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The Future of Virtual Reality in Education: A Future Oriented Meta Analysis of the Literature

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Abstract

Many have elaborated on the potential of virtual reality (VR) in learning. This article attempts at organizing the literature in this issue in order to better identify indicators that can account for future valid trends, and seeks to bring to attention how authors who wrote about the future of VR in education confused futures' terms and produced excessive expectations about its applicability in learning. The majority of writers missed the difference between *probable* trends and *possible* trends as well as between *wild* and *preferable* scenarios. Therefore, the aim of this article is twofold: a. to clarify the difference between these future approaches; and b. to develop a valid forecast of a *wild future* for VR in education. It seems that VR could suggest a wild paradigm in learning. The wild turnabout identifies the potential of VR not as an accessory to learning but as an IQ and cognitive booster.

Futures' studies approaches

In the process of its development as an academic discipline, Futures Studies passed through four basic stages (Passig, 2003), which developed in turn to four approaches dedicated to helping scholars study the future. Each approach had its advantage and weaknesses. The first approach, the classical school, aimed at identifying the most *probable* trends. The second, the scenarios school, aimed at identifying some *possible* trends. The third, the wild cards school, aimed at identifying the *implausible* trends, and the fourth, the futures designer school, aimed at developing *preferable* futures. Following is a synopsis of the philosophical foundation of each approach. It is important to keep in mind the principles of these approaches, while attempting to understand what has been done in terms of identifying the future of VR in learning. Without these principles in mind, to the best of my knowledge, one cannot evaluate a valid trajectory of VR in the future.

Probable futures

The first approach, also known as the classical approach, focuses on the prediction of trends, and is based on the assumption that there is logic to evolution. The futurists of this approach try to find patterns of logic, which express themselves in evolutionary processes, and to translate them to valid, reliable models. The reliability of the models, according to a number of studies conducted during the last decade, runs on the average of 0.70 (Cornish, 1997). Futurists identified with this approach use these models to draft forecasts in order to help organizations adapt themselves to newly developing trends. This approach was dominant among senior decision makers in the 1940s and 1950s, primarily in the United States.

Today, futures' research tends to focus on five ranges of future time. Just as there are institutions, organizations, institutes, and experts who are involved with research into different aspects and approaches of the future, it follows that they specialize in different ranges of time. The following are the five ranges of future time discussed in the literature (Joseph, 1974): The *immediate range*—up to five years, the *short range*—five to ten years, the *median range*—ten to thirty years, the *long range*—thirty to fifty years and the *very long range*—fifty to one hundred years. I have chosen to focus in this chapter on the short range, that is, the second decade of the 21st century.

Possible futures

The second approach, the scenarios approach, takes as its point of departure the assumption that, even with the understanding of evolution available to us today, it is still beyond the realm of the possible to understand sufficiently how systems develop, and to draft predictions. This approach, which began to develop in Europe toward the end of the 1960s, maintains that the more the pace of change is accelerating, the less valid are the models we have at our disposal. For this reason, the practitioners of this approach suggest the preparation of a number of possible and reasonable scenarios. They suggest making a thorough analysis and formulation of those scenarios, together with the client organizations, in order to plan the procedures of the organizations' response in a way that will be most fitting for each scenario.

Wild futures

The third approach, in contrast, assumes that if one is to focus on scenarios which logically speaking are unlikely to develop, and then on the basis of those scenarios, prepare response procedures in case they might really happen, she or he will be preparing themselves better for any complex and extreme possibility that might occur.

The goal of the third approach is what is called the dealing of wild cards, and the preparation of the society for any extreme situation.

I have chosen to draft a wild future of VR in learning in the current chapter and have chosen to focus on this kind of trend, since very few scholars have written about it to date. I assumed that if one is to fully understand the potential of VR in education she or he needs to be acquainted with this forecasting approach.

