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# Categorizing the Educational Affordances of 3-Dimensional Immersive Digital Environments

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## Abstract

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| Aim/Purpose | This paper provides a general-purpose categorization scheme for assessing the utility of new and emerging three-dimensional interactive digital environments (3D-IDEs), along with specific pedagogic approaches that are known to work. It argues for the use of 3D-IDEs on the basis of their ludic appeal and ability to provide intrinsic motivation to the learner, and their openness that allows the learner to gain a more holistic understanding of a topic. |
| Background | Researchers have investigated the affordances, benefits, and drawbacks of individual 3D-IDEs, such as virtual worlds, but teachers lack a general-purpose approach to assessing new 3D-IDEs as they appear and applying them to teaching practice. |
| Methodology | The categorization scheme is based on the analysis, reflection, and comprehension of the research on limitations, challenges, and opportunities for teaching in virtual environments by Angel Rueda, Valdes Godines and Guzmán Flores; the scheme is discussed in terms of an experiment to trial virtual genetics labs in Second Life. |
| Contribution | The paper describes a general-purpose approach to applying existing and new 3D virtual spaces to education, shows a worked example of the use of the categories, and describes six approaches to consider in applying these technologies. |
| Findings | 3D-IDEs are categorized in terms of the way in which they interface with the user's senses and their ability to provide 'immersion'; two forms of immersion are examined: digital perceptual immersion – the generated sense of reality – and ludic narrative immersion – a less cognitive and more emotional engagement with the learning environment. |

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Recommendations for Practitioners
Six specific forms of pedagogy appropriate for 3D-IDEs are examined and discussed, in terms of the affordances and technology required, as assessed by the categorization scheme. More broadly, the paper argues for a change in the assessment of new digital technologies from the technology's features to its affordances and the pedagogies it can support.

Recommendation for Researchers
The paper offers a practical approach to choosing and using 3D-IDEs for education, based upon previous work. The next step is to trial the scheme with teachers to ascertain its ease of use and effectiveness.

Impact on Society
The paper argues strongly for a new approach to teaching, where the learner is encouraged to use 3D-IDEs in a ludic manner in order to generate internal motivation to learn, and to explore the topic according to their individual learning needs in addition to the teacher's planned route through the learning material.

Future Research
The categorization scheme is intended to be applied to new technologies as they are introduced. Future research is needed to assess its effectiveness and if necessary update the scheme.

Keywords
3D-IDE, virtual environment, immersion, ludic, intrinsic motivation

## INTRODUCTION

Society is in a time of technological change. The last decade has seen the rise of powerful, pocket-sized computing devices, beginning with the launch of Apple's iPhone. In many countries these devices have become a ubiquitous part of everyday life. The always-connected nature of these devices has allowed new uses to develop, and in particular has seen a rapid expansion of social networks. Facebook, for example, has over two billion active users (Statista, 2017). As a result, social interactions now take place both in the physical world and online. As computer technologies become ubiquitous and interconnected, the dividing line between the real and the virtual is becoming blurred. On the near horizon is Virtual Reality, with several headsets now available, such as from Sony, and the Facebook-owned Oculus.

Meanwhile, educational institutions have sought to incorporate these technologies into their pedagogy, with varying degrees of success. The technology industry is continually presenting educators with new technologies that claim to improve the learning processes – from CD-ROMs to Virtual Learning Environments to Virtual Reality. It is becoming clear, however, that these innovations do not easily fit into existing pedagogies, creating the need for radical changes in teaching style for the teachers who will use them.

Another challenge is the speed of change in contemporary society. Bauman (2007) views society as having moved from a stable, definable entity, to what he calls "liquid modernity", where the only constant is change, and knowledge is merely a staging post from one form to another. Thus, knowledge today is something to find, use, and forget, since anything learned will become outdated. Necuzzi (2013) continues the analogy of society as liquid, describing how information is omnipresent, spread across multiple places and technologies.

Thus, it is increasingly important for students to understand a topic in a way that allows for future changes to knowledge of that topic – a holistic understanding of the concepts becomes more important than a memorized list of details. For educators, pedagogies that involve discussing and working with a topic are more effective at instilling a holistic understanding than rote learning and memorization.

Valdés Godines (2016) discusses the concepts of Three-Dimensional Immersive Digital Environments (3D-IDEs) – technologies that provide virtual physical experiences – and immersion – the sense of being in a real space – in relation to teaching. He describes how cognitive development can be facilitated by immersion in sensory spaces. The student becomes the builder of skills and innovative ways of learning. 3D-IDEs are able to provide these experiences. Maldonado (1994) provides evidence for the impact that virtual models can have on the teaching of both technical or scientific, and humanistic disciplines. He describes how the virtual can help facilitate the transmission, reception, and production of knowledge, and can support students with the process of collaboration.

Utilizing these digital environments requires the use of educational scenarios outside of traditional pedagogy – in particular a more playful, or ludic, environment in which the learner has greater control over how they learn. In turn, this requires better communication between the designers of technology and the teachers who will utilize the technology in their classrooms.

This paper begins by describing the different levels of digital experience and their ability to create a perception of reality. Our categorization scheme for 3D-IDEs comprises two top-level categories: the format in which the 3D-IDE connects with the user, and the user experience – in terms of Space, Time, Body, and Identity. Within the latter we identify two forms of immersion, based on 1) perception (third-person, conscious, total or full-deep) and 2) ludic narrative (space, time, body, identity and emotional). Finally, we offer teachers a conceptual foundation that will allow them to generate an effective didactic strategy for their students, and give an example of this strategy in use.

## *MULTIPLE REALITIES*

This paper uses the term 3D-IDE to describe the overall space of perception between the real and the virtual. The term came from an analysis of the phenomena found in investigations by Angel Rueda, Valdes Godines and Guzmán Flores (2017), where they raise and describe the limits, challenges, strengths and opportunities of teaching with virtual worlds, and in Angel Rueda and Valdés Godínes (2016), where they propose a teacher training course in virtual worlds for educational purposes. The term 3D-IDE encompasses all forms of virtual, or partially-virtual, experience; we begin by defining the main terms involved.

The starting point is "Good Old-Fashioned Reality" (GOFR), from the term "Good Old-Fashioned Artificial Intelligence", coined by John Haugeland (1985) – the physical, analogue reality we experienced before the advent of digital technology, since the era of the 'cave man'; we see this term as more explanatory than those such as "Consensus Reality". Figure 1 shows how digital technologies can expand a person's perception beyond GOFR. Collectively, we refer to these technologies as 3D-IDEs. The term is used to describe all potential artificially-induced perceptions of reality, up to and including an artificial environment indistinguishable from GOFR – something not currently possible. Regarding types of virtual experience, we refer to the following three terms in common use.

Virtual Reality (VR) attempts to create a complete reality, to the exclusion of whatever physical world the person may be located in, the intention being that the person experiences only images, sound, and other sensations, created by the technology. Rubio Tamayo and Gértrudix Barrio, (2016) attribute the first description of VR to the publication in 1935 of the science fiction novel Pygmalion's Spectacles by Stanley Weinbaum. This work describes an immersive system for viewing films and simulations. He describes not just virtual sound and vision, also touch and smell. The CAVE (cave automatic virtual environment) has been a significant technology for delivering VR – typically, a six-sided 'room' with back-projected images on each of the six sides, giving the user the impression of being in a virtual space – see Muhanna. (2015) for a description. More recently, researchers have turned their attention to the current (as at 2018) crop of head-mounted display (HMD) technologies, such as the Oculus Rift. Worn like a visor, these block out all light, but create a visual and audio image as though the person were in a physical space, such as another room or the bottom of the ocean.

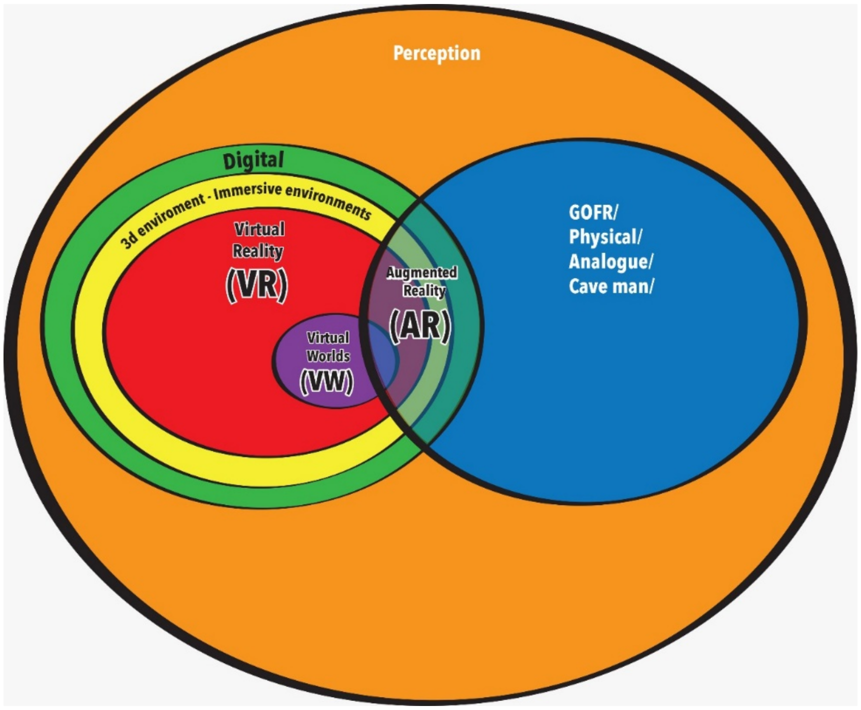


**Figure 1. Overlap between "Good Old-Fashioned Reality" and Virtual Reality (VR), Augmented Reality (AR) and Virtual Worlds (VW)**

Augmented Reality (AR) integrates virtual reality and GOFR, mixing artificially generated images and sound with those of the physical world in which the person is situated, or changing the appearance of the physical world. The virtual objects appear real and a part of the physical world – for example, virtual chess pieces on a physical table, changed to look like a chess board. The term Augmented Reality was coined in 1992 by Tom Caudell and David Mizell, researchers from Boeing, at the International Conference of the IEEE in Hawaii. van Krevelen and Poelman (2010) describe the three main forms of AR technology: projection systems that add images to the physical world, HMDs as used in VR that use cameras to sample the physical world and display a mix of the live feed and virtual images, and HMDs that are transparent, whereby the user sees the physical world unaltered but also the virtual overlaid. This latter is currently the leading method, of which the Microsoft's HoloLens is most visible example.

