

Manifestations of hard and soft technologies in immersive spaces

Jon Dron
School of Computing and Information Systems
Athabasca University
Canada
jond@athabascau.ca

Torsten Reiners
School of Information Systems
Curtin University
Australia
treiners@curtin.edu.au

Sue Gregory
School of Education
University of New England
Australia
sue.gregory@une.edu.au

Abstract: Immersive spaces are innately flexible. However, for learners, some constraints and scaffolding may often be valuable. This paper looks at immersive spaces as soft and hard technologies. Soft technologies are technologies enabling creative and flexible use, while hard technologies embed processes that limit creativity but provide efficiency and freedom from error. Technologies may be softened or hardened by assembly. For instance, if your Learning Management System (LMS) has no wiki, then it may be softened by adding one from outside the system. If your wiki has no assessment management system, then it may be hardened by using a LMS. For learning, the intrinsically soft nature of immersive spaces sometimes requires scaffolded hardening. This paper provides an example of an ongoing project that realizes these soft and hard technologies in an immersive virtual space and discusses the rich potential of such spaces for technology assembly.

Introduction

Soft technologies exist mainly in people's heads. They are the processes that we use to operate knitting needles, use email as a scheduling system, use a wiki to manage a project, apply pedagogies; the way we orchestrate phenomena. Hard technologies take those processes and turn them into hardware and software, embedding that orchestration in a machine. Soft technologies enable creativity and flexibility; hard technologies provide freedom from error, speed and efficiency. Neither is better than the other, it is just important that you have the right balance at the right time. An effective way to soften or harden a technology (and, as Arthur (2009) observes, the way that technologies in general tend to evolve) is to combine, aggregate and assemble different technologies. This can soften a hard system by adding different paths or functions, or harden a soft one by replacing human-orchestrated processes with more formalized or automated equivalents. In a perfect world, such assembled technologies become a single integrated new technology, though such integration can itself be a soft technology. For example, a teacher in a classroom may simply tell students that a discussion forum will be used to engage in discussion and an automated test bank will be used to assess their learning without having to build software to integrate the two.

Soft vs Hard Technologies

We agree with Arthur that a technology is an “orchestration of phenomena to our use” (Arthur, 2009, p. 53). Phenomena are assembled to achieve individual, group or society-derived goals. Technologies may be used in ways that differ from the intentions of the inventors. Technologies are seldom, if ever, atomic but represent assemblies of, or rely on the existence of, other technologies (Arthur, 2009). While it is obvious that complex technologies such as computers, cars, production lines and corporations are composed of smaller pieces that may themselves be seen as technologies in their own right, common sense might suggest that, if we continue the process of decomposition, we will eventually reach something that might be identified as an atomic technology that involves no other. In fact, as Arthur suggests, there is no such animal. All technologies are systems that may be viewed as a single whole, and systems are constituted through the relationships between their parts. Thus, while there may be interesting things to be said of the parts, to think of a part of a technology without considering its relationship with the whole makes little sense. For example, a stick lying on the ground is not yet a technology. However, this changes if it is used to scratch your back, utilizing the physical phenomena of the effects of sharp things on itching skin, as well as a method of use that orchestrates those phenomena to relieve itching. None of the phenomena or object features that are orchestrated—length, sharpness, effects of sharp objects on skin and so on—are technologies in themselves but the entirety of the orchestration magically transforms it into a back scratcher. If we use the same tools and even some of the same phenomena for a different purpose (for instance, to use the stick to stir paint, point to an object, dislodge an apple from a high branch, rub with another stick to make fire), they are assembled into a different technology.