Preferable futures

The fourth approach, which aims at inventing the future, assumes that it is the task of the futurists not to make predictions whilst systems are in soaring disequilibrium, but to help the members of any social, political, or business entity to mold for themselves future images or a shared vision of the future stemming from their collective wisdom. This approach began to make headway in the mid-1980s and today is considered to be one of the approaches with the broadest acceptance.

It is important to note that these approaches and their derived methodologies and procedures are tiers standing on each other. Entities willing to better prepare themselves for the future use all these approaches in constructing their futures' imagery. Others choose the most urgent for their needs and invest their resources accordingly.

Methodological confusion

The literature that addressed future trends of VR in education used these approaches in surprising confusion. Many of the scholarly papers that were published in the last decade did not succeed in clarifying upfront with which approach the research has been conducted. Most of the papers tended noticeably to mix the preferable with the probable without noticing this methodological mistake. Most of the authors did not even find it necessary to note that there is a need in a valid forecasting methodology with which one should engage in forecasting the trends. They have just used their "commonsense" or their "gut feeling" to evaluate the "probable" trajectory of VR in education. Here are a few examples that demonstrate this kind of confusion.

Future requirements for augmented reality in schools

Claiming that relatively little is known about the potential of Augmented Reality (AR) to support teaching and learning with groups of young children in the classroom, a recent study (Kerawalla, Luckin, Seljeflot & Woolard, 2006) have suggested four design requirements that need to be considered for AR to be successfully adopted into classroom practice in the future. These requirements according to the authors are: Flexible content that teachers can adapt to the needs of their children; guided exploration so learning opportunities can be maximized in a limited time; and attention to the needs of institutional and curricular requirements.

Even though this particular study deals with augmented reality rather than virtual reality, one could find many similarities between them. AR as well as VR affords the demonstration of spatial relationships and the interactions of elements within a 3D space. AR, however, as opposed to VR further provides the potential for seamless interaction between the real and virtual worlds. It has the potential to engage and motivate learners to explore material from a variety of differing perspectives, and has been shown to be particularly useful for teaching subject matter that students could not possibly experience first hand in the real world .

One of the main differences is that whilst VR can immerse the user so that they cannot see the real world around them, AR allows the user to see a real world that is supplemented with virtual elements. Historically, AR has been of particular benefit when teaching or training people in potentially hazardous environments where real world experience is necessary but the actual presence of people in such an environment would incur an unacceptably high level of risk. For example, experiencing the touch and feel of a human limb and its resistance against a biopsy needle is important in medical training. However, the risk of using a real limb is too great, so overlaying an artificial limb with an ultrasound image of a real limb is beneficial in training medics in real world procedures .

Thus, it is possible that all four of the design requirements would also be true for general virtual reality as well as augmented reality. Nonetheless, in this study, it seems that the authors failed to distinguish between an educated wishful trajectory and a plausible trajectory based on evidence gathered with a reliable future oriented methodology.

Future teaching with disabilities

Take another recent research that conducted a meta-analysis of a cluster of published studies in an attempt to foresee the trajectory of VR applications in education. According to its authors (Standen & Brown, 2006), early expectations of the contribution that VR could make to education far exceeded actual applications. In their opinion, this was largely due to the initial immaturity of the technology and lack of evidence on which to base design and utilization. Their claim was, while the early developments in computer based learning largely concentrated on mainstream education, leaving those with special needs behind, the potential of VR as an educational tool was exploited for those with intellectual disabilities right from the start. Their study describes the empirical evidence that has contributed to the development of educational VR, mainly for those with intellectual disabilities. However, without paying attention to the flaw of their underlying methodology, they just projected this evaluation to the future and claimed that VR will continue to best suit intellectual disabilities in the future. The authors were not aware of the poor predictive validity of “trend-extrapolation” as a viable methodology to foresee the probable trend.

The future of VR in education organized under the four forecasting approaches

Before engaging in evaluating a wild future of VR in education, I believe it is important that the readers will learn to recognize the above four approaches in the studies that were published in recent years. These approaches were implemented in the evaluated trends they claimed to suggest unintentionally most of the time. Their authors, I believe, were not aware of these approaches. However, if they were to undertake an approach, I assume they were to take the approach I chose to append them to.