Virtual worlds (VW) can be seen as a subset of virtual reality. The term refers more to the virtual experience than the process of experiencing. VWs offer the experience of being able to roam around a large virtual space (not just a single room or building) and meet people (represented by avatars – a graphical image that represents a person) all of whom also experience the same place, but from their own perspective). VWs can be experienced using virtual reality. However, at present it is often experienced using a computer monitor and controls, such as a mouse or gamepad, to move around the world and to change the viewpoint. VWs can be built for the purpose of playing a specific game (such as World of Warcraft), or may support the person to conduct any activity they choose and create any object, building, landscape etc. that they wish (such as Second Life (Linden Lab, 2017)). VWs came to public attention with the publication of Neal Stephenson's (1992) science fiction novel "Snow Crash".

In the term 3D-IDE, "environments" refers to extrinsic, organized artificial spaces in which a user can act as though they are in a physical world. "Three-dimensional" describes the type of representation this space contains, in that the user can move their viewpoint around three axes (although two-dimensional images exist within the 3D space). This ability to move around the space in three dimensions is critical to the environment's ability to create immersion – a sense of 'being there'. "Immersive" refers to the ability of the user to believe in the experience and act within the environment as though it were real, rather than having to consciously interpret the environment as one would, for example, a text-based environment. Finally, "digital" describes the technology used to create the environment: contemporary computer-based technology. Note that the term "virtual" is not included in our description. This is considered superfluous, as anything beyond the regular GOFR is, by definition, virtual. These environments can be implemented in different forms, such as virtual worlds, virtual reality and augmented reality. Each form has its own unique properties.

In Figure 1, 3D-IDE sits inside "digital" as the technology and the ethos that supports it. On its own, a 3D-IDE would be described as Virtual Reality, in that the physical world is excluded as far as the technology allows. The alternative is to use technology that deliberately allows both the physical and digital worlds to be experienced together. We follow Milgram and Kishino (1994) in describing this as Mixed Reality. However, most forms of mixed reality add a relatively small amount of digital information to the physical world (systems like Microsoft's HoloLens, for example) and are best described by the term Augmented Reality. At the other extreme, a system that is primarily a digital experience, but with some aspects of the physical world mixed in, could be described as Augmented Virtuality (e.g. as described in Milgram and Colquhoun, 1999, pp. 5-30). However, at the time of writing such systems are, at best, experimental. Therefore, we concentrate here on discussing Virtual Reality and Augmented Reality as forms of 3D-IDE.

## *Previous Categorizations*

We believe this to be the first attempt to categorize the educational affordances of 3D-IDEs in general, to give teachers a general-purpose approach to assessing current and future 3D-IDEs in order to apply them in their teaching practice. Existing categorization schemes focus more on the technology or user interface without directly extrapolating to the educational benefits.

Looking at previous categorizations for 3D-IDEs, papers from the 1990s concentrate on virtual reality as an alternative user interface (UI) to the computer, rather than as an experience. For example, Coomans and Timmermans (1997) describe six attributes for a VR UI. "Visualization" and "Interaction" can be seen as referring to the computer's output and input, "Real space" to the internet (we can say with hindsight); "Immersion" is described as an inevitable outcome of VR, "Simulation" is implied as being the point of VR, and "Autonomous agent" (which could lead to our concept of "Personal tutor") is mentioned in passing.

A simpler taxonomy was proposed by Milgram and Colquhoun (1999), comprising three orthogonal axes: real-virtual, egocentric-exocentric (1st-3rd person viewpoint) and congruent-incongruent (match between controls and effects). This taxonomy also describes the interface.

More recently, Weidig, Mestre, Israel, Noël, and Perrot (2014, p. 53) observe that "a purely technical oriented approach can be too restrictive for the definition of new services and interaction techniques in VR applications", and instead classify VR interaction from the user's perspective. They (Weidig et al., 2014) categorize user interaction with VR systems with three pairs of categories: User / Interoperability, Object Medium / Device Type and Purpose / Feedback. Each of these six is subdivided. For example, "Purpose" is divided into "Manage", "Observe", "Creative Design" and "Assemble". These are further sub-divided into multiple attributes (e.g. "Recognize", "Interpret"). The classification system is made available as an Excel spreadsheet. Thus, Weidig et al. (2014) are categorizing VR systems by detailed elements of the user's interaction with the system, rather than the technology or the user's experience.

A much simpler recent classification scheme for VR systems is offered by Muhanna (2015). While more practical to apply (because of its simplicity) it again focusses on the technology, with a top-level split between "basic" (screen-based) and "advanced" (true VR). Within advanced there is a split between partial and full immersion, with the lowest level being the type of technology (e.g., CAVE or "wall projector").

While many previous categorizations were created from the technology or interface point of view, our categorization scheme references the user's experience of engaging with the virtual technology. Our categories relate to the way in which 3D-IDEs interface with the user's senses and their ability to provide 'immersion'; two forms of immersion are examined: digital perceptual immersion – the generated sense of reality – and ludic narrative immersion – a less cognitive and more emotional engagement with the learning environment. The significance of these categories is that they may be applied to any technology, current or future, since the relevant categories are found by studying the user's response, not the technology itself.

### *METHODOLOGY*

The development of the categorization scheme described in this paper began with a study described in Angel Rueda et al. (2017), which begins with a literature survey to identify, classify, and reference scientific and academic articles related to educational activities carried out in VWs. It then describes an iterative process of giving lessons in several VWs, an analysis of each being used to improve the teaching methods for the next iteration. An adapted SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) was used to identify themes and classify the teacher's opportunities and challenges, and the technology's limitations and strengths. This generated knowledge and experience of educational activities carried out in VWs.

For the present paper, the bibliographic information and data analysis from Angel Ruedaet al. (2017) were analyzed to identify concepts related to teaching in 3D-IDEs. The analysis, and further reflection, led to a process that would create the structure of a categorization scheme.

For this purpose, we used the idea of "macro concepts" proposed by Morin (2001), which describes how macro concepts develop when associating complementary / concurrent / antagonistic concepts in a combining / supplementary way to form a complex unit. The macro concept – in this case, the 3D-IDE – then describes its functioning.

In this process of constructing a macro concept, we grouped the identified concepts, such as "Third person immersion", together to generate hierarchical categories, such as "immersion" within "experience". This generated the final categorization scheme.

## CATEGORIZING THE EDUCATIONAL AFFORDANCES OF 3D-IDES

The essential and outstanding characteristic of 3D-IDEs is the user's connection to, experience of and interaction with, the artificial environment – VR, AR, VW, or other system, present or future. Figure 2 shows our analysis. Firstly, Connect (System) describes the format of the environment, provided by the technological platform, with which the user can connect. We then analyze 3D-IDEs using two global concepts to describe the user experience. One is how the user perceives immersion in the 3D-IDE (Digital Perceptive Immersion). The other is the type of immersive interaction that can generate pleasure for the user when in the 3D-IDE (Ludic Narrative Immersion). We follow Ryan (2001) in describing narrative elements of immersion as the spatial, temporal, and emotional, but we add body and identity to account for the effects of the user's representation in the virtual.