The literature on soft and hard technologies uses the terms inconsistently. One use of the term “hard” refers to physical devices such as in hardware and machinery, while “soft” is associated with immaterial artifacts, for example, describing (business) processes or production techniques (Burgess and Gules, 1998; Hlupic, Pouloudi, and Rzevski, 2002). For some, such as Zhouying (2004), hard technologies are about knowledge coming from natural science operating in the physical worlds, while soft technologies are associated with knowledge from non-natural science like human thinking, ideologies, emotions, or human and organizational behavior. Another perspective sees soft technologies as a compliant and yielding system while hard technologies inhibit and constrain. As Norman puts it, “hard technology makes us subservient, soft technology puts us in charge” (Norman, 1993, p. p232), a distinction that echoes Franklin’s (1999) division of technologies into those that are holistic (soft) and those that are prescriptive (hard). These different perspectives are largely reconcilable if we remember that technologies are assemblies. What makes technologies soft is that the orchestration of the phenomena they use is undertaken by humans whereas, in hard technologies, that orchestration has been built into the technology itself. This is not a question of automation. Some very hard technologies such as factory production lines or legal systems rely in whole or in part on humans engaging, often skillfully, in their operation. However, the role of humans is proscribed by such hard technologies: the operator of a machine that requires a certain pressure of steam to be maintained through the operation of valves and levers would be unwise to exercise too much creativity or to significantly adapt the process. Similarly, a judge who modified laws as he or she felt fit would not last long in most legal systems. Participants in soft technologies, on the other hand, may exercise great creativity: a knitter who changes the knitting process to produce a novel pattern, or a teacher who adapts a pedagogy to suit a class may change the technology at will. Our perspective recognizes both the fact that humans enact soft technologies and the restrictive nature of hard technologies that may have far-reaching and undesirable sociological effects (Ellul, 1970). In brief:

- *soft technologies* are filled with latent possibilities and potentials, enabling many creative and flexible uses, whether they are human processes or embodied in machines
- *hard technologies* are concerned with efficiency, replicability and the elimination of errors.

Both soft and hard technologies may be created and evolve through a process of assembly. The difference between them lies in the manner of assembly. Hard technology assemblies *replace* softer parts with harder ones: for instance, an automatic assignment submission system may replace a softer and more flexible manual submission

process. Soft technologies become softer through *augmentation and extension*: the hardest of technologies may be softened by adding it to another. For instance, to extend the previous example, were a teacher to allow students to submit via email in the event of the automated submission system failing (for instance, if it limited upload sizes or allowable dates for submission) then it would become softer, more malleable and forgiving.

We should emphasise that there is no right or wrong in selecting either soft or hard technologies and that few technologies are purely soft or purely hard. It is more about the right balance at the right time to implement systems according to the anticipated goals. It is generally advantageous to combine, aggregate, or assemble systems incorporating both soft and hard technologies. For example, wikis can be considered to be soft technologies allowing a high degree of freedom, while most LMS build strong structures to control the learning process including management mechanism for assessment. Combining both technologies would harden the wikis but soften the LMS, offering the benefits of both creative assembly and process control

Immersive Spaces

Immersion describes the state where the consciousness projects the physical awareness to a new, generally artificial, environment. That is, the sensory perception is (partly) overloaded by other means; for example by visual projections using glasses, sounds from a different surrounding, or haptic feedback from data gloves. The extreme is a total immersion where the virtual reality seemingly covers all channels and gives the user the impression of having left physical reality. The kinds of immersion are diverse. The most common are narrative immersion (becoming part of a book or movie), strategic immersion (during a chess game to find the best solution for the next move), or spatial immersion in flight simulations (for pilot training) or games (Adams, 2004).

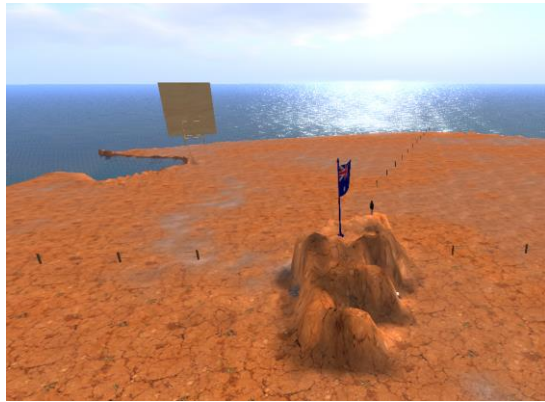
In this paper, we focus on a specific subtype of immersive spaces: virtual worlds. A virtual world is a 3D subset of immersive, interactive spaces. Immersive spaces are learning environments enabling interaction and immersion providing the user with a sense of being there, even if it is in a soft space such as a virtual world. In 3D virtual worlds, co-presence is more likely to exist (Dalgarno & Lee, 2010), that is, there would be more than one person there to get a sense of interaction and immersion. The following sections point out some examples for soft and hard technologies in immersive spaces, where we focus on social navigation and stigmergic effects.