Probable futures in VR & education

In the realm of probable futures, very few studies were conducted with valid Futures' methodologies. Here are a couple of studies that could have represented this approach.

Teaching social justice with VR

In an attempt to line up future probable beneficial uses of imaging technologies in higher education that advance social justice, Brunner, Hitchon, and Brown (2002) discussed how the misuse and ineffectiveness of shared decision making, specifically as related to power relationships and the redistribution of decision-making authority, would be addressed through the development of, what they termed as, technologically delivered experiential simulations (ES). In their study, the authors outlined ways in which ES can change higher education preparation programs to meet and adapt to the challenges of the future. ES entails using computer technology to modify a person's appearance, thereby evoking an atypical response from an audience. The key to their assessment for future use of ES is having the person with the modified persona learn lessons pertinent to democratic cultures and social justice from their experience of immersion in that response.

Although not stated explicitly, the authors in this study have implemented a methodology called “Precursor Events,” which tends to identify predictive events signaling a larger trend. Unfortunately, they didn’t follow its detailed procedure. Thus, their conclusion can barely be considered as a reliable prediction of a probable future.

The future VR literacy

Following the approach of predicting the most probable futures, I myself, have immersed in an attempt, in the early nineties, to foresee the probable development of VR in education (Passig, 1996), using a very simple Futures' methodology named "Relevance Trees" (RT). The RT is a diagrammatic technique for analyzing systems or processes which display distinct levels of complexity. The basic approach disaggregates a system's performance into a hierarchy of subordinate (secondary, tertiary, etc.) performance levels. The relevance tree depicts the hierarchical relationship in a tree-like pattern that helps provide a more complete understanding of a system and its trajectory. My study aimed at assessing the trajectory of the skills that VR could probably demand from users in the future. Drawing from the way immersive technologies have developed during the previous 50 years, the study developed a literacy scale depicting a continuous augmentation of literacy VR will probably be able to provide the learner with in the future. As in the history of the development of immersive technologies, from batch processing systems, through shared control and sensory intelligent systems, towards total inclusive systems, the study found it relevant to calculate that similar road VR literacy will probably take—from navigation skills, through manipulation and inclusion by effectors skills, towards total sensory support. My study elaborated on the methodology and discussed the credibility of its results.

Possible futures in VR & education

In the realm of possible futures, many studies have been conducted, but only very few with valid Futures' methodologies. The following two studies could have represented this approach.

Future VR rehabilitation and therapy

A nice study that used a semi Futures' methodology worth mentioning is the study done by Rizzo and Kim (2005). They decided to conduct this study since they believed the use of VR in the areas of rehabilitation and therapy is continuously growing, and found encouraging results reported for applications that address human physical, cognitive, and psychological functioning. They were therefore interested in seriously assessing its current and future trends. Aware of the need for a credible Futures' methodology, they have chosen the SWOT (Strengths, Weaknesses, Opportunities, and Threats) to conduct a methodical analysis for the field of VR in rehabilitation and therapy. Their structured examination of the factors relevant to the current and future status of VR in rehabilitation and therapy provided a good overview of the key issues and concerns that could be relevant for understanding and advancing VR rehabilitation and therapy. I assume they believed that they were conducting a study with which they were to understand the probable trends. However, actually they used a methodology that best suites the analysis of possible futures. Thus, even though they thought to understand the probable trends, in actuality they understood the possible trends only. Nonetheless, this study is one of the rare attempts to conduct a VR trend analysis with a valid procedure. In my opinion, the only flaw in this study was its fuzziness to better define its goals.