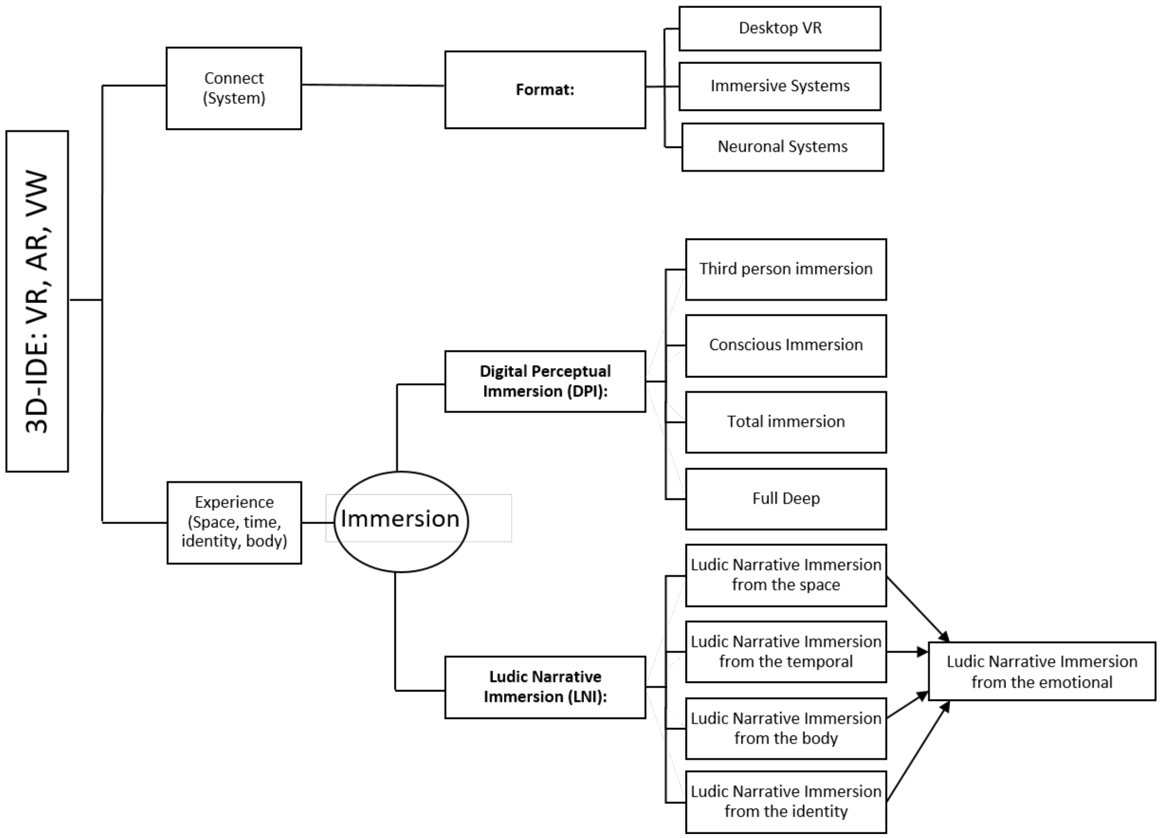


**Figure 2. Analyzing the 3D-IDE**

## *Connect (System)*

First, we consider the way in which the digital space is presented to the user, which affects how they perceive and interact with the environment. Mazuryk and Gervautz (1996) look at these elements from the perspective of technological usability, describing different levels of immersion according to the technology involved – more specifically the nature of the interface.

We follow the view of Mazuryk and Gervautz (1996) in identifying two contemporary forms of connection, Desktop VR and Immersive Systems. With Desktop VR (often a VW), the environment is accessed through a computer monitor, keyboard and mouse, whereas Immersive Systems employ some form of head mounted display, or 360 degree projection system, and hand control interfaces. Both technologies generate a sense of presence in a digital space – a body (which may or may not be visible) with its own identity that can generate emotions in the user with physical signs in a timeless and a-historical space, but in real time.

In addition, we introduce the concept of Neurological Systems to refer to future systems where the user connection will be at a more intrinsic level. This is described later, along with our vision of technological developments that may come in the long term.

### Desktop systems

Systems of this nature are shown through a window presented on a computer monitor or mobile device, such as smartphone, tablet, or similar. This form of VR may employ third person immersion in order to ameliorate the distancing effects of these technologies – users are represented to themselves and others as avatars. Desktop systems are the easiest way to implement VR (see, for example

Second Life). Simple AR applications have been developed for use with desktop systems, using a camera to sample the physical world and providing a "viewfinder"-style image with virtual objects added (see, for example, Pokémon Go (Niantic 2017)).

### Immersive systems

These are systems that provide an all-round view of the virtual space. At present, this means the use of a head mounted display, such as the Oculus Rift, or 360 degree projection system, such as the CAVE, and hand control interfaces. They seek to give realism to interaction with the digital (VR) or (using an HMD) between the real and the digital (AR). They are more suitable than Desktop systems for achieving total immersion.

Where the body and or identity is an important aspect of the experience, some immersive systems utilize third person immersion, as this allows a constant reminder of the user's form in the virtual space. Even where a first-person view is used, some aspects of the user's body may be represented, such as the hands and lower arms. While this may be for practical purposes (pressing virtual buttons, for example), the form of the body that is visible acts as a reminder to the user's alternate identity. In addition, the user may appear as an avatar (with its body and identity) to other users in the environment, and they may see other users as avatars.

### Neurological systems

Neurological systems are theoretical future user interfaces, where a virtual experience is created through a direct connection to a person's nervous system and or their brain. It could be said that this type of system would be the only one that could achieve an experience indistinguishable from GOFR, an experience we describe later as "Full Deep". At present this type of system only exists in the imagination and in science fiction. However, it is important to take it into account because it is the ideal to strive towards with 3D-IDE technology.

A Neurological system for AR is depicted in the anime movie Sword Art Online: Ordinal Scale (Kadokawa Corporation Ascii Media Works, 2017), where a wearable device interfaces with the user's brain and thus has control over their five senses. They move physically within the world, but the experience is mediated – and changed – by the technology. A neurological system for VR is depicted in the movie The Matrix; in this case, the physical world becomes irrelevant to the experience.

Early work has proposed potential mechanisms for this type of interface; for example, the inventor Raymond Kurzweil (Fernández, 2016) discusses the use of nanotechnology as a means of direct connection to the brain.

In such a system, true first-person depiction would be possible, where the user sees their own body from a natural perspective. The ultimate goal of a Neurological system would be to create an experience that was indistinguishable from GOFR.

## *Experience (Space, Time, Body, and Identity)*

We describe a person's perception, and thus experience, of a 3D-IDE using four categories: space, time, body, and identity, and the interaction between them. These categories are descriptive, not hierarchical. The categories will later be applied to the use of 3D-IDEs for educational purposes.

### Space and time

Martínez Ojeda (2006) describes the traditional vision of space-time, in which the fundamental parameters are the location of human beings and the distribution of natural phenomena that affect them. With respect to virtual spaces, there are two potential representations. The first is explained by Martínez Ojeda (2006) as cyberspace – a space removed from the emotionality characteristics of traditional societies and the distinctions of "sacred place" yet incorporated into the geographical landscape and territory. A tangible example of cyberspace is "Web 2.0", where space is something imaginary.

The second representation is the space, still imaginary, found in three-dimensional immersive digital environments. Sánchez Martínez (2013) defines this type of space as the "world copy" – it has the characteristic of being an imperfect copy of a perfect original. However, the intentional suggestion of its existence seems to be subject to an inverse of intention: that the virtual space be perfect, to remove the imperfections of the physical world. Another particularity of these copy spaces is that basic bodily functions are no longer imperatives: eating, being born, dying, and so forth. In addition, they are a-historical – they are timeless yet happening in the present, and may have personifications of the past and future. This has led to studies of the anthropology of virtual spaces, such as virtual fashion, virtual architecture or virtual history.

As regards the category of time, Martínez Ojeda (2006) mentions that in traditional thinking time is chronological, with events happening at specific times, whereas in virtual spaces time is merely sequential. As described in the space category, we can perceive the a-historical and timeless features of virtual spaces as characteristics, while being very clear that they may have representations of the past and future. Thus, virtual spaces warrant deeper study into their representation of, and experience of, time.

### Body and identity

Lévy (1999) describes how the word virtual comes from Medieval Latin "virtualis", which in turn derives from "virtus": strength, potency. In its current use, the term virtual is often used to express a pure absence of physicality. For this reason, and reflecting the non-space places in cyberspace, we can conclude that in modern computing the material (the computer) becomes transparent within a navigable communication space, focused on information flows. That is why today the computer (i.e., the physical material) is everywhere and nowhere – the physicality of computers is in hypertext – in cyberspace, in the virtual.

Thus, in the virtual, body is no longer the primary representation of physical presence; virtuality allows an almost unlimited visualization of the body, while the non-materiality allows these visualizations to be explored, for example to change shape, gender, race, and physical ability, to appear as an animal, in fact, to transform the corporeal into whatever the imagination wishes. These modifications of body in the virtual do not mean that the physical body ceases to exist; it is, rather, a case of multiple presences.

Our definition of ourselves as a whole – Identity – includes the body, but is much broader and emerges from the way we interact in space-time with our surroundings, including our social interactions. In the digital world, it is possible to play with identity in ways not practical – or not possible – in the physical world. A virtual identity may be similar to a physical identity, or it may be markedly different. In the virtual, one may have special abilities – to fly, to use magic, to have a social position such as leader, magic user, or business owner. This definition, as described by Sánchez Martínez (2010b), is not fixed, since it is defined by circumstance. Here, the category of space may resolve the question of body and identity.

## *Digital Perceptual Immersion (DPI)*

Immersion, as a general concept, describes the extent to which a user has transferred aspects of their perception from the physical to the virtual. DPI relates to the user's perception of the digital environment. Different levels of immersion can be achieved, in relation to space, time, body and identity. We examine two aspects of immersion (see Figure 2): Digital Perceptual Immersion (DPI) – the user experience – and Ludic Narrative Immersion (LNI) – the educational potential.

### Third person immersion

The lowest (least immersed) level of DPI consists of interaction in the virtual environment from a third-person perspective. The user observes a representation of themselves – a digital body, or avatar – and controls the representation to interact with the digital environment on their behalf. They interact with the environment at a distance (both physically and psychologically), observing their represented-self take action in the digital world. At this level there is a duality of space, time, identity, and body. The user remains aware of themselves being in two places and times – their physical existence and the digital environment. They have two bodies, the physical and the avatar, with a sense of comparison between the two, as described by Sánchez Martínez J. (2013). In terms of identity, this level of immersion creates a duality of perception, at once the physical and the digital.

Note that third person immersion can take place without an avatar actually being visible. While, strictly speaking, the user may have a first-person view, the technology can provide other third person cues, such as a single viewpoint (e.g., no change as the user turns their head) or actions emanating from a location in the digital space where an avatar would be. It is, then, the user's perception that determines third person immersion, their having in mind that the experience is happening to a separate version of themselves, rather than directly to them.