Soft and hard technology in immersive spaces

Despite the hype surrounding virtual worlds such as Second Life, such technologies are unpopular when compared with web or mobile social networks like Facebook and Twitter. They mostly attract innovators and early adopters (Stamford, 2010). Such users' expectations in the technologies are high, especially with respect to exploration and taking advantage of the system by individual adaption and modifications. For such users, Second Life or Open Sim provide an compelling platform due to their unrestricted opportunities to build content from scratch and offer the highest degree of flexibility for such users to interact with objects (including avatars, personal presences in the virtual world) and influence their behavior. Achieving wider acceptance of the technologies by other groups (early majority, late majority and even laggards) with new expectations and different pre-knowledge is partially dependent on the level of experiences and how the user is introduced into the system, and what expectations they have of the system. A new user (or 'newbie') is a learner, and learners need scaffolding and help. A new user should not find an empty space as construction is generally beyond their knowledge thus would lead to frustration and rejection of the system.

Using Second Life as an illustration, we can depict this by observing the first appearance of an avatar that bought its own island (that is, space in a virtual world), and an avatar that enters the virtual world as a new user. For

the island owner there appears on an empty space that can be freely transformed and used to place any imaginable object. The immersive space has to be considered as a very soft technology with the widest possible range of flexibility to be a creative user (see Figure 1(a) demonstrating an avatar sitting on top of a mountain (Uluru in Australia) on their land where it has an open soft space to work with). New avatars without land ownership experience a harder space. They must begin on an introductory island where the basics of the system are explained (see Figure 1(b) where an avatar has just arrived at “Info Island” and is reading through instructions in order to start learning about the virtual space). Here, avatars can neither change the existing space nor create new objects. Furthermore, movements are guided, and freedom is restricted as teleports are limited (that is, movement between locations in the virtual world).



(a) A single avatar on a large empty space



(b) Information being provided to a Newbie

Figure 1: Demonstrating the soft and hard perspectives on immersive spaces

Virtual worlds are and can contain a huge spectrum of soft to hard technologies, not just because of their digital malleability but also because they are, by definition, assemblies of objects that have behaviours within the virtual space. Immersive spaces combine (machine) technology as well as human behaviors, processes, norms and rules. While the technology defines (and restricts) the functionality and establishes the platform for communication and collaboration of avatars (or in a broader sense software agents), virtual worlds have few predefined behaviors. Their form and behavior depends not only on individuals molding the space, but on their direct and indirect interaction. The avatars, and therefore the user controlling it, represent small adaptive/adaptable programs, which determine the characteristics of the whole system; cyborgs that are part human and part automata. Even for newbies, Immersive spaces are soft and unpredictable as multiple factors have to be accounted for such as the nature of each individual and how they affect each other by indirect or direct communication and observation. For example, if a person observes another avatar buying an object in a store, he or she is much more likely to buy the items as well. Note, that the *awareness of others* provides many advantages over other technologies like Web-based Social Networks as it allows for socializing and influences (mimicry) between co-present avatars. This *crowding* can, under the right circumstance, lead to a kind of intelligent group behavior that can help to create systems in some ways superior to those developed by individuals. With this in mind we turn to *Social Navigation* and *Stigmatic Communication*.

