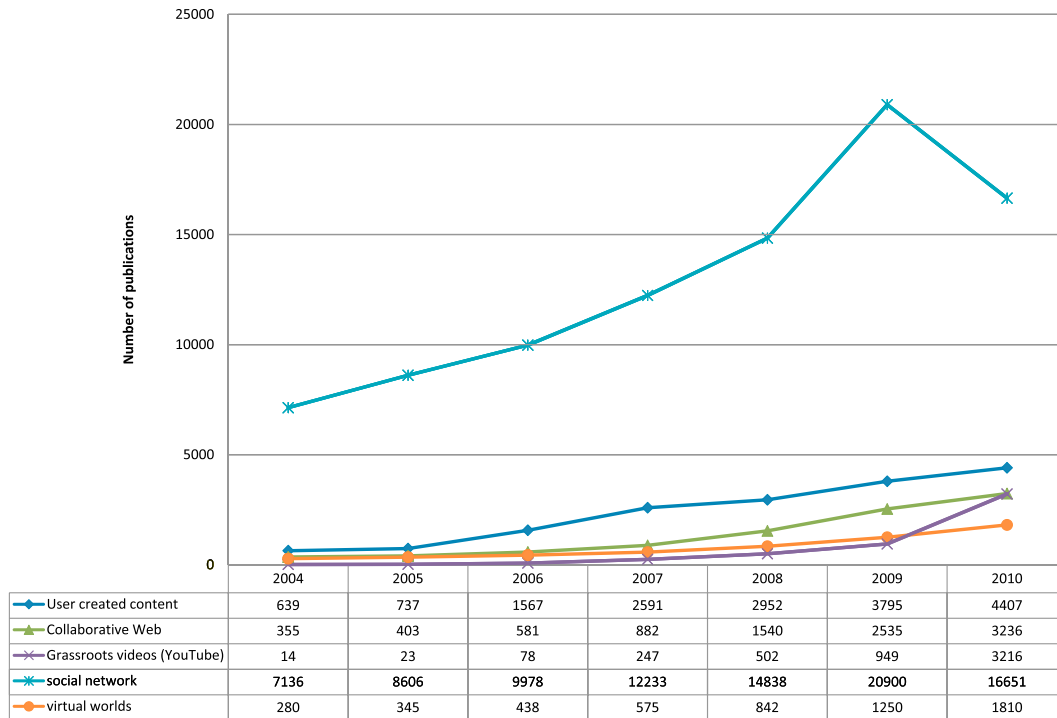


Fig. 9. Publishing evolution of the social web technologies from 2004 to 2010 according to Google Scholar.

The impact of semantic applications in education-related publications is increasing every year, having more than 3300 articles published in 2010. If this technology continues with this trend, the HR prediction for its impact on 2012–2013 will be successful, although the impact that had in 2010 was high enough to be considered as important. On the other hand, the predictions made around knowledge Web did not find the expected results according to the bibliometric analysis for this technology, with an important difference between publications around semantic Web and Knowledge Web (Fig. 10). The number of articles available during the term 2007–2009 was lower than 30 articles per year.

The impact of Learning Objects on publications (Table 3) did not have the expected impact on education, although the number of publications available of this technology increased from 222 in 2004 to 631 in 2010. This fact becomes especially true regarding to open content, as most of the publications were related to not-open learning objects. Thus, the HR prediction around open content, and the evolution flow from learning objects to open content seems to not have had the expected success.

The bibliometric analysis of augmented reality in the term 2008–2010 indicates that, although the number of articles available is increasing, it cannot be considered as important as other technologies forecasted for the same term, such as mobile devices or social web.

