Human evolution has become human technology co-evolution: We’re becoming part of the machine, and it is becoming part of us.

(Ayesha Khanna, Parag Khanna, Technology will take ona life of its own. Welcome to the Hybrid Age, “Foreign Policy”, 2011)

The increasing integration between humans and technology, the multiplying interaction modalities, the enhancement of realism, presence and immersivity; the opening to soft sciences and to new multidisciplinary, interdisciplinary and transdisciplinary fields; the relationships and cooperation element coming to the fore: these are the key issues of the huge “scientific research potential of virtual worlds”, as the title of a well-known Science article stated (Bainbridge, 2007). And these are also the core peculiarities of virtual laboratories of today

The theoretical background: the virtual dimension and the Network

The Science’s position has provided the scientific validation of the conceptual framework already developed by Pierre Lévy (Lévy, 1990, 1994, 1995).

According to the French scholar, the evolution in progress is grounded on two cornerstones: the pervasiveness of technologies and networks and the virtual dimension, which consists of the continuous circular passage from actualisation to virtualisation and vice versa, and at the same time of an essential deterritorialisation. On the one hand, the constant and permanently dynamic flow from virtual to actual and, again, from actual to virtual - that uninterruptedly detects new stimuli, explores new paths, discovers problems and thinks up solutions - is the so-called Moebius effect identified by Lévy: it bears a meaningful resemblance to the SECI model, set up just at that time by Nonaka e Takeuchi (1995), in which the knowledge creation vital process (from tacit to explicit and vice versa) takes the characteristic shape of a spiral (the knowledge spiral: Socialisation - Externalisation - Combination - Internalisation).
On the other hand, deterritorialisation evolved from the previous radicalism of the nomad planet to the current perspective of concrete networking, more softened and flexible and simultaneously more robust and tangible, which has overcome Deleuze and Guattari’s classical polarity between nomadism and sedentariness, between the smooth space of the nomads and the striated space of the sedentaries.

The extreme paradigm of the nomad, so of the cybernaut, the solitary hero of a cyberspace without identity, centre, directions or landmarks, belonged to the imaginative world of the eighties of the twentieth century - as it was drawn by the film *Tron* (1982) and by the novel *Neuromancer* (1984) - and lasted until the millennium’s end (Krämer, 2011).

As repeatedly highlighted by Lévy, through their social and community dimension the new relational technologies have dramatically transformed the universe of humans - as individuals as well as members of many intersecting groups; and novel spaces and scenarios have been taking shape for knowledge, culture, learning, and for the nature of society itself. Collective intelligence, cooperative learning, new humanism and cyberspace democracy became the new watchwords.

At the turn of the third millennium, the technological progress combined with the globalisation demands and really seemed to open up to everyone new horizons for personal and social, educational and cultural development, formerly inconceivable, especially for the most backward and marginal areas of the world. From the UNESCO’s programme on “Education for All” (EFA) - launched in 1990 and re-affirmed in 2000 through the Dakar Framework for Action - to access for all and open education, up to the lately increasing models of open university (Baldazzi, 2009), equity, universal education - from primary to highly specialised - empowerment and emancipation of individuals and groups, finally everything looks possible and Freire’s *popular education* and his utopian *pedagogy of the oppressed* seem to actually become a reality.

At the same time - particularly within scientific research, education and didactics - we observe the triumph of constructivism and, parallel to the rise of virtual worlds, the progressive predominance of socio-constructivism, whose favoured environments are definitely virtual laboratories.
Virtual laboratories: first steps and the shift of virtual worlds

The cultural contexts of origin are physical-mathematical and engineering-technological, but, thanks to the increase of realism and the enhanced value of relationships and interactions, have rapidly extended to social sciences and humanities, and to all their disciplinary sub-varieties and contaminations. The virtual laboratory - created by computer simulation and through the masterly exploitation of networking - allows enormous savings compared to the real one, letting foresee extraordinary development perspectives.