Social Navigation

Social navigation is the use of cues left intentionally or unintentionally by previous or current visitors (Forsberg, Höök, & Svensson, 1998; Kurhila, Miettinen, Nokelainen, & Tirri, 2002; Riedl & Amant, 2003). At its simplest, it involves leaving bookmarks or, in immersive spaces, visible/audible signposts such as graffiti or cairns

(objects to which new visitors intentionally add markers that thus grow over time) (Platt & Willard, 1998). These approaches lead to the equivalent of mediaeval glosses, the notes made by scholars in the margins of books that, over time, sometimes became more significant than the original texts (Norton, 1909). Other methods rely on implicit cues, such as leaving footprints or otherwise causing wear and tear to the virtual space that indicates the former presence of others. It is hard to replicate the richness and complexity of natural cues of this nature in virtual spaces. For example, Seely Brown & Duguid (2000) note the importance of odor in tracing the social history of letters.

On the whole, social navigation provides phenomena that may be orchestrated by others to achieve a purpose: to make it easier to find places or objects of interest. This allows most forms of social navigation to become components of soft technologies: they provide an effect caused by others that may be exploited by individuals to reach more interesting goals. In a learning context, implicit cues carry a strong risk of accentuating mob stupidity, as out-of-control positive feedback loops and preferential attachment can over-reward early navigators (Surowiecki, 2004) leading to mob stupidity rather than crowd wisdom (Dron, 2006).

Stigmergic Communication

Stigmergy is the indirect communication of agents through signs left in the environment (Grassé, 1959). Environmental changes stimulate reactions by other agents, who themselves modify with the environment and trigger the next step on the chain of actions. Using stigmergic communication, simple agents are able to multiply their capabilities and assemble complex systems without intelligent planning or centralized control. An often cited example is that of ant trails, where ants have to optimize their path from the nest to the food source (Bonabeau, Dorigo, & Theraulaz, 1999). Exploring ants leave a trace of pheromones (which also evaporates over time) being reused by other ants, which select the path according to the strength of the scent. Over the time, the most direct path (and therefore the fastest) get on average the most pheromones and, therefore, is selected by more of the following ants. This simple mechanism allows barely-intelligent and indirectly communicating agents (ants) to find the shortest path from the nest to the food. Wikipedia also harnesses stigmergy. Users leave traces (words in an article) that are later used by others to add even further material (Elliot, 2006; Heylighen, 2007; Yu, 2009; Wikipedia, 2011). Thus, agents cooperatively create a complete encyclopedia that combines their thoughts and knowledge without having to know each other, meet, or discuss how to proceed. The modifications alone trigger other agents to continue and lead to articles at least as rich as those developed using traditional collaborative methods. It is a large-scale extension of an old familiar process: this paper, for example, has evolved in a similar way.

Stigmergy is a natural hardener that embeds history through path-dependencies: it creates structure for free. The environment, in which the agents operate, is soft as each agent is unrestricted and flexible to proceed in any possible way. Over the time, the environment hardens as the agents' nature binds them to interact with traces. This proceeds until one path (ant trail) is defined and further changes to the environment depending on external influences. This concept depicts a mechanism for immersive spaces to create trails for visitors to follow, e.g. exhibits or learning content. First, the access is unrestricted, avatars can freely explore. Through external observation, the paths can be used to build guidance systems (pheromones), e.g. by putting up signs, build walkways on the ground or numbering exhibits with numbers to imply an order. The effect is strengthened by the social navigation as new avatars observe and mimic the behavior of others.

Hardening Immersive Spaces

The foregoing examples described how soft and hard technologies link to immersive spaces and that the concept requires broader as well as deeper consideration to enhance the overall experience for users in the future.

But virtual worlds are generally very soft. In this section, we present three examples how hardening soft technologies in immersive spaces can be used to a learner's advantage.