There can be advantages in having a separation between physical and digital identities. For example, during early experiments with teaching in virtual worlds, Rudman, Lavelle, Salmon, and Cashmore (2010) observed one participant, who identified as male in the physical world, but choose a female avatar. They treated this as their identity throughout the study, for example, by selecting appropriate virtual clothing and using the female (avatar) changing area. Other study participants were willing and able to treat them as female in the digital space while simultaneously treating them as male in the physical world. Having a clear distinction between the physical and virtual allowed the participant to differentiate clearly between the two identities.

### Conscious immersion

With third person immersion, the interaction occurs in real time. However, it is possible for the user's attention to become sufficiently captivated that the distinction between actual and apparent time becomes blurred. This creates a deeper level of immersion – conscious immersion. Similarly, the user may attain a complete spatial awareness, acting as though they are located within the virtual space. One may compare this to watching an engaging film: one may be "transported" to an alternative location, but one never fully loses the experience of being in a cinema. (For example, there is no sense of wanting to reach out and touch objects in the film.) This second level of immersion can be seen as a transition between a third person experience and total immersion in the first person, with its own characteristics that make it a separate level.

To attain conscious immersion within a third person setting requires the digital environment and the activity to become sufficiently engaging that the user's attention becomes entirely focused on interaction with the digital environment; conscious immersion does not happen automatically as an effect of using the technology. As with time and space, a sufficiently engaging experience may cause the two identities to become blurred, with the user acting intuitively as their digital identity and feeling as though the digital body is their own. Again, though, there remains a distance, with the user never truly losing their physical identity.

Conscious immersion does not necessarily have a long duration, unlike other levels of immersion. The user may become aware of the external environment and be distracted from their mentally-created world, essentially "breaking the spell".

### Total immersion

The third level of DPI arises from true first-person interaction. This is where the experience is sufficiently engaging, and technology is able to provide a visual and audio experience of being present in the digital environment, without any obvious distractions of the physical world. There is no sense of an avatar intermediary. Typically, this requires seeing and hearing the digital environment as though one were present, with a 3D view giving nearby objects depth and the view and sounds changing appropriately as one turns one's head.

At this level of immersion, the user loses spatial awareness of the physical and concentrates completely on their interaction with the virtual environment. It is as though the body has been transported to the digital space. However, there remains the knowledge that one is not in a "real" environment. For example, while there may appear to be a glass of water on the table in front of the user, they may intuitively know not to try and drink from it. Thus, only the space occupied by one's body is fully transferred to the digital environment. Beyond one's personal boundary the space becomes less immersive.

Identity is both easier and more difficult to construct with full immersion. It is easier in the sense that one feels very much present in the artificial situation, making it easier to act as one's chosen identity, especially if the environment supports the identity (for example, being a train driver in a railway engine). However, without an avatar to represent the body, identity is not reinforced visually, requiring of the user more cognitive effort to "become" and retain their alternative identity.

At this level of immersion, it is easy for the perception of time to be different from actual time. This is in part due to the increased sense of reality provided by the immersive environment, and in part by the reduction in external cues from the physical world.

The emotional effects of the digital environment are magnified by the increased immersion. It is very difficult not to react to situations experienced in the digital environment. For example, even though one may not think of drinking from a virtual glass of water, one could experience a deep sense of empathy for a thirsty man (even if they are represented by an avatar), or sorrow for spilling the water over some papers, despite no physical paper being damaged.

### Full deep

It is a distinctiveness of being human that we try to change our environment to suit our needs and desires. Even without technology, storytelling is a powerful way of experiencing a different situation to the physical life in which we find ourselves. From the horse simulator of the First World War, through simple video games, movies, virtual worlds like Second Life and globally-connected games such as World of Warcraft, to head-mounted displays and Microsoft's HoloLens, technology has added realism to experiences that are not as they appear. Thus, advances in technology have made the digital environment increasingly immersive – increasingly believable – with many technologies that seemed impossible a few decades ago now being commonplace. It is logical to assume that this progression will continue until there is no apparent difference in experience between a digital environment and the regular GOFR physical environment.

At the time of writing, the necessary technology is not available to create the highest level of immersion. However, one can obtain a clear picture of how this immersion would look from a combination of three sources: extrapolation from the history of digital environments, comparison with physical environments and depictions of virtual environments in science fiction.

Starting with body, current technology is only able to simulate two senses well – sight and hearing. Experiencing the body involves other senses, and the lack of simulation of these senses reduces the immersion. Therefore, an advanced digital environment would include being able to touch and interact with digital objects – for example picking up a glass of water. Ideally, in a fully immersive, or "Full Deep", environment one would be able to drink from the glass. One would feel hot or cold according to the environment, smell appropriate scents and feel textures, such as when standing bare-foot on a beach.

Current technology does not work well with movement. One is often tethered to a computer by wires, or one "moves" around the digital environment using a hand-held device to change the scene. With Full Deep immersion one would simply walk, run, etc. with no apparent limitations. This would provide a true sense of space. With complete immersion in this manner, time would be defined by the environment in the same way as one adjusts to a new time zone when travelling.

Augmented Reality is able to partially circumvent these limitations by careful mixing of physical and digital objects and experiences. For example, one may see a "bubbling magic potion" on the table and have the full experience of drinking it, whereas what was actually happening was there was a physical glass of water on a physical table, but the digital augmentation made the glass of water look like a bubbling, sparkling magic potion.

At present, Full Deep immersion is seen only in science fiction, such as the Holodeck of the Star Trek franchise, or movies like Sword Art Online: Ordinal Scale. With Full Deep, there is no perceptible difference between the virtual environment and GOFR. Thus, the ultimate goal of a Full Deep experience is to be indistinguishable from GOFR.

## *Ludic Narrative Immersion (LNI)*

The concept of Ludic Narrative Immersion comes from Ryan (2015), where she proposes a compatibility between ludic immersion and narrative immersion, along with the idea of the actor who builds their own narrative, as described by Janet Murray (1998, 2017). In terms of a 3D-IDE, we find a mutual coexistence between four types of ludic narrative immersion: space, time, body and identity. The fusion of these four appears as a fifth element: emotion.

Ryan (2001) conceived the digital revolution around hypertext theory, an approach that dominated digital literature and its narrative for over a decade. Fifteen years later, Ryan (2015) concluded that hypertext was no longer the only narrative for describing digital technology, but rather one of many approaches. She builds her new vision through what she calls textual theories of literature, which conceives text as a game of signifiers and considers language as essentially referential. In this vision, the bond between the original text and textualism ends, allowing representations of content, emotional involvement with characters, and immersion in fictitious worlds.

Janet Murray (1998, 2017), in her book "Hamlet on the Holodeck: the future of Narrative in Cyberspace", describes narrative and play in the new digital media as overlapping but distant pleasures; the narrative arises from our need to interpret the causes and effects that involve us emotionally and morally, while play arises from the delight in shared care with other human beings. This means that new technological tools, such as VR, expand the possibilities of narrative expression; unlike with traditional media, the user is supported in building their own narrative thanks to the interactivity inherent in these media.

Thus, narrative immersion is a commitment of imagination in the construction and contemplation of a world of stories that depends on purely mental activity, while ludic immersion is a deep absorption in the performance of a task thanks to the intensity of the enjoyment provided by it. These cognitive processes come together when the individual interacts in a 3D-IDE; enjoyment of the activity can engender a deep level of concentration, which in turn can facilitate the construction of narrative, while external narrative can engage the imagination, leading to enjoyment of the activity.

### Ludic narrative immersion: Space

Hall, in his book The Hidden Dimension (1966), describes how everything that humans do is related to the experience of space, within which sensory data is understood. In his later work, Hall (1990) describes how spatial changes nuance communication, and sometimes even exceed the spoken word. Movement and the modification of the distance between people when they interact is an integral part of the communication process.

Ryan (2015) describes two aspects of a person's interactive narration of space: the strategic and the emotional. The strategic is a dynamic spatial interaction with objects in the environment; the emotional relates to what geographers and phenomenologists call a sense of place – the feelings that are generated by any particular space, and the attachment to it.

3D-IDEs can offer new modes of narrative expression by incorporating the spatial as a means of transforming the interaction offered to the user. The sense of place, and interactions made available, can be tailored to fit with a given learning experience, allowing a narrative to play out within the created space. The learner is afforded guidelines for the pleasures of the immersion of acting (Murray 1998). This use of space, in terms of interaction and communication between users, is a feature of 3D-IDEs not provided by other digital environments.

## Ludic narrative immersion: Time

Hall (1990) describes how time can speak more clearly than words, because it is manipulated in a more consensual manner, and is subject to less distortion than spoken language. Time can indicate the importance of the occasion, as well as at what level an interaction between people should take place. Time is not only about duration, but can also refer to the sequence of events.

Ryan (2015) describes three narrative effects that can affect the sense of time in which one is immersed: curiosity, surprise, and suspense. Through interacting with an ongoing narrative in a 3D-IDE, these can alter perceptions of the flow of time.

Thus, narrative within a 3D-IDE can alter the perception of time, which can be used to support a ludic narrative process.

## Ludic narrative immersion: Body

In understanding of the body's role in immersion, Le Breton (2002) points out that the body generates and maintains many of the bases of individual and collective existence. The body in the world is the place and the time in which reality is anchored. The idea of territory exists because there is a body – physical or virtual. Thus, body underlies many social and cultural aspects of reality. In the virtual, body is an important point of connection to the space-time of the virtual and affects the interaction with these elements.