The start of millennium marked a crucial turning point, announced by a very successful film, Matrix (1999): the birth and the immediate proliferation of virtual worlds, electronic environments that visually imitate “complex physical spaces, where people can interact each other and with virtual objects, and where people are represented by animated characters”, the avatars (Brainbridge, 2007, p. 472).

From the outset, among them two main metaverse types have been recognised, both critical for innovation in didactics, studies and research: the massively multiplayer online role-playing games (MMORPGs), in which players, as modern medieval knights, perform feats, various challenges and real quêtes, facing dangers and ambushes and travelling through evocative scenarios (forests, cities, oceans, deserts and mountains), enabled by very advanced graphics applications; and the online multi-user virtual environments (MUVEs), three-dimensional environments “that support exploration, simulation, role play, interaction and experimentation via avatars, or 3-D self-representations” (Kokak, Ozarslan, 2011, p. 118). Open and geometric spaces, conceived to be designed and built by users-residents, take shape and acquire meaning and consistency, thanks to their creativity.

Among the formers, EverQuest dates back to 1999 and more celebrated World of Warcraft (WoW) to 2004; among the latters, the famous city of Second Life (SL) - which, as its official website proudly declares, is “a 3D online persistent space totally created and evolved by its users: Within this vast and expanding place, you can do, create or become just about anything you can imagine” - was released in 2003, although already prefigured by a 1992 novel, Snow Crash.
Persistence, physicality, interactivity; multi-user sharing of the social space and active building of contents and teams; real-time interaction; the intertwining of identities (virtual, real, blended) and roles, the fertile dialectic of their relationships; growing realism and immersivity; complexity of communication and expansion of visual and graphical aspects; all these elements of virtual worlds are founded on the “human technology co-evolution”, peculiar to the “Fourth Wave”, the current revolution of the “Hybrid Age” and of Technik, following the Third one, the Information Age (Khanna, Khanna, 2011; 2012).

The heterogeneous universe of journals faithfully reflects this ideal evolutionary pathway. In fact, around 2000 several journals arose, addressing human-computer interaction, computer-mediated communication, online world and network issues. Since 2004, journals concerned with virtual worlds - explicitly mentioned in their titles and among their chief areas of interest - have considerably increased (Table 1).

The peak of new journals devoted to virtual worlds was reached in 2011, eight years after the launch of SL and seven after the launch of WoW.

The Journal of Visualization and Computer Animation’s destiny is exemplary: established in 1999, in 2004 changed its name to Computer Animation and Virtual Worlds, when its focus was transferred to the overall topic of virtual worlds.