Modifications to Guide

Open space is valuable but can be overwhelming: for example, in the case of groups with specific learning purposes, but restricted expertise in immersive spaces or just limited resources to dive further into exploring the technology. For educational purposes, stakeholders, like educators or instructional designers, may simplify the process by re-shaping the environment to make it easier to use and/or by imposing guidelines and rules (which are themselves technologies). Familiar technological structures like classrooms can help learners to orient themselves and safely learn how to behave and interact with others as well as objects like blackboards, books or furniture. Besides behavioral parameters, users also derive functionality and association with roles from their surroundings. Being in a classroom will be associated with learning and teaching and can use known signposts and cues. For example, a standing avatar facing a group of sitting avatars within a classroom implies, in most cases, a teacher–learner situation. In Second Life, it is common to use holodecks; rooms that can change their look and functionality; e.g. from a classroom to a dance floor. In this case, the distribution of roles within the classroom might change, as the perception of dance floors seldom go along with learning (assuming the subject was mathematics rather than dance or music).

This small example demonstrates that the environment can support processes as it triggers the expectations of users and defines social behaviors without requiring additional instructions. The guidance through hardening the environment reduces need for verbal control, using pre-learned behavioral patterns from the users. Its great advantage over a real-world classroom is that the modification is not restricted to take place before the event but can be part of the intervention. The aforementioned dance floor can be used after the teacher (in a normal classroom setting) has explained the choreography to perform practical exercises. Afterwards, the room is changed back for discussing the feedback. Thus, the environment is able to change according to the required purpose. Note that, for the teacher, it is a very soft technology though, to the students, it is deliberately constraining. The technology assembly that also includes the processes and pedagogies of teaching is assembled to replace the default environment, and is designed to make it notably harder.

Building to Preserve

Immersive worlds are mainly characterized by the (social) interaction between multiple avatars. While the environment provides recognition of the purpose and guidance for avatars, communication and collaboration over time defines the identity and uniqueness of a location. Immersive worlds are persistent, synchronous, and reactive, but rarely able to preserve or replay previous states, apart from through recordings (Machinima – video recording of the lesson in the virtual world). Even when recorded, there is no option to undo errors or taking a different path. It is possible to review any moment or period in the past and to precisely replicate the environment, the objects in the immersive space and interactions originating from scripts. However, the ghost in the machine is irrevocably altered. The people behind the avatars have continued their existence since the time the reset was initiated. They already gained experience and gathered new knowledge via communication with other avatars or the space. Therefore, the soft processes and technologies will have changed. Their ongoing behavior will be different than had they not had the previous experience. It is possible to preserve the past by recording states of the immersive space (the hard technology) but the soft technology that drove them is lost.

Automate to Interact

Interaction, given via avatars (social interaction) and bots (automated robots), increases immersion as it engages the user in the immersive space and counteracts the feeling of being alone. Providing human interaction is difficult as it requires people to be online at the same time in the same space. Furthermore, social interaction depends on inter-personal characteristics and can cause positive as well as negative experiences. The interaction can also be influenced in individual emotions and feelings and changes over time and with the number of repetitions. Thus, adaptive bots can be used to emulate human-controlled avatars, whereas the behavior has to be programmed and related to aggregated data. In immersive spaces, the actions can be based on previous recordings, taking the aggregated information and extract a pattern; e.g. watch tour guides with respect to groups (parameters have to be included like interest and age) and extract behaviors for a scripted bot that dynamically adapts to a new group. Below, we describe a current project, where role-play for self-guided learning scenarios is supported by bots interacting with the environment and reacting to human-controlled avatars.

Learning Using Bots

The idea of soft and hard technologies, i.e. mapping social behavior from human controlled avatars to bots to *harden* the immersive space, is a key component in the project VirtualPREX (virtual+professional+experience) (See <http://www.virtualprex.com> for more information).. In this section, we provide a brief overview and discuss the importance of defining guidance for students in a self-guided course setting while keeping the flexibility of the system to react to behavior during the training session.