Future educational applications

In an attempt to assess future VR applications, Briggs (1996), conducted a Cross-Impact analysis in order to make an educated estimate of the future possibilities VR applications will provide in the forthcoming decade. Cross-impact analysis is a method that helps the process of scanning the field of possible futures to reduce uncertainties. The cross impact model was designed as a means of accounting for the interactions between a set of forecasts, when those interactions may not have been taken into consideration when individual forecasts were produced. Although not explicitly stated in Briggs' paper, this study scanned the vast possibilities of VR applications in a large variety of domains from architecture and business to religion and training/learning. Briggs (1996) surveyed the wide range of existing applications at the time, and examined the interlacing interactions between these applications. The result was fascinating at the time. He predicted, as a viable possibility, that by 2006 students will be able to study a vast array of subject matters in VR labs—from chemistry to history. Now, a decade later, one can say that his possible forecast turned out to be actual reality, at least in the education and training domain.

Wild futures in VR & education

To the best of my knowledge, no study was conducted with a valid Futures' methodology in the realm of wild futures. Wild futures are actually trends that are fulfilled less than 20 percent. Nonetheless, futurists tend to develop scenarios about them in order to prepare society for trends that might have tremendous impact on the environment. In this kind of study, it is therefore important to stress the percentage of its probability to occur in order not to confuse the readers into thinking that they are probable to possible futures. In a very extensive search of literature, I could not find any such study conducted in the last decade. However, one can interpret some studies as inclusively applying this approach without paying attention to its probability level. The following two studies could have represented this approach. Both studies evaluated the future use of multi-sensory systems in education.

Future VR social touch

Haans and IJsselsteijn (2006) reviewed a variety of applications in the area of mediated or remote social touch. Whereas current VR applications rely predominately on vision and hearing, mediated social touch allows people to touch each other over a distance by means of haptic feedback technology. Their review has found interesting future potential, such as the communication of simple non-verbal concepts, establishing a feeling of connectedness between distant people, or the recovery from stress. They found that the beneficial effects of mediated social touch are usually only assumed and have not yet been submitted to empirical scrutiny. Therefore, based on social psychological literature on touch, communication, and the effects of media, the authors proposed future directions for the field of mediated social touch and foresaw their realization.

However, they did not discuss why the potential of haptic feedback technology was not applied to date within educational applications. I assume that if they were to follow a Futures' thinking procedure with their analysis they could have concluded that within the following decade it will be considered a wild card to see the use of remote touch technologies within educational applications, even if the benefits seems to be obvious.

Future multi-modal interfaces

The same could be said about the following study. Richard, Tijou, Richard, and Ferrier (2006) conducted a survey of theory and existing Virtual Environments (VEs) in the field of education that included haptic or olfactory feedback. They found two different configurations that support interaction, size and reification through the use of immersive and multi-modal (visual, haptic, auditory and olfactory) feedback. One is the *haptic* interaction, which is achieved using different techniques ranging from desktop pseudo-haptic feedback to human-scale haptic interaction. The second is the *olfactory* interaction, which provides information using different fan-based olfactory displays (ODs). Based on this characterization, they discussed future development of such multi-modal VEs for education. What they concluded can easily fall into the definition of wild futures, since ODs' possibility to materialize in education within the near future as they claim is slim.

Preferable futures in VR & education

In the realm of preferable futures, very few studies were conducted with valid Futures' methodologies, even though one might have assumed this category to be a major endeavor in VR educational context. The following two studies, which were conducted using a futurized procedure, represent this category.

Future preferred path for VR in education

Al-khalifah and McCrindle (2006) conducted a meta-analysis of studies involving desktop-based or head-mounted VR systems in education. Their study aimed to determine what VR should contribute to the education process, and to formulate the perceived merits and limitations of using VR in general, and immersive CAVE-like systems in particular, as an education tool. They provided the results to a group of final year undergraduate students, who were registered on a module that described VR in terms of the scientific issues, application areas, and strengths and weaknesses of the technology, and asked for their view regarding the preferred path they think VR should take in education.

This procedure can be considered as representing the preferred path a specific group of students would like VR to take in education. However, it cannot be considered as representing the preferred direction future users would like VR to take. For a study to represent the majority of users or developers, a more valid future methodology is needed. The following study is such a procedure I have conducted with a more rigorous Futures' methodology.