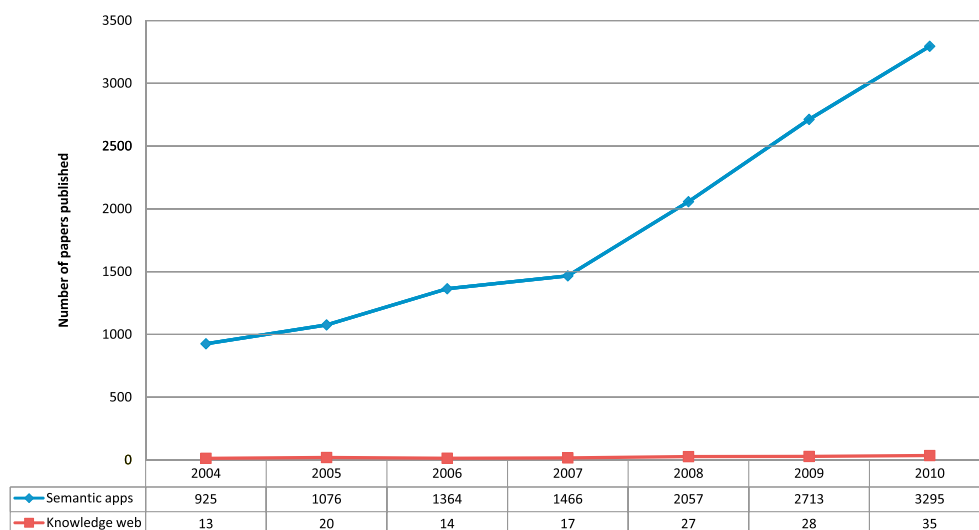


Fig. 10. Publishing evolution of the semantic web technologies from 2004 to 2010 according to Google Scholar.

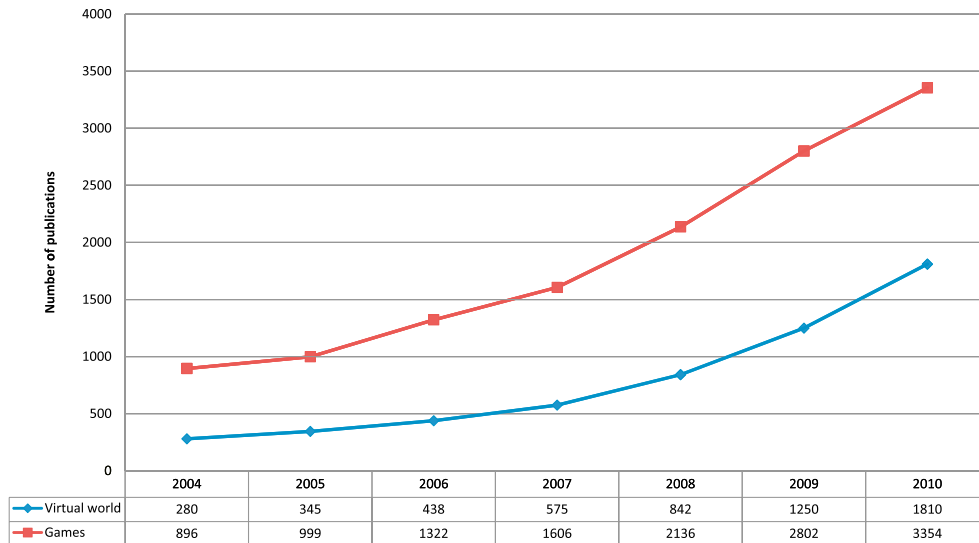


Fig. 11. Publishing evolution of the gaming technologies from 2004 to 2010 according to Google Scholar.

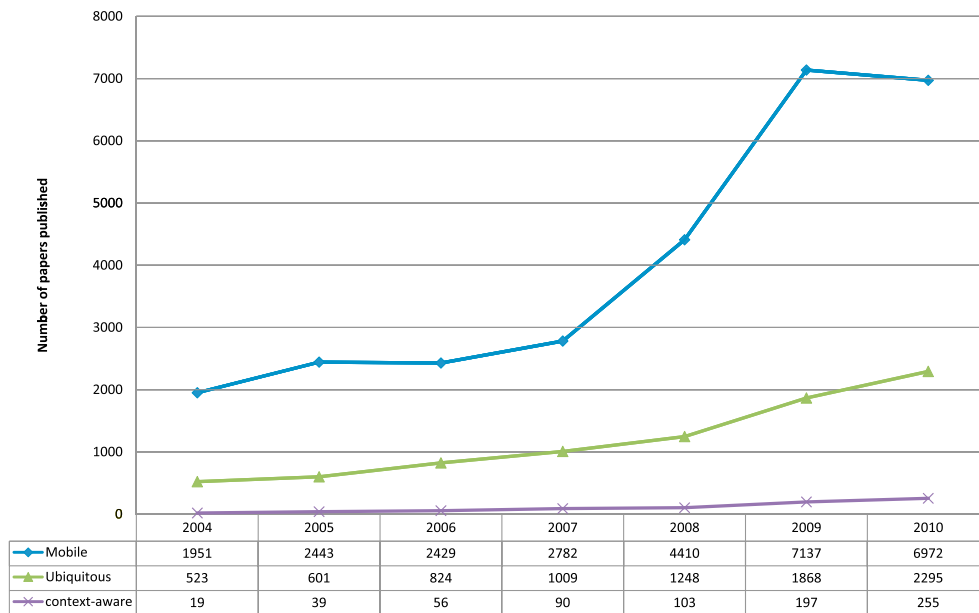


Fig. 12. Publishing evolution of the mobile and ubiquitous technologies from 2004 to 2010 according to Google Scholar.