Self-Guided Learning Environment

In this section we report on the development of virtual-world-based professional experiences for pre-service teachers.. This emerged from a need to assist pre-service teacher's exposure to professional experience in an authentic learning environment without the need of real classrooms filled with students. The best and most authentic experiences for pre-service teachers is exposure to real classrooms but cost, timing and risk to learners of insufficiently learned teachers can make that impractical or inconvenient. A virtual world can partially replace this experience. Figure 2 shows such teachers taking classes in a virtual world. Pre-service teachers are able to practice their teaching cheaply and to any schedule without dire consequences or ramifications of "not getting it right" with real students. This self-guided learning environment is set in a 3D immersive virtual world where pre-service teachers can enter and interact with bots. The bots are programmed to react with the teachers and different triggers cause them to react in various ways. Bots that provide this self-guided learning assist the teachers in developing authentic teaching strategies that would work in a "live" classroom, to experiment in safety and to explore many 'what-if' scenarios without risk.

Self-guided learning can also be incorporated into a virtual world where a holodeck can, at the click of a button, change a room. A holodeck is a scene changer. It may simply change the background with images to provide a different spatial context or can use more complex objects to utterly alter the space, according to context. Incorporating holodecks and bots into the one environment can provide rich self-guided learning experiences that are partially shaped by the environment's designers. Such bots and holodecks instantiate a soft technology that is thereby hardened in an immersive space.



Teacher interacting with students in classrooms in VirtualPREX

Figure 2: Two teaching role-plays at VirtualPREX where the teacher is learning strategies to engage the students in their activities.

Recording Users to Create Behavior

VirtualPREX is an immersive space in a virtual world where pre-service teachers can undertake virtual professional experience with either peers or bots (Gregory, et. al., 2011).. VirtualPREX with peers involves an activity in which pre-service teachers practice their teaching skills with peers who play the roles of school students with either “good” or “naughty” characteristics. In a workshop, each pre-service teacher has the opportunity to teach a lesson to their students and to establish ways to immerse the whole class in the planned activity (lesson). Different strategies are trialed to engage the role-played students. In each workshop, approximately 10 students engage in a lesson, one playing a teacher, the others playing pupils. These lessons are recorded (via machinima) and the students can view these for reflection and as assessable tasks. Others can learn behaviors, or mimic behaviors, in the virtual world by viewing this machinima. The person viewing the machinima can repeat, replay and recreate the lesson. By viewing machinima to learn behaviors, the learner can roll back, or go back to a certain section to practice. Note, as observed earlier, that the machinima does not roll back the complete immersive space to a previous state but represents a series of snapshots – it does not and cannot replicate the precise complex of activities to a point that might allow different decisions to be made because part of the technological ecosystem is in the heads of the participants themselves. . Using bots provides pre-service teachers with increased opportunities to practice through interaction in and with a virtual environment to try out skills and apply concepts in authentic and immersive virtual world learning spaces (Antonacci & Modares, 2008).

Patterns that the pre-service teachers learn when interacting with bots and viewing machinima are the soft technologies that they are using in the immersive spaces. Pre-service teachers use the simulated classroom to practice such behaviors in immersive spaces.. They can interact with the environment synchronously with their peers or when they choose with the bots. The behaviors that the pre-service teachers learn with the bots could be as simple as when the teacher walks closer to a misbehaving ‘naughty’ bot, then it stops interrupting the class with irrelevant statements. Pre-service teachers receive high quality education where they are provided with opportunities to observe (machinima) and interact (bots and peers) in authentic learning environments, real or simulated, (Gregory & James, 2011). Authentic learning environments are used to preserve a link with reality. VirtualPREX also provides opportunities to translate what they have learned in the classroom (soft technologies) into practice through a virtual world (hardening the soft technologies in an immersive space). According to Dalgarno & Lee (2010), 3D virtual world environments and objects that are modeled on real places, such as VirtualPREX school classroom scenarios through both automated and role-plays can provide a greater sense of presence and realism than non 3-D spaces (soft technology).

Outlook and Conclusion

Immersive spaces that give their inhabitants the capability to change their surroundings and the objects with which they interact as well as to engage in social processes that may evolve in infinitely diverse ways are innately soft but may contain within them technologies that are as hard or soft as needed. This is achieved by a combination of natively easy assembly and tools that make it far simpler to manipulate the virtual space than it is to manipulate physical space. We have provided examples of how this might occur.