The body in the virtual, if present, is usually identified as an Avatar, which contains semiotic characteristics of cyberculture – meanings of its attributes that may differ from the physical world. Sánchez Martínez (2010a) describes the virtual body as an extension of real space, the important difference being that the virtual body's greater flexibility increases its potential as a signifier. Thus, the body becomes the space which supports that flexibility. He (Sánchez Martínez, 2011) suggests that the avatar is both an image of the subject and at the same time an image of the image of the subject who manipulates it.

The individual has the opportunity to transform the avatar into an actor, with a role suggested by the space-time of the virtual environment and by the person's own choice. This would generate a narrative construction from interpretation of the character and its role, as suggested by Janet Murray (1998). Within a 3D-IDE, the person is free to experiment, to imagine and to enjoy an environment of ludic immersion.

If the individual identifies with the representative construction of their body in the virtual environment with a sense of enjoyment, it will be easy for them to relate to the space-time of the virtual environment; this was observed by Angel Rueda et al. (2017) in an exploratory field study with four groups of students of different educational levels: bachelor's, specialization and doctoral. Thus, the avatar, with its semiotic characteristics, can become a catalyst for a process of immersion.

Even without a visible avatar, the user has an implied body; the presence of an environment indicates the presence of a personal space, within which is the embodiment of the user. Even if not visible, the body will exist in the user's imagination.

### Ludic narrative immersion: Identity

It is necessary to understand, and to reflect on, the construction of identity in the physical in order to understand identity in the virtual. Sánchez Martínez (2010b) describes identity as a basic principle behind one's social definition.

There is a strong relationship between the body in the virtual environment and a person's identity (as previously described with the male participant and female avatar (Rudman et al., 2010). The body is our identity card, a container of information, and our channel of communication, through which we project our values and put others to the test. In the process of communication in the virtual, a person's identity is imagined from the information held in the virtual body. The technical mechanism that processes the information (the digital technology) recodifies the presentation and narrative of the self. Identity gives life to the ludic narrative process from the corporeal.

Identity in the 3D-IDE is the information factor that determines narrative play through time and space, and interaction within the 3D-IDE.

### Ludic narrative immersion: The emotional

This type of immersion is the result of the interaction of the four aspects of ludic narrative immersion: space, time, body, and identity.

One form of ludic narrative immersion, created from the emotional, relates to social interactions that recreate the combination of impressions. Ryan (2015) describes how individuals try to limit the complex universe of emotions by combining emotions that come from life in the physical with emotions centered in the virtual. Interaction with their virtual persona, and others', generates interactivity and the feeling of being personally concerned with both their character and others.

Importantly, if the imagination is committed to contemplation of the development and construction of an infinity of stories, imagined through the narrative of the 3D-IDE, it will, as a consequence, have the power to generate emotions that can support a process of ludic immersion.

# TOWARDS IMMERSIVE LUDIC LEARNING

## *THE EDUCATIONAL POSSIBILITIES OF 3D-IDES*

An analysis of the educational possibilities of 3D-IDEs has very important implications for pedagogical theory, not only for the application of technology in this area, but also for traditional pedagogy, beginning with the school system. Pérez Tornero (2000) writes "The school [...] specializes in this complex task that consists of teaching to read and write. And no other institution is more effective in this regard. Thus, in fact, there is an intrinsic and significant relationship between teaching, school and the writing and reading system" (pp. 39-40).

The theoretical, conceptual and methodological references that support current approaches to information and communication technologies (ICT) in schools come from a pedagogy that focuses on the book as a concept and as a technological object. Simone (2011) writes "[...] at the end of the 20th century we have gradually passed from a state in which evolved knowledge was acquired mainly through books and writing" (p. 37).

Early uses of ICT in schools sought to replicate the book, through text- and page-based presentation of information held on media such as CD-ROMs. However, digital technologies allow a multitude of alternative interactions and were soon offering interactions through hypertext, Web pages, blogs, social networks, platforms, video games, applications, Virtual Worlds, etc. In consequence, the educational potential of these digital technologies is diverse, allowing new pedagogical approaches in schools and diverse forms of learning.

Thus, traditional school pedagogy is designed to work from and for a uniform, standardized environment, based around and encouraged by, the book as a primary technology. While ICT can provide these characteristics, it can also transcend them, allowing the use of pedagogies that encompass a better understanding of the sociocultural dynamics and freedoms of learners that is emerging from the use of digital technologies.

This paper considers current, advanced ICTs, in the form of 3D-IDEs, and their educational potential. We propose a pedagogy with ludic characteristics, based on the use of 3D-IDEs, that utilizes the emotional and pleasurable characteristics of this type of resource. We also question other characteristics of current school pedagogy, such as the idea of mass and standardized communication. In considering a ludic approach to education, incorporating emotional and pleasant features to learning does not exclude structure and rules, but is not intended to imply the use of a formal "game".

The non-rational (different from irrational) aspects of thought are closely related to the construction of knowledge and belong to the plane of the emotional-pleasurable. Piaget described the different approaches: "The symbolic game poses ... the question of symbolic thinking in general in opposition to rational thought, whose instrument is the sign" (Bartra, 2013, p.79), while Vygotsky describes the ludic approach as "the imaginary and illusory realization of unrealizable desires" (Bartra, 2013, p.77).

As an example, Himanen (2002), in the text "The Hacker's Ethics", presents an aspect of pleasant learning. He refers to the passion that the hacker develops during their work of programming, and the way in which this passion drives a process of learning as and when necessary. This contrasts with the idea of school learning where teachers define the "right learning" – learning "as it should be".

> The hacker programs because he finds the programming activity intrinsically interesting, exciting and joyful ... Problems related to programming awaken a genuine curiosity in the hacker and arouse his desire to continue learning ... The activity of the hacker is also joyful. It is often rooted in ludic explorations. (Himanen, 2002, p.14)

The idea of a ludic sense of learning can be viewed from a more philosophical perspective, as raised by Aristotle with the maxim "All men desire, by nature, to know". In this sense the idea is to understand learning from this ludic perspective as "desire to know" (Samaranch, 1995) rather than "learning as a duty" or as "obligation". The pedagogical approaches adopted by schools have characterized learning as an obligation, leaving out the idea of learning as desire and the pleasure obtained in achieving something. The school philosophy is that students are there to learn and not to play, that knowledge is not a game, and that school is a serious thing. Even the old "recreation" has been transformed into a "recess", just as what were once "holidays" are today "class breaks" or "work recess".

Learning as desire generates pleasure by obtaining sought-for knowledge, less formal but no less valuable than school knowledge. This latter is more concerned with obtaining content than the pleasure that comes with acquiring it. As Samaranch (1995) points out, learning as desire is led by a dimension of pleasure and the desire of reason.

This form of motivation, where the pleasurable aspect of learning is part of the reason to learn, opens up the possibility of an alternative pedagogy – one that motivates students through a desire for knowledge and their recognition of the pleasure of achieving it.

We can take the example of Apple computer as a successful incorporation of pleasurable recreational aspects in the business environment, which can be replicated for educational purposes. As described by Himanen (2002):

> Wozniak refers to the many features of the Apple computer that came from a game, and the fun features that were incorporated had simply the purpose of carrying out

> a personal project that was to program ... You need to play, you have to want to explore. (p. 14)

We propose the use of ludic elements as part of a pedagogic strategy, not as an end in itself. The ludic elements create pleasure in learning; they are not applied in the sense of a "game" (even if a game is employed), played for the purpose of competing or "winning", or obtaining some reward. A pedagogy with a ludic emotional basis allows the student to be freer in exploring and making decisions in the learning process, exploring the content based upon their interest rather than a regimented sequence prescribed by the teacher.

The ideas of pleasure and passion for what is done are present in the attitude of the artist and the craftsman towards his work – it is a matter of attitude rather than aptitude and obligation. Much of the ludic immersive aspect revolves around this approach, recovering the ideas of pleasure and passion for learning.

> Many hackers have learned to program in an equally informal way, giving direction to their passions. The example of the ability of ten-year-olds to learn very complicated programming issues speaks very clearly of the importance of passion in the learning process, unlike the slowness that often results from education in traditional schools. (Himanen, 2002, p. 59)

A ludic approach motivates the learner to explore the content without the need for detailed instruction from the teacher. Bartra (2013) describes how, on the surface, "it is difficult to see an immediate function or utility" in the ludic, indeed, the pleasantness of the work may appear to be a waste of time. However, this does not take into account the cognitive processes undertaken by the learner; while the learning process is less formal than with traditional school pedagogy, the knowledge is no less valuable.

From this ludic perspective, the task of the teacher is not to impose knowledge through strategy planning, but rather to guide the student in the construction of their own knowledge, and to arouse desire and pleasure for the subject.

## *3D-IDEs as Environments*

The opportunity to use 3D-IDEs for educational purposes is a good time to reestablish and consider the ludic-emotional-pleasurable element of learning, because the technology is pleasurable by its nature. This is intrinsically different to the book, where the content (text) is devoid of context. A 3D-IDE allows the learner to be immersed in both the content and a contextual environment. Having an environment separate to and supporting the content allows ludic elements to be incorporated into the learning experience without affecting the content. Thus, immersion takes place with both the content and the surrounding environment simultaneously, with the environment providing the ludic-pleasurable-emotional elements.

Immersion in a 3D-IDE has a sensory aspect which allows an emotional and pleasurable perception of the environment. One could say that it is not a passive immersion, as the user is part of the environment, not merely within it. This is an important feature of the 3D-IDE: the manipulation of the environment generates a pleasant experience. It is a relationship in which the body plays a fundamental sensory mediation role, with aspects such as (among others) orientation, location, manipulation, distance, and apprehension combining to create a total immersive learning experience.