Geographically, the developed West - not only English-speaking - predominates; new emergent countries have appeared, such as Turkey, China and Taiwan; and there are also a few solitary and ambitious European experiments.
<table>
<thead>
<tr>
<th>Title</th>
<th>Start year</th>
<th>Country</th>
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<tr>
<td>The Turkish Online Journal of Distance Education (TOIJDE)</td>
<td>2000</td>
<td>Turkey</td>
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<td>Journal of Interactive Online Learning</td>
<td>2002</td>
<td>USA</td>
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<tr>
<td>Turkish Online Journal of Educational Technology (TOJET)</td>
<td>2002</td>
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<td>International Journal of Distance Education Technologies (IJDET)</td>
<td>2003</td>
<td>Canada</td>
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<td>Journal of Educators Online (JEO)</td>
<td>2004</td>
<td>USA</td>
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<tr>
<td>Computer Animation and Virtual Worlds</td>
<td>2004</td>
<td>Switzerland (John Wiley &amp; Sons, Ltd.)</td>
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<td>Innovate: Journal of Online Education</td>
<td>2004 (-2009)</td>
<td>USA</td>
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<td>E-Beratungsjournal. Fachzeitschrift für Onlineberatung und computervermittelte Kommunikation</td>
<td>2005</td>
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<td>International Journal of Online Engineering (ijOE)</td>
<td>2005</td>
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<td>International Journal of e-Collaboration (IJeC)</td>
<td>2005</td>
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<td>The Metaverse Journal</td>
<td>2006</td>
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<td>International Journal of Internet Research Ethics (IJIRE)</td>
<td>2008</td>
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<td>Educação, Formação &amp; Tecnologias</td>
<td>2008</td>
<td>Portugal</td>
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<td>Journal of Virtual Worlds Research (JVWR)</td>
<td>2008</td>
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<td>@tic. Revista d’innovació educativa</td>
<td>2008</td>
<td>Spain</td>
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<td>Journal of Gaming and Virtual Worlds</td>
<td>2009</td>
<td>UK</td>
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<td>Journal of New Frontiers in Spatial Concepts</td>
<td>2009</td>
<td>Germany</td>
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<td>Journal of Virtual Worlds and Education (JVWE)</td>
<td>2010</td>
<td>USA</td>
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<td>International Journal of Virtual and Personal Learning Environments (IJVPLE)</td>
<td>2010</td>
<td>UK</td>
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<tr>
<td>International Journal of Cyber Behavior, Psychology and Learning (IJCBL)</td>
<td>2011</td>
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<tr>
<td>International Journal of Online Pedagogy and Course Design (IJOPCD)</td>
<td>2011</td>
<td>Taiwan</td>
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<tr>
<td>International Journal of Game-Based Learning (IJGBL)</td>
<td>2011</td>
<td>Ireland</td>
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<tr>
<td>International Journal of Computer-Assisted Language Learning and Teaching (IJCALLT)</td>
<td>2011</td>
<td>China</td>
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<td>International Journal of Cyber Ethics in Education (IJCEE)</td>
<td>2011</td>
<td>Turkey</td>
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<td>International Journal of Social and Organizational Dynamics in IT (IJOSDIT)</td>
<td>2011</td>
<td>USA</td>
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<td>International Journal of Art, Culture and Design Technologies (IJACDT)</td>
<td>2011</td>
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Between research and education: virtual laboratories and science

The contribution of virtual worlds to research has spread - from a specifically methodological perspective - beyond the traditional boundaries of the hard sciences, to the social, behavioural, economic sciences, and to the human-centred computer science, successfully contrasting the excessive disciplinary fragmentation. Due to the high number of research subjects who can be involved, SL provides in particular wide opportunities for experimenting in observational ethnography and quantitative analysis of economic markets and social networks.

WoW, fostering the cooperation among the individuals, is an environment more conducive to the study of human behaviours. However, they certainly make their greatest contribution to education and, above all, to science education, in the wake of cognitivism, constructivism and socio-constructivism, as it can be noted in the latest virtual laboratories.

In fact, in conjunction with the success of SL and WoW, the emphasis has gradually moved from online experimental laboratories to virtual laboratories founded on the two major virtual worlds, where the accent is firmly on realistic interaction and on relationships and cooperation factor (*collaboratories*) (Brainbridge, 2007). Virtual laboratories based on the simulation of experiments put at disposal of users - firstly students and teachers/researchers - a wide range of flexible solutions to meet their manifold disciplinary needs - learning/teaching and research, financial, organisational, logistical. Therefore, in 2006, within a traditional sector such as chemistry, it could be legitimately asked what was the most efficient way among real, virtual and remote laboratory: a third hybrid mode, the remote laboratory, in which the student controls the experiment - real and not simulated - from a remote computer, was added to the two specular ones (real-virtual) (Naef, 2006).

Between 2007 and 2008, even in the most technological domains such as materials sciences and engineering, the focus of virtual laboratories has steadily shifted from the merely technological aspect to social interaction, a key asset especially for didactics. Then, there are the successful exploitation of the virtual laboratory posts and the increasing demands to develop their methodology; and the stress on the crucial role of interactive and multimedia didactic aids,
decisive, within a constructivist scientific frame, for the success of active learning/teaching and of new educational processes, as well as for the simulation of phenomena and natural processes, nowadays widely used in research laboratories (Dobrzański, Honysz, 2007; 2008).