There are obstacles to the widespread adoption of such practices. We have noted that the current generation of immersive spaces is unpopular when compared with web-based social technologies. This is partly due to technical complexity and partly to the lack of standards for the creation of distributed virtual spaces. Softness and hardness are situated in context: for the creators of technologies, immersive spaces will usually be softer than for the end users of those technologies.. It does not have to be that way: a great deal of the promise of immersive spaces lies in their malleability through assembly by all their inhabitants. Immersive spaces are assembled out of pieces of technology that may be soft or hard, that may embody or enable processes as well as physical forms. To do this in physical space is difficult and costly. It is not much easier on the conventional Web. Many sites allow the use of RSS feeds, APIs or simple copy and paste to draw together content and some allow more complex technologies to be integrated – Facebook apps, Google Gadgets and W3C widgets, for example, can provide more interesting assemblies. However, programming skills are usually needed for more complex mashups and integration is seldom perfect – differences between components in reliability, speed, security, privacy and, often, even the interface make a perfect assembly a rare beast on the web. The very notion of a ‘site’ implies separation. Perhaps the most unsung but potentially powerful aspect of immersive spaces is that they give mashability for free. Objects cannot exist in immersive spaces unless they are integrated and aggregated into them so, to use or create an object in an immersive world implies a level of integration and aggregation that would be hard to achieve on the more open Web. An immersive space is an assembled space, with each part of the assembly playing a potential role in replacing others (giving hardness) or in adding to what is already there (giving softness). By providing an increasing number of pre-assembled components, objects and technologies that exist within a virtual space, learners may be empowered to soften or harden them on their own. For example, a student faced with a complex problem may add an automated agent to the space to assist with the task (Blair & Lin, 2011), thus hardening an otherwise over-flexible space.

Hard technologies reduce the need for creative thought and increase efficiency while reducing error, but they constrain and reduce the potential to adapt. Soft technologies provide capacity for creativity and invention, but tend to require more effort and more opportunities to make mistakes. Both soft and hard technologies have value for learners. Hard technologies can reduce complexity where complexity is not needed, allowing learners to concentrate on what is being learned rather than extrinsic aspects of the process. They can thus become technological manifestations of scaffolding. Conversely, soft technologies provide the means to construct, to concretize, to create, to explore a knowledge space as much as a virtual space, to invent, to adapt: the very stuff of learning. The power of immersive environments lies in many things but one that has till now been overlooked is their capacity to support an infinite range of assemblies without the complexities involved in creating such assemblies in hypertext or other programmed environments. In this paper we have shown some of the potential for this capability.

References

Adams, E. (2004). Postmodernism and the three types of immersion. http://designersnotebook.com/Columns/063_Postmodernism/063_postmodernism.htm