3D-IDEs are "spaces of play" (Erikson, in Bartra, 2013, p. 74) that allow the learner to explore content within the context of a relevant, immersive environment – something not possible in traditional learning environments. The environment supports the learner in finding their own route through the learning material, with the teacher providing pedagogical mediation to guide the student in their journey (being consistent with the pleasurable ludic experience).

In order to utilize these characteristics of the 3D-IDE – to maximize the ludic pleasure of educational processes – it is important to construct a pedagogy that serves as a foundation and guideline. The role of the teacher is important – the aim is not to instruct, but to induce the student to arouse desire and pleasure for the subject using ludic immersion within the relevant environment.

One of the main ideas of this paper is to contribute to the construction of this pedagogy. It is not a question of transferring the practices of the traditional classroom into the virtual space and continuing to reproduce established school dynamics. The pedagogical possibilities of 3D-IDEs go further, requiring theoretical-conceptual and methodological approaches from perspectives other than those traditionally employed by school pedagogy.

## 3D-IDEs in Practice: The SWIFT Project

We revisit here an experimental use of a 3D-IDE that one of our authors participated in and consider its ludic pedagogical approach.

The SWIFT project at the University of the University of Leicester, UK, was set up to investigate the educational potential of virtual worlds in the area of genetics teaching. The project created and trialed virtual undergraduate genetics laboratories, built in the VW "Second Life" (SL) (Linden Lab, 2017). We consider here the first two phases of the project.

In phase one, the virtual laboratory was used to give new students an induction into laboratory equipment, safety and the general behavior expected in a laboratory – see Rudman et al. (2010). Thirteen first year Biological Sciences undergraduates at the University of Leicester, volunteered to participate in the study. There were two sessions. First, they underwent training in small groups in the use SL. In the physical world, participants sat together, using laptops to access the VW; a teaching fellow was present to assist as necessary. In the virtual world, the participants (as avatars) were together on a large open space, and were given tasks involving movement, such as ice skating around obstacles, to practice using the controls. There were also two separate rooms in which they practiced changing their avatars' clothes, specifically, putting on and taking off a lab coat. In the early trainings, instructions were given verbally, but later a set of posters was placed in the room so that participants could follow the instructions at their own pace (see Figure 3).


**Figure 3. Part of the SL training area**

Second, participants took part in a lesson within SL introducing them to the lab, its main equipment, and the many health and safety rules they would need to know when using the physical lab. Six or seven participants sat together in the physical world, with the Teaching Fellow in a separate room. In the VW, the Teaching Fellow showed the participants around the virtual genetics laboratory (see Figure 4), describing the main items of equipment, health and safety issues in general and issues for each item of equipment. Next, in groups of two or three, participants completed a worksheet. The worksheet was provided on paper in the physical world, but participants worked together as avatars in SL to complete their worksheets, communicating using group text chat. The work required participants' avatars to take photos of three lab objects and place them on an in-world notice board, answer health and safety questions and collect information. Finally, the Teaching Fellow led a discussion about the worksheet exercise in SL with all participants. The Teaching Fellow communicated using Voice within SL while participants used text chat to communicate with the Teaching Fellow and each other (although they could also speak to each other in the physical room if they wished).

**Figure 4. SWIFT virtual lab from Phase 1**

Phase two of the SWIFT project (currently unpublished, but described in Rudman and Lavelle, 2012) used an upgraded version of the virtual lab (see Figure 5) to allow participants to conduct a sequence of procedures. Laboratory work involves a complex sequence of interactions with different materials and pieces of equipment. Undergraduates need to focus at two levels simultaneously: the detail of selecting materials and manipulating equipment, and the overall process of performing the correct steps in the correct sequence. In addition, they need to keep in mind the theoretical aspect of what they are trying to achieve. It is known that undergraduates may become focused on the detail. They want to avoid making mistakes in the detail, to avoid breaking equipment, harming themselves or others, wasting materials and so forth. They have a worksheet or book that outlines the sequence of steps to take, and they may rely on this to guide them rather than memorize the sequence of procedures. They may be so focused on the practical work that the theory behind, and purpose of, the procedures is not considered until after the lesson.

Thus, phase two investigated allowing students to experience use of the lab at a higher level of abstraction to help put their use of the physical lab into context. 24 medical students at the University of Leicester volunteered to participate. Prior to the lesson, they were sent instructions and asked to register for SL and use the SL training area – in an automated maze-style virtual location.


**Figure 5. SWIFT virtual lab from Phase 2, showing animation of chemical changes**

## *Digital Perceptual Immersion*

SWIFT participants used a desktop system to access the virtual world, in which each participant was represented by an avatar. This equates to Third Person Immersion. Participants appeared to be aware of being in two places – the physical and the virtual. For example, they were seen to hold text-based conversations in the VW, spontaneously switching to speech in the physical world, and back again, or would laugh out loud at a text conversation, or comment in text on something someone had said out loud. This was not random though. Text statements were addressed to a person as their avatar persona, and spoken statements were addressed to the person as they knew them in the physical world. For example, where a male participant chose to be represented by a female avatar, other participants referred to their avatar as "she", but to the person as "he".

However, sometimes participants were seen to attain Conscious Immersion. In the ice skating task (during training) participants were seen to be competitive, occasionally being excited or disappointed at winning or losing – the emotional moments suggest this higher level of immersion.

In the second phase of the project, participants carried out procedures in the virtual lab, using the equipment (e.g., clicking on an image of a pipette to transfer liquid to a machine, or clicking on the machine to start it). In interviews, one student commented that the avatar "got in the way" of using the virtual lab. This suggests a potential for Total Immersion, albeit held back by the technology.

## *Ludic Narrative Immersion*

The university's physical genetics labs hold up to 120 students and contain complex-looking equipment the students may be unfamiliar with. There is insufficient lab and tutor time available to give small-group induction in the physical labs, so 'induction' takes place as and when required. However, for many participants, working – or even being – in a laboratory is an unfamiliar experience. Indeed, some participants had previously attended a school where they did no laboratory work at all. The primary aim of the intervention was to help the participants feel comfortable in the physical labs from their first visit. This was addressed in phase one by using the 3D-IDE to create a ludic experience in the context of a laboratory setting, whereby participants could learn about the labs without any stress associated with a physical visit.

The ludic nature of participating was introduced from the beginning with a training session on the technology, which involved exercises in walking, including (virtual) ice hockey, changing clothes and moving the camera direction.

SWIFT tried to utilize the features of the 3D-IDE to generate a narrative of belonging in a genetics laboratory. All four categories of perception were addressed in the virtual space in order to achieve this:

> Space: A laboratory with all identified key features (benches, equipment, sinks, waste bins, notices, etc.)
> Time: A set lesson period
> Body: The requirement to "wear" a lab coat (i.e., on the avatar)
> Identity: The need to act appropriately (not running, washing hands as required, etc.)

As described earlier, an important aspect of the VW training was to provide an experience of undergraduate laboratories in a safe, non-threatening way, so that participants would later be more comfortable in their regular lab classes. The ludic element of the VW was important for this. Firstly, the scene was set in the training session, in which use of the 3D-IDE was taught using games within an informal atmosphere. Then, in the teaching session, any sense of danger was removed from the virtual lab, since it was not possible to misuse or damage any of the virtual equipment or chemicals.

All the participants reported enjoying the VW sessions and reported having learned more about the labs, especially of health and safety information – something not specifically taught in the physical labs, but, rather, introduced as necessary. Participants reported having learned about new equipment and revised existing knowledge.

### Body

The training session had a two-fold purpose. Ostensibly, its purpose was to ensure that the participants could use the VW technology well enough for it to become sufficiently transparent that they would to be able to concentrate on the virtual environment, i.e., the technology would not be an impediment to immersion. However, its second purpose was to familiarize the participants with their avatar, as an extension to their own body. Thus, the task of ice skating required maneuvering the avatar through a fairly complex route. An important part of this was actually putting on (virtual) ice skates. Similarly, the task of dressing the avatar in a lab coat was intended to draw attention to the virtual body, as representation of the physical.

In the early training sessions avatars were separated by gender for changing their virtual clothes. After a while, it became apparent that this was unnecessary, and one room was used, with a screen in the corner. In fact, only one person was observed to take their avatar behind the screen before getting changed. However, this may have been because a lab coat is not seen as in intimate item. In one of the training sessions a male participant accidentally removed all of his avatar's clothes (an easy mistake to make with the software at that time). Although avatar bodies are not fully gendered, two female participants who had avatars nearby immediately turned their avatars to face away. This suggests there was an emotional feeling of connection with the avatar as extension of the body.

### Identity

Students who take biological Sciences at undergraduate level come from a variety of educational backgrounds. While some have used similar laboratories in their school, for others they are a completely new environment. As one participant commented:

> When I first started labs in September I was really scared of going into the labs 'cause we did no [lab] work in biology in A-level ... and if we had of had this induction it would have really helped. (Participant-4f)

In part, it is a case of understanding the purpose and use of all the equipment, in part it is about specific safety rules, but an important element to feeling comfortable in a large laboratory relates to one's identity. There is a lab culture in which one has to fit. Simple rules, like which protective clothing to wear and when, how to wear one's hair (tied back), how to behave (don't run, don't eat, don't use your phone...), and being familiar with the equipment sufficiently to know that one won't damage anything or "blow anything up", combine into a sense of being someone who fits in, who belongs to the culture of the lab. It is this sense of identity – as someone who belongs in a lab – that the VW sessions were intended to generate.

In particular, the use of the virtual body to wear a lab coat was symbolic of this change.