Simulation ensures all the possibilities of classical e-learning for virtual laboratories, potentially broadening learning opportunities to include the immense audience of all internauts: platforms available for all users of the global network, not only for students and researchers, autonomous use/learning, access independent of time and space, great adaptability to user needs, equipment inexpensive, safe in its use, practically indestructible represent their undisputed advantages in comparison with real laboratories.

In 2009 the three main laboratory types - hands-on, simulated, remote - were once more compared by an experimental research (Elawady, Tolba, 2009), which examined their strengths and weaknesses in scientific research in a broad sense, without restricting itself to engineering and applied sciences, for a long time in the middle of the international debate.

Remote laboratories - more and more popular among researchers and students - have again monopolised scholars’ interest. Their excessive cost still damages hands-on laboratories, since both students and equipment must be physically present in them. Nevertheless, simulated laboratories - where there are neither students nor equipment, but all the experiments simply consist of the imitations of real ones - are also more expensive than ever imagined. On the contrary, in the hybrid solution - i.e. remote laboratories - reality is only mediated by distance: the experiment is real, place and devices are materially present, but the experimenter is physically distant; in fact, the student who performs the experiment uses real data, controlling the equipment from a distance. Thus remote laboratories are preferred by students, because, concerning the number and the performances of experiments, they are more effective than simulated and more flexible than real ones.

With regard to the four principal educational objectives identified - i.e. conceptual understanding; design and scientific skills; social and communication skills; professional, technical and application skills - the study highlighted relevant differences between the three types of labs.

Hands-on laboratories allow to achieve all the four objectives to
a sufficient degree, excelling in conceptual understanding and in design and scientific skills. As for simulated and remote laboratories, the most satisfactory outcomes are reached in conceptual understanding and in professional, technical and application skills, while learning achievements are rather inadequate in social and communication skills and in design and scientific skills. Remote laboratories, however, show the best chances for development: in fact, their enhancement and their desirable conversion into augmented reality laboratories (ARLs) can considerably improve social and communication skills, as well as design and scientific skills. In 2011 a comparative analysis studied three learning environments, experimentally assessing their educational effectiveness within a discipline traditionally laboratory-based, such as physics and particularly optics: simulations developed in a hyper-realistic virtual environment, traditional schematic simulations and classical optics laboratory. The former have generally appeared much more effective than both the latter competing modalities (Martínez et al., 2011).

Another experimental research - carried out this year in Turkey (Tatli, Ayas, 2012) - evaluated very positively the learning effectiveness of the virtual chemistry laboratory, as a model of constructivist learning environment in secondary schools, in comparison with the real laboratory.

In fact, since 2007 Turkey has deeply reformed its national education system by introducing a constructivist approach, and has precisely modified the science curriculum for secondary education. Thus the virtual chemistry laboratory has been identified as a place of excellence where to accomplish this new science education, becoming, so to say, its symbol. Here, with the aid of the VCL (Virtual Chemistry Laboratory) software and of the POE (Predict, Observe, Explain) strategy (White, Gunstone, 1992) - well-known and consolidated within the constructivist framework - the function of experiment in developing scientific habits, experimenting and problem solving skills is totally enhanced: the student can control equipment and materials, collect data, perform the experiments by trial and error, taking full advantage of interactivity and cooperative dialogue. The POE strategy - supported by a powerful set of collaborative and interactive facilities - has become the pillar of the new scientific education.
The triumph of virtual worlds in novel three-dimensional learning environments

The overcoming of traditional distance learning has finally marked the giving up of behaviourism, in favour of Bruner’s constructivism and of socio-constructivism.

The latest virtual education - in which the Net combines with virtual worlds - has inaugurated a new ethical humanism, equally inspired by Lévinas’ ethics of responsibility and Freire’s ethics of emancipation and autonomy, in the sign of the genuine opening to the other. Beyond the cyberethics, the focus is now on the relationships among the avatars, namely communication, dialogue and face-to-face interaction. In the “kaleidoscope of identities” - generated by the tireless dialogic exchange between the real and virtual dimensions and by their mutual influences - the face appears as a construction simultaneously individual and social, because it is the product of the relationship with the other (Gomez, 2009).