Therefore, the prediction made in the 2005 and 2006 HR were not as successful as expected. However, thanks to the synergy created with mobile devices, the impact predicted for 2011–2012 by the 2010 HR will be probably true if its publishing trend continues growing.

The number of publications from 2005 to 2007 (Fig. 11) around immersive environments indicates that the predictions around games can be considered successful with around 1600 articles published in 2007. Regarding virtual worlds, their impact on publications is less significant than games. Nevertheless, its predicted impact on 2008–2009 can also be considered successful, because the research work done during that term produced an important number of articles in 2009 and 2010, with 1250 and 1810 respectively.

Ubiquitous computing and context-awareness did not have the forecasted impact on education according to the results in Fig. 12. However, the predictions around mobile devices to impact in the 2007–2012 term can be considered as successful because the number of publications was very important since 2005. The extremely high number of publications achieved in 2009 and 2010 around mobile devices illustrates the importance of this technology for researchers.

In summary, social web and mobile devices are currently the most important technologies for the near future in education according to HR experts and their publishing evolution. Games should also be considered as an important technology likely to have a deep impact on education, although it is not as extended as social web and mobile devices. Other promising technologies, such as augmented reality and learning objects, do not have enough maturity in education according with their publication impact. However, although these technologies are in their initial stages in education, they are becoming more important and will probably play an important role in the future.

5. Conclusions

The findings of this research suggest that the predictions given by HR can be used as the basis for metatrends analysis of technologies likely to impact education. The temporal variable of the predictions given in the reports, the yearly release since 2004, and the world-wide recognition of their content make them good candidates to be used for this analysis. However, this analysis must be complemented with some objective evaluation method, such as bibliometrics, to assess whether the predictions were successful or not, and to corroborate the existence of the obtained metatrends.

The bibliometric analysis over the predictions highlights that some of the predictions were right, e.g., social networks, user-created content, games, virtual worlds and mobile devices. Other predictions did not have the expected impact, e.g., knowledge Web, learning objects and open content, context-awareness and ubiquitous computing. However, other predictions were successful, although their impact was delayed one or two years, e.g., grassroots videos and collaborative Web. Regarding the application of the bibliometric analysis to the obtained metatrends, the evolution of learning objects toward open content did not seem to be successful due to the low index of publications about open content. However, the metatrend of ubiquitous computing and context-awareness toward mobile devices was successful, according to the high index of publications. Other metatrend that can be considered successful was the evolution from augmented reality toward mobile augmented reality. The increasing importance of mobile devices in education is fostering all the technologies related to them. Augmented reality did not have the expected influence in education in 2008–2010, although, according with its publication evolution, it will probably play a more important role on 2011–2012.

This work can help researchers to understand the past, current and future technology metatrends in education. This can be useful to help them decide where to focus their future research efforts. The results illustrate how some technologies have become very important for education experts, while other important technologies in other environments finally did not have the expected impact on education.

The predictions and metatrends given in the current work present some limitations due to their broad focus. Each education field (e.g., humanities, engineering, medicine) has some particularities that make them more suitable for the use of certain methodologies and technologies. Thus, as directions for future work, a more detailed analysis should be done focusing on each field.

Acknowledgments

The authors acknowledge the work carry out by the New Media Consortium and the EDUCAUSE Learning Initiative publishing the Horizon Reports. An excellent piece of work that inspires the work of many other researchers.

The authors acknowledge the Spanish Science and Innovation Ministry for support of the projects TIN2008-06083-C03/TSI “s-Labs – Integración de Servicios Abiertos para Laboratorios Remotos y Virtuales Distribuidos” and CYTED-508AC0341 “SOLITESOFTWARE LIBRE EN TELEFORMACIÓN.” Finally, the authors acknowledge the support provided by e-Madrid Project, S2009/TIC-1650, “Investigación y Desarrollo de tecnologías para el e-learning en la Comunidad de Madrid”.

Appendix. Supplementary material

Supplementary data related to this article can be found online at [doi:10.1016/j.compedu.2011.04.003](https://doi.org/10.1016/j.compedu.2011.04.003).

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