### Space

In the physical world, participants were confined to a small room; in the VW, through their laptop, participants were able to experience a large laboratory with a variety of relevant equipment (see Figure 6). In phase one, they (i.e., their avatars) could walk around the lab, firstly as a guided tour and then as they wished, examining the equipment and reading information about it, and discussing it with their classmates. They had the experience of a large laboratory without the danger of damaging anything or hurting themselves.

**Figure 6. Avatars in the SWIFT Phase 1 virtual laboratory class**

### Time

In the case of the laboratory tour, time in the VW matched that in the physical world. In the second phase of SWIFT, participants used the more complex virtual laboratory to practice procedures they would later undertake in the physical laboratory. The aim was to help the students gain an overview of the steps involved so that later they would be able to concentrate on the details of achieving the tasks, with the benefit of an existing understanding of the whole.

In the physical lab, the task would take a three-hour class, some of which involved waiting for chemical reactions to take place. In the virtual lab, this waiting was unnecessary, since the intention was to teach the steps rather than the detail. Thus, time could be compressed as convenient.

In addition, the opportunity was taken to connect the students' prior theoretical learning with their practical task by showing a number of animations at critical moments. These animations represented the molecular changes that were taking place inside an otherwise bland container or machine. The animations lasted a few seconds but represented the minutes or hours necessary for the physical reactions to take place (see Figure 5).

## Guidelines for Using 3D-IDEs in Education

### *Utilizing the Technology's Strengths*

Ludic Narrative Immersion is key for the effective educational application of 3D-IDEs. The use of narrative allows the teacher to generate and depict an imaginary scenario in which the learner experiences the learning material within a meaningful context. The ludic aspect provides the impetus for the learner to engage in that scenario. Together, they replace the external requirement to engage with abstract (out-of-context) material, with an internal motivation to engage with material within a meaningful and supportive context.

Thus, the key to utilizing 3D-IDEs is to create a relevant context in which to place the learning material and to provide a ludic narrative that learners can build upon as they explore the learning material. Rudman (2014) describes the main forms of representation that 3D-IDEs excel at, from the perspective of virtual worlds. Based on this, we discuss here six approaches, as applied to 3D-IDEs in general. In each, one or more of Space, Time, Body and Identity are manipulated to generate an effective learning experience.

#### Field trip

Perhaps the greatest strength of 3D-IDEs is their ability to provide a contextual environment – an alternative Space for learning. For example, when learning a language, context allows the learner to connect their learning with a tangible situation – one in which they are likely to need that learning in the future, such as buying tickets at a railway station, ordering food at a cafe, etc.

3D-IDEs allow environments to be experienced that may not be practical in the physical world. Any space may be visited, from the microscopic (such as within living cells) to the inaccessible (such as the human heart) or expensive (such as visiting the pyramids in Egypt) to the macroscopic (such as visiting other planets or the deep oceans). For example, the UK's Open University used a Virtual Geology Field Trip to augment their Geology course (Burden et al., 2017).

The ludic aspect of this learning approach is important for the learner to be able to explore the environment, filling in their own gaps in knowledge rather than, or in addition to, being led through what is logically important but possibly missing important factors that the learner is assumed to know. Thus, the minimum requirement for a 3D-IDE field trip is total immersion for DPI, with an LDI focus on Space.

#### Role play

Within a contextual Space, a change of Body and Identity can place the person in "another's shoes", helping them to understand what it is like to be in someone else's situation at a more emotional level than is possible simply by reading an explanation. In SWIFT, students took on the role of people who used laboratories; the feeling of being "at home" in a lab persisted when visiting the physical labs.

The LNI requirement for role play within a 3D-IDE is one of Identity, which may be supported by Body. Space may also be important in supporting the role, as an appropriate environment may create behavioral cues. For DPI, either 3rd Person or Conscious immersion is appropriate, depending on whether an avatar representation of the user would help them inhabit their role (through a visual representation of Body).

#### Experience

The combination of a compelling narrative, delivered in a realistic context – through the use of a 3D-IDE – can lead to meaningful emotional experiences that can add greatly to the learning experience. Thus, Emotion as LNI is a key feature of this pedagogical approach.

Rearranging Space, Time, Body, and Identity can create a powerful experience. In the Second Life VW there is an area in which one can role-play a person with PTSE (Post Traumatic Stress Syndrome) (Hemmerly-Brown, 2011). The user is placed in an unfamiliar place and time (a marketplace in Afghanistan), with a particular identity (a soldier), and is led through what would be (in the physical world) a very stressful experience. They are then taken to the equivalent of an everyday experience at home (a shopping mall) where everyday events are directly related to individual traumatic events previously experienced (e.g., a sudden movement brings the expectation of a deadly attack).

This combines several features of 3D-IDEs. It incorporates Field Trips or Simulations in which PTSE may be initially set up, and later experienced, and it allows the user to Role-play a soldier in those situations. For users who have actually experienced the traumatic situation depicted it allows them to practice everyday life situations that may be difficult as a result of the trauma; for users who are not affected it provides the experience of PTSE that goes beyond a description of the situation – there can be a genuine, albeit muted and safe, feeling of fear when engaging with the simulation. This ability to generate emotional responses to a role-play situation can create a very powerful learning experience.

The ludic element is important to this experience as it is not possible for a teacher to predict exactly what factors will capture each learner's emotions, whereas the learner will select details of interest to themselves, which are likely to be those details with an emotional effect.

The starting point for creating the Experience of others in a 3D-IDE is to incorporate it into another approach; the 3D-IDE needs to support DPI and LNI appropriate to that approach. So, for example, the PTSE simulation described above takes place in both a Field Trip (a war zone plus an everyday event) and Role Play (as a soldier). Thus, Experience comes from narrative that takes place within other settings.

## Simulation

Simulation provides an experience that is intended to accurately recreate a specific situation from the physical world (rather than a general experience). A simulation is often thought of as requiring highly accurate details. This is certainly important where the learning focus is on the details. For example, Microsoft's Flight Simulator, while using a screen-based interface, provides photo-realistic images of locations and equipment. In the VR game Star Trek Bridge Crew (Ubisoft, 2017) players work together to pilot an imaginary – but virtually real – spaceship. Commercial flight simulators provide a sufficient match to the physical experience (including replica physical controls that may be manipulated) to allow a pilot to take control of a real commercial plane having only ever experienced that type of plane in the simulator. For this form of simulation, total immersion is necessary as DPI, and full deep is desirable.

However, for education, a simulation does not necessarily require the same complexity of experience as the physical world; it only need offer sufficient authentic detail to support the intended learning. For example, to understand the alignment of the pyramids in Egypt the relative size and orientation of the pyramids is important, as is the direction of the sun, but the pyramids themselves do not need to be photo-realistic, since the intended learning is not about the pyramids' construction and decoration. Indeed, by abstracting the essential features of the physical, one may create a clearer view of the system as a whole, without unnecessary or confusing details. For example, in phase two of SWIFT, students could conduct laboratory procedures, learning the main steps, without the need for detailed use of equipment. In such cases, the relatively simple 3rd person DPI may suffice.

The primary LNI requirement for a simulation is Space, in creating the copy of the physical. However, Simulation offers the opportunity to manipulate Time, by expanding or compressing physical events to a speed that is easily followed by a learner.

### Artistic medium

The almost limitless ability to change Space, Time, Body, and Identity as one wishes within a 3D-IDE offers unique possibilities for artistic expression. The user can work in any situation that may inspire their creativity, in ways not practical in the physical world. For example, they can create their own studio or gallery, or work outdoors or any other place they may find inspiring. It is possible to collaborate directly with other artists who are physically located anywhere in the world.

The intrinsic ludic aspect of 3D-IDEs is supportive of artistic expression (within the media the technology supports – usually visual and audio at present); users can create work without the usual constraints of workspace, lighting, acoustics, material cost, or even gravity. While the teacher may provide a narrative to guide the art, the user, as artist, is free to generate their own narrative for other users (as audience).

The VW Second Life runs an extensive annual arts festival based on the Burning Man festival (Burn2, 2017). As with the physical festival, users may take on identities appropriate to their artistic vision of the festival, which may in turn affect their art.

Any form of DPI is sufficient to enable artistic creation, but 3rd Person may affect the user's view of Body and Identity, which may be beneficial or distracting depending on circumstances. Similarly, the artist may choose to focus on Space (such as creating 2D visual art), Time (such as creating moving sculptures), or even Body (such as dance) and Identity (such as acting). The artist may wish to instill a particular experience in the audience. In short, the requirements of a 3D-IDE for artistic expression depend entirely on the artist; conversely, artistic expression is enabled by the 3D-IDE's affordances.

### Personal tutor

Many attempts have been made over the years to create a "teaching machine" (e.g., those of Gordon Pask (Watter, 2015) and B.F. Skinner and others (Benjamin, 1988)). However, thus far the ability of technology to support the learner has been limited by the technology's knowledge of the learner's actions.

Within a 3D-IDE, all aspects of the virtual are mediated by the digital technology. Therefore, the technology has detailed information of everything the person does – their every move, word and interaction with the 3D-IDE and its teaching environment. This allows for the possibility of comprehensive personalized teaching assistance.

For example, in a second phase of SWIFT, students carried out procedures in a virtual lab – albeit clicking on an object to represent its use. On some of the (virtual) machines, when started, a 3D animation of the molecules appeared over the machine, showing the process that would be taking place inside. This helped to connect practice to previously-learned theory.

A more advanced system could keep track of a learner's behavior and extrapolate the areas yet to be learned. From this, personalized feedback or extra tasks could be given.