Future preferred mission for VR in K-12 education

This study (Passig & Sharbat, 2000, 2001) did not aim to predict the future of VR in K-12 education. It aimed to evaluate the preferred mission of VR before the technology is widely used in schools. This study, in a sense, has taken a proactive approach in evaluating the needs and the appropriate educational theories to guide the development of VR before its widespread utilization. Other studies have aimed at observing evidence that show trends. However, this study, that involved 50 worldwide VR experts and scholars, aimed in drafting a preferred VR future pedagogic mission.

In the study we used a version of the classical Delphi forecasting methodology named the Electronic Imen-Delphi (EID) technique to draft a preferred mission in an anonymous online procedure. The EID procedure, as opposed to the Delphi technique, does not direct the participants to foresee future events. Instead, the procedure guides them towards general agreement and future growth. They are directed to reach one of the following five types of anonymous agreement: Total agreement, majority agreement, bipolarity agreement, partial agreement, or total disagreement. The agreement indicates the responsibility, self-awareness, and concept enhancement of the participants.

This study is best described as an exploratory investigation into two aspects of the participants' future images:

1) the complexity of their views regarding VR in K-12 education, and
2) their capacity to draw upon their future images and agree on a list of future mission statements.

The EID procedure with which the investigation was facilitated is based on three rounds with iterative feedback. In the first round, the researcher provides the participants with a number of "teasers" and asks them to draft questions around the teasers. The researcher later drafts the first questionnaire from the collection of questions that are received from the participants anonymously through electronic means. The participants then receive the first-round questionnaire for completion. The second round includes a list of statements that are drafted from the answers collected from the first questionnaire. In this round, the participants are asked to organize their preferences, their desires, and their vision regarding each of the statements on the list. In the third round, the participants receive a final list of agreement upon mission-statements. This list is given to the participants in order to express their satisfaction with the present situation and draft recommendations for future implementation.

The results of this specific procedure regarding a preferred VR educational mission indicated that the preferred perceptions and images of the future held by that international group of experts point to a striking transformation of the perceived role they would like to designate to future developers of VR in curricula. They preferred to see their role shifting from just providers of teaching aides to primary providers of a variety of new and alternative classroom structures, learning styles, and cognitive skills. Those mutually agreed upon concepts and mission statements regarding the use of VR in schools pointed to a new preferred pedagogy that is desired to be addressed by developers, users, scholars and teachers.

Initial indicators for a wild future

Wild futures' methodical procedures

Since I have chosen in this article to suggest a wild future's paradigm in educational VR that could enter the main stream by the end of the second decade of the 21st century, it is only right to elaborate on the rational and main procedures of the wild futures' approach.

Most of the futurists who study wild trends agree that such thinking is able to free creativity, which in turn could ignite the imagination to think about futures that are considered at present to be implausible but in time might turn out to be probable. Many describe wild card futures as a hammers' drill with which one can shape stiffly and stubbornly different thoughts that could lead to development of unusual and bizarre ideas, which might have a great chance to materialize in the future. Some futurists even claim that with such thinking one could foresee revolutionary products in history, such as, the leap from the horse to the car, the pen to the typewriter and from the typewriter to the personal computer.

Petersen (1997) organized many such methodologies with which researchers nowadays are able to identify wild futures. Most of them use procedures that identify "bifurcations" in the development of the system that could take a shape of significant "attractors" later on. He found two main venues to identify wild futures. One venue is to try to identify the basic principle underlying the system at hand. After identifying and clarifying the principle as clearly as possible, the researcher can engage in identifying its anti-thesis. Following, the researcher can start to examine whether there are phenomena that could account for “attractors” towards the anti-thesis. These initial symptoms are called “weak signals” in literature (Coffman, 1997). If the researcher finds a logical number of weird phenomena that could fall under the anti-thesis she or he has identified earlier, the researcher then can draft a version of a wild future with great confidence that it will not be detached from reality, and that whatever looks like impossible today could easily be possible tomorrow, or whatever looks bizarre today could easily be acceptable tomorrow.