An empirical research - conducted in 2009 on the basis of virtual ethnography - highlighted the role of avatars, within EverQuest and SL, in communication and more specifically in transmission, attribution and transformation of meanings (Jensen, 2009).

The study has cleverly exploited a cardinal distinction - borrowed from Latour’s actor-network-theory (ANT) (Latour, 2005) - between the concept of intermediary and the concept of mediator: the intermediary - a black box that carries the meaning without touching it, and ensures a perfect match between input and output - is in contrast with the mediator - who, on the contrary, transforms the meaning he transports, so that the output is “uncertain and unforeseen” (Jensen, 2009, p. 31).

In advanced virtual worlds, such as SL and EverQuest, avatars arise as intermediaries, created for this purpose by the actors, but immediately change into personal mediators, setting up a constant dialectic with the actors, through a dynamic process of sense-making, adaptation and individuation: in fact, the meaning continually changes moving from actors-gamers to avatars into they turn, and, again, from avatars to actors, who are therefore radically modified by the experience.

Among the motivation factors that drive actors to participate in virtual worlds, the building of social relationships and, at a short distance, innovation, creativity and imagination predominate;
achievement and status, self-confidence, prestige and influence follow; lastly there are manipulation and escapism. Cutting-edge learning environments - where connectivism is associated with socio-constructivism - ensure a better integration between real and virtual aspects and an easy and natural flow from one to the other and vice versa. It happens especially because of three-dimensionality of the virtual context, its precise reference to physical reality, and of sophisticated use of visual metaphors, all characteristics which significantly increase the realism of the simulation and the immersivity, and dramatically foster social presence and action, of avatars as well as of corresponding actors. Current avatars present features no more static and schematic, but dynamic, versatile, multifaceted and rich in shades, able on the one hand to maintain the most personal and subjective part - emotional, affective, imaginative, ludic - and on the other hand to greatly enhance the social and community dimension and collaborative work. In fact, each of them - at both individual and social level - is endowed with a blended identity, at the same time virtual, due to the image, and real, through the voice. In the virtual scenario, the voice - i.e. the real component - is now the favoured communication medium, the true protagonist of the interaction with the others and of the active participation in co-construction of learning (Capdet, 2011). Compared to classical collaboration technologies - instant messaging, e-mail, group decision support systems etc. - the strengths of the great success of virtual worlds for cooperative learning as well as, more generally, for virtual team collaboration are two (van der Land, Schouten, van den Hooff, Fledberg, 2011):

- the experience of “actually being there”, which markedly improves information processing;
- the awareness of “being with others” enabled by the avatars, critical for the achievement of communication.

**SL and learning: a first assessment**

SL has also a decisive importance in advanced corporate learning. In fact, SL offers a realistic experience - genuinely immersive - of learning and allows to learn from native colleagues, directly interacting with them, without the need for travelling; the outcomes
reached are even better than those achieved by people living in contact with different cultures (Siegel, 2010). Among the MUVEs, SL is now an essential means not only for scientific and experiential learning in a broader sense, founded on experiments and projects, but also for language education; and all the more it has spread for English language learning purposes worldwide through English-as-a-foreign-language (EFL) students (Samur, 2011).

In comparison with other Internet-based methods (blogs, text chat, podcasts), MUVEs such as SL present several advantages. From the students' point of view, the significant strengthening of oral and written interaction and of learning co-operative component as well as the development of communication and social skills specifically entail the possibilities for speaking, exchanging and sharing ideas and experiences with English-speaking foreign communities or with diverse civilisations; besides, for communicating with native speakers or other language learners.

From the teachers' point of view, thanks to avatars and spatial dimension, the teacher can appreciate and evaluate the voice and how it is used, its tone, the distance, the movement, and even the attitude of the avatar, especially when certain English expressions, idioms or very effective ways of sayings are utilised.