As with Experience, the starting point for creating a Personal Tutor using a 3D-IDE is to incorporate it into another approach; the 3D-IDE needs to support DPI and LNI appropriate to that approach.

## *Defining the Limitations*

Having chosen the form of representation best suited to the educational content, the other important choice is that of which 3D-IDE system to use, the technology that will support it, and the format of the virtual space it will provide. Until the existence of true neurological systems, the user will be limited in their experience from the 3D-IDE. As described earlier, it is often not necessary to provide a Full Deep experience in order to facilitate learning. Indeed, some level of abstraction – a reduction of detail – can be beneficial in highlighting other aspects of a situation, as with the second phase of SWIFT where sequence and meaning were the important elements rather than physical details.

The level of Digital Perceptual Immersion becomes less significant as it increases; there is a large difference between Third Person and Conscious Immersion. It is not simply a difference in the technology, it is a difference in the user's experience. With the former, the user experiences an environment through the technology. With the latter, the user experiences the environment directly. While a third-person view, created by desktop VR, may encourage Third Person Immersion, it does not prescribe it; the user may experience Conscious Immersion provided the Ludic Narrative presented is sufficiently compelling.

The difference between Total Immersion and Full Deep is less, in that both allow the user to forget they are not experiencing the GOFR of a physical world. However, once the Full Deep experience becomes available, the removal of all cues reminding the user that their experiential input is not physical will lead to new educational opportunities. These are likely to be existing uses of 3D-IDEs that have not been effective because of the user's connection with their physical body and identity, and synchronization with physical time and space. For example, any experience of exploring the moon's surface will not be complete when accompanied by the earth's gravity.

The usual overriding factor in choice of 3D-IDE is to use whatever technology is currently available. Thus, while an Immersive System is preferable to Desktop VR, both types of system can be used to create effective learning environments, although the former may be easier for users to gain the experience the teacher intends with the user being less distracted by artefacts introduced by the technology.

Similarly, a Neurological System would be the most preferable system, but there is no need to wait for such a system to be created for 3D-IDEs to be beneficial as learning environments. One particular area where this is the case is in the ability to touch objects, pick them up, and manipulate them. The SWIFT project provides a good example. In phase one, students were not required to interact with the equipment in any significant way; they learned more general aspects of the equipment – what it was for and the main safety rules to be aware of.

However, the second phase intended to support students in using the labs to perform practical procedures; in the physical labs this would include the dexterous manipulations of objects. For example, the micropipette requires practice in order to successfully move tiny amounts of liquid from one container to another (University of Leicester, 2009). This detailed work was not possible with the 3D-IDE technology employed by SWIFT. Indeed, it is not possible with any contemporary 3D-IDE technology. Instead, concepts and process were taught, allowing the physical lessons to focus more on detail.

Thus, while 3D-IDE technology may not, at present, be able to assist with detailed physical work, it can help to instill an understanding of the steps required for a particular procedure and link these steps to the theoretical description previously learned in the classroom. The technology can support learning by providing a higher-level experience of procedure and meaning, leaving the lower-level experience of practicalities to the physical world.

Finally, not all forms of pedagogy are suited to use within a 3D-IDE. For example, a classroom setting where students sit in rows while a teacher at the front lectures and shows PowerPoint slides is unlikely to be more effective in the virtual environment than in the physical. Given the technological overhead of utilizing a 3D-IDE, that form of teaching is best done in the traditional way. It is important to consider which approach is best for each learning experience.

## DISCUSSION

This paper proposes a general-purpose categorization scheme for assessing the utility of new and emerging 3D-IDEs, based on the user experience rather than the technology's features, along with specific pedagogic approaches that are known to work with 3D-IDEs. The advantage of such a scheme is that it categorizes 3D-IDEs in terms of the way in which they interface with the user's senses and their ability to provide 'immersion', both the generated sense of reality and a less cognitive and more emotional engagement with the learning environment. By examining the user experience, it should be possible to assess any future virtual system, regardless of the type or complexity of the technology, and even proposed technology.

Having said this, there is the possibility that a future technology may provide an experience that goes beyond GOFR. For example, Thomas Nagel's (1974) classic question "What is it like to be a bat" could potentially be addressed by a future technology that provided the experience of echolocation, flight, and so forth. While the categorization scheme as-such would remain valid – human evolution is a far slower process than technological change – it is not certain that the scheme would remain as complete a description of the user's experience in the face of such advanced technological capabilities. If such technology were to allow for all manner of non-human senses (smells, electric fields, vibrations, etc.) an additional category might be needed.

Six specific forms of pedagogical practice appropriate for 3D-IDEs were examined and discussed. It is notable that all are experiential approaches. This is at once the benefit and the challenge with using 3D-IDEs for education. The benefit is that students (and their teachers) are freed from the requirement to have the book as mediating technology. Students can experience the world more directly, but in a safe environment at a relatively low cost. A virtual field trip to, say, the pyramids of Egypt or Mexico, can offer a contextually rich experience of those sites in a way that text, drawings, or even videos cannot create. Role Play, and experiencing the world as others see it, is much easier within the detailed context available virtually. Simulation is possible of anything from the cell nucleus to galaxies. Artistic expression is expended when physical limits are removed. The ability of the technology to act as a Personal Tutor has been less explored (e.g., Rudman, 2005), but offers significant opportunities for the future.

The challenge for teachers is that this experiential learning requires the learner to *choose* to experience, and thus to learn. With a book, a student can be told to read, and they may read every word; they may memorize the words, and this may look "good" on a recall test, but they will not necessarily understand the deeper meanings. With a 3D-IDE, a student can be exposed to the same information as from a book, but within a meaningful context in which they can interact with the information, learning about its deeper meanings and gaining a more holistic understanding of a topic. However, since the information is, at least partly, embedded in the context, they need to engage with the experience to gain the full learning benefit. This is where the ludic element applies, by generating intrinsic motivation – by making the experience pleasurable the student can be persuaded to want to engage fully and thus achieve the full learning gains available.

A secondary challenge is that of assessment. While multiple-choice questions are easy to administer, and can be effective at testing recall, it is very difficult to assess understanding without eliciting more nuanced responses which, in turn, require much more time to mark. Thus, the deeper learning that may take place through 3D-IDE-based pedagogies may go unnoticed.

Thus, the question is how to evolve the schooling system to gain benefit from 3D-IDEs. It is important to consider the teacher as a transforming subject of their own pedagogical practice, mediated by the use of these digital technologies. On the one hand, there is the freedom to use the technologies, in all its forms, provided by the socio-cultural environment outside of school, on the other, there is the historical, cultural and regulated environment within the school. Within these, there is the need to evolve pedagogical practice for the future.

Previous technologies, the internet being a conspicuous example, were not taken up generally by mainstream education until the students had easy and frequent access to the technology at home; then education had little choice but to incorporate the technology into everyday schooling. As technology advances further, so 3D-IDEs are likely to become a regular part of people's lives. HMDs will get smaller, be built into glasses, perhaps even contact lenses. In short, 3D-IDEs are a class of technology that cannot be ignored indefinitely. It is hoped that the categorization scheme described here, and associated pedagogic suggestions, will help in the process of assimilating these technologies into mainstream education.

The next step will be to trial the scheme with teachers to ascertain its ease of use and effectiveness. It may be that a more nuanced description of the forms of pedagogy appropriate for 3D-IDEs is required, according to student age, subject, school philosophy and other variables. Overall, we see this categorization scheme, and the suggested pedagogic approaches, to be part of a much bigger process of understanding the potential contribution of 3D-IDEs to education.

## CONCLUSION

We have used the term "Three-Dimensional Interactive Digital Environments" (3D-IDEs) to describe all forms of physical-world-style experience that seek to emulate "Good Old-Fashioned Reality", mediated by modern-day computer technology. The purpose was to abstract the key elements of virtual environments to create a generalized description of their affordances; this would allow a discussion of the educational opportunities of both current and future systems.

We then examined traditional schooling, with its mechanistic structured approach to learning, and argued that the advent of 3D-IDEs provides a unique opportunity to create a "digital pedagogy" that would engage students, provide internal motivation, and allow new forms of learning support. We proposed a pedagogy with ludic characteristics, based on the use of 3D-IDEs, that utilizes the emotional and pleasurable characteristics of this type of resource. Rather than the teacher constructing uniform narratives, learners would construct their own learning narrative, in response to the environment, narrative and activities provided by the teacher. Thus, learners would be empowered as creators of their own learning.

In order to support teachers in this approach, we analyzed existing 3D-IDEs and created a category system that may be used to assess any 3D-IDE and thence select an appropriate pedagogy for a particular learning intervention. Our main areas of analysis were the way in which 3D-IDEs interface with the user's senses, and their ability to provide 'immersion'; two forms of immersion were examined: digital perceptual immersion – the generated sense of reality (third-person, conscious, total or full-deep) – and ludic narrative immersion – a less cognitive and more emotional engagement with the learning environment (in terms of space, time, body, identity and emotion).

Finally, we proposed six pedagogic approaches to the use of 3D-IDEs and discussed them in terms of our 3D-IDE analysis. These were: Field Trip, Role Play, Simulation, Experience, Artistic expression, and Personal Tutor.

Pedagogical innovation must build its own principles and differentiate itself from technological innovation. It must also differentiate itself from traditional school practices. The educational uses of 3D-IDEs will arise from the inventive diversity generated in the daily practices of the users of this technology. This pedagogical innovation, with pleasant play and ludic immersion as a learning vehicle, is largely found in the construction of theoretical, conceptual and methodological references and will lead us to a better understanding of the educational possibilities of 3D-IDEs.

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