Another way to draft a valid wild trend, which many researchers prefer, is to turn the procedure over. Meaning, to start looking for unusual phenomena in a specific field, and only thereafter to examine whether these phenomena could flip over the basic assumption upon which the field is founded. If enough phenomena are identified to be able to shake the foundations of the system being analyzed, then one can engage in understanding their implications and draft a wild trend around them.

I have chosen to take the same road in this article by identifying unusual applications in VR and education and examining whether they could point to a wild educational paradigm that could emerge from them. The following are, however, a cluster of unusual studies in VR and education that have emerged in literature lately. I will evaluate their impact on the trajectory of the current paradigm.

Enhancing consciousness to body and self with VR

In recent years, some very interesting studies were conducted to enhance the way we perceive our body and self with VR. Some were designed to enhance the self image of handicapped children and adolescents and some were designed to enhance adults’ self consciousness. Here are some studies that could point to a wild paradigm in the making.

Out of body experience with VR

Oddly enough, two teams in cognitive neuroscience independently reported, during the same month, methods for inducing elements of an out-of-body experience in healthy volunteers with VR. Ehrsson (2007) reported an illusion in which individuals experience that they are located outside their physical bodies and look at their bodies from this perspective.

The method Ehrsson used involved placing two video cameras next to each other, like robot eyes, behind a volunteer. The image captured by the cameras is displayed in an HMD worn by the volunteer, who consequently sees his or her body from behind. Simply seeing one’s own body as another would see it does not in itself constitute an out-of-body experience. Such an experience also requires that the person sense their self outside of their physical body. Ehrsson and his colleagues managed to produce just such a sensation. A team member stood behind the volunteer and touched him or her outside of the frame of the camera. The volunteer then reported to be able to feel the sensation, but could not see his or her body being touched.

It seems that the brain responds to the hand that touches the illusory body, whereupon the volunteer has a powerful experience of being several meters outside their actual body. According to Ehrsson (2007), the self has thus moved 2 meters in space and left the actual body, which instead feels like an empty shell, a doll.

To test the method further, Ehrsson hit the 'phantom' bodies of the 12 volunteers of this study with a hammer and measured the degree of skin sweating in response to the provocation. He found that the volunteers exhibited the same physiological stress response as they would were their real body threatened.

The study claims that this new knowledge will enable scientists to investigate the 'self' for the first time and that in the future it may be possible not just to control a person in a virtual environment, but to become the virtual person, that is to say one's self will be able to move to virtual persons.

Manipulating bodily self-consciousness with VR

Interestingly, in the same issue of Science Magazine, Lenggenhager and his colleagues (Leggenhager, Tadi, Metzinger, & Blanke, 2007) published a study that used VR to manipulate self-consciousness. They designed an experiment that uses conflicting visual-somatosensory input in virtual reality to disrupt the spatial unity between the self and the body. Humans normally experience the conscious self as localized within their bodily borders. This spatial unity may break down in certain neurological conditions such as out-of-body experiences, leading to a striking disturbance of bodily self-consciousness.

On the basis of these clinical data, they found that during multisensory conflict, participants felt as if a virtual body seen in front of them was their own body, and mislocalized themselves toward the virtual body, to a position outside their bodily borders. The results of the experiment indicated that spatial unity and bodily self-consciousness can be studied experimentally, and are based on multisensory and cognitive processing of bodily information. This demonstrates that the experience of being localized within the physical body can be determined by the visual perspective in conjunction with correlated multisensory information from the body.

Enhancing body image of handicapped children with VR

Using VR as a tool to enhance the perception of oneself has been a concept that a variety of studies have been exploring. One study (Aharonovitch, 2004) examined the effect that an interactive activity using a self enhanced 3D virtual body representation