Moreover, the following weaknesses are noted:

- the absence of the teacher and of his/her direct supervision may give rise to misunderstandings and errors; because of insufficient body communication, mediated and distorted by the avatars, students cannot perceive the posture, the gestures and the body language of their interlocutors; the voice, though real in the most advanced virtual environments, in any case is at least slightly altered by technological mediation and may often be cut off for technical reasons;
- communication synchronicity may easily turn from an asset into a burden, since it can be difficult to plan synchronous virtual meetings with the agreement of all participants;
- likewise, the graphical wealth of the scenarios and their dynamicty, although generally appreciated, can distract;
- persisting technical and technological problems - for ex. an equipment outdated or anyway unsuitable, Internet connection not enough fast and stable - may compromise
the optimal exploitation of virtual learning environments;
• users’ low computer skills or their inadequate training on the use of virtual worlds can represent an insurmountable difficulty;
• financial resources required to participate in SL for some people can be a serious obstacle.

Among the suggestions for teachers and instructors, as well as for designers and developers, there is advice to pay special attention to the quality and reliability of the technological equipment; to enhance and update users’ ICT skills and to provide them - through all the available tools (special courses and tutorials, dedicated websites, blogs etc.) - with adequate training in order to optimise the use of virtual learning environments; to increase and improve, within virtual communities, asynchronous communication and information sharing, by skilfully exploiting all the tools offered by Web 2.0 and social networks.

The main strategies proposed to consolidate and expand the use of SL for teacher education and training are the following: firstly, to establish a consortium of the related institutions and to share experiences and best practices; secondly, to train teacher educators and trainers in the use of virtual worlds; finally, to compulsorily include the mastery of virtual worlds use for educational and didactic purposes into the curriculum of future teachers, all the more because they are expected to teach digital natives (Misra, 2011).

Concerning the students’ point of view, it is useful to consider the results of a survey recently carried out in a Turkish State university (Kobak, Ozarslan, 2011).

Students’ evaluation of SL has been predominantly positive for two sets of reasons.
First of all, its ludic and immediate gratification aspects stand out:

• the realism of the scenario and the opportunity to do and experience what is impossible in the real world (for ex. flying, being teleported);
• the rich sophistication of visual features;
• the entertainment and recreation.

In the second place, its benefits and concrete advantages on the educational side are pointed out:

• the audio-visual simultaneity allows to set up a SL campus,
where to interactively participate in seminars, conferences etc.;
• language skills are more easily developed through SL;
• SL, a pivotal instrument for distance learning, allows to create a truly open university;
• SL appears as an ideal environment for practical courses, but not so for theoretical ones.

However, some negative opinions and perceptions still persist among students.
Technical difficulties - integral to the technology requirements essential for SL access and use (high speed of Internet connection, hardware performance characteristics) - are stressed; furthermore, psychological problems emerge, among which the risk that the fun and escapist dimension may cause distraction or turn into a true addiction.
At last demands, limits and obstacles of a social nature are noted:
• the need for a preliminary training which ensures all SL users gain mastery of basic language skills and for guidance and help in using SL is deeply felt;
• it is demanded that the necessary financial support should be assured, whose lack could be an actual hindrance to some people;
• the explicit sexual content in SL sometimes hurts students’ feelings.

At the same time product and cause of the “major historical transition” which has radically changed research and education landscape (Brainbridge, 2007, p. 472), virtual worlds - and notably SL - seem bound to remain for a long time the predominant hallmark of virtual laboratories, which have already incorporated all the prerogatives of traditional e-learning, keeping them intact.
In the future virtual laboratories will certainly show, in much more advanced simulation contexts, a further refinement of realism, physicality and immersivity; nevertheless, within them, most of all relationships will deepen and improve, and will steadily benefit by the wealth of information and communication tools, simple and versatile, drawn from Web 2.0 and social networks.
Conversely, they will presumably receive from users a welcome
less spontaneous and enthusiastic, but rather mature, cautious and pragmatically constructive.

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