- Antonacci, D.M., & Modaress, N. (2005). Second Life: The educational possibilities of a massively multiplayer virtual world (MMVW). <http://www2.kumc.edu/tlt/SLEDUCAUSES2005/SLPresentationOutline.htm>
- Arthur, W. B. (2009). *The Nature of Technology: what it is and how it evolves*. New York, USA: Free Press.
- Blair, J., & Lin, F. (2011, 22-25 March 2011). *An Approach for Integrating 3D Virtual Worlds with Multiagent Systems*. Paper presented at the Advanced Information Networking and Applications (WAINA), 2011 IEEE Workshops of International Conference on.
- Bonabeau, E., Dorigo, M., & Theraulaz, G. (1999). *Swarm Intelligence: From Natural to Artificial Systems*. New York: Oxford University Press.
- Burgess, T. F., & Gules, H. K. (1998). Buyer–supplier relationships in firms adopting advanced manufacturing technology: an empirical analysis of the implementation of hard and soft technologies. *Journal of Engineering and Technology Management*, 15, 127-152.
- Dalgarno, B., & Lee, M. J. W. (2010). What are the learning affordances of 3-Dvirtual environments? *British Journal of Educational Technology*, 41(1), 10-32.
- Dron, J. (2006). *On the stupidity of mobs*. Paper presented at the WBC 2006, San Sebastian.
- Elliot, M. (2006). Stigmergic Collaboration: The Evolution of Group Work. *M/C Journal*, 9(2).
- Ellul, J. (1970). *The Technological Society* (J. Wilkinson, Trans.). New York: AA. Knopf.
- Forsberg, M., Höök, K., & Svensson, M. (1998). *Design principles for social navigation tools*. Paper presented at the 4th ERCIM workshop on "User interfaces for all", Stockholm, Sweden.
- Franklin, U. M. (1999). *The Real World of Technology*. Concord ON: House of Anansi Press.
- Grassé, P. P. (1959). La reconstruction du nid et les coordinations inter-individuelles chez *Bellicositermes natalensis* et *Cubitermes* sp. La theorie de la stigmergie: Essai d'interpretation des termites constructeurs. *Insect Societies*, 6, 41-83.
- Gregory, S., Dalgarno, B., Campbell, M., Reiners, T., Knox, V., & Masters, Y. (2011). Changing directions through VirtualPREX: engaging pre-service teachers in virtual professional experience. In G. Williams, N. Brown, B. Pittard, & B. Cleland (Eds.), *Changing Demands, Changing Directions. Proceedings ascilite Hobart 2011*. Presented at the ascilite2011, Hobart.
- Gregory, S., & James, R. (2011). VirtualPREX: Open and Distance Learning for pre-service teachers. Expanding Horizons - New Approaches to Open and Distance Learning. Presented at the 24th ICDE World Conference on Open & Distance Learning, Bali.
- Heylighen, F. (2007). Why is Open Access Development so Successful? Stigmergic organization and the economics of information. In B. Lutterbeck, M. Bärwolff & R. A. Gehring (Eds.), *Open Source Jahrbuch 2007*. Berlin: Lehmanns Media.
- Hlupic, V., Pouloudi, A., and Rzevski, G. (2002). Towards an Integrated Approach to Knowledge Management: 'Hard', 'Soft' and 'Abstract' Issues. *Knowledge and Process Management*, 9(2), 90-102.
- Kurhila, J., Miettinen, M., Nokelainen, P., & Tirri, H. (2002). *Use of Social Navigation Features in Collaborative E-Learning*. Paper presented at the E-Learn 2002, Montreal, Canada.
- Norman, D. A., & Dunaeff, T. (1993). *Things that make us smart: defending human attributes in the age of the machine*. Cambridge, MA: Perseus Publishing.
- Norton, A. (1909). *Readings in the History of Education Medieval Universities*. Cambridge: Harvard University.
- Platt, P., & Willard, A. (1998, 19 May 1998). *The ramblers guide to virtual environments*. Paper presented at the The 3D Interface for the Information Worker (Digest No. 1998/437), IEE Colloquium on.
- Riedl, M. O., & Amant, R. S. (2003). *Social navigation: Modeling, simulation, and experimentation*. Paper presented at the The 2nd International Joint Conference on Autonomous Agents and Multi Agent Systems, Melbourne, Australia.
- Seely Brown, J., & Duguid, P. (2000). *The Social Life of Information*. Boston, Massachusetts: Harvard Business School Press.
- Stamford, C. (2010, October 7). Gartner's 2010 Hype Cycle Special Report Evaluates Maturity of 1,800 Technologies. *Gartner Newsroom*. <http://www.gartner.com/it/page.jsp?id=1447613>
- Surowiecki, J. (2004). *The Wisdom of Crowds*. London: Little, Brown.
- Wikipedia. (2011). Stigmergy. <http://en.wikipedia.org/wiki/Stigmergy>
- Yu, Z. (2009). *Wiki-enabled emergent knowledge processes through acceleration of stigmergic collaboration*. Master of Philosophy, City University of Hong Kong, Hong Kong.
- Zhouying, J. (2004). Technological progress in history: a survey of evolution and shift of research emphasis from 'hard-tech' to 'soft-tech' development. [Article]. *International Journal of Technology Management & Sustainable Development*, 3(2), 133-148. doi: 10.1386/ijtm.3.2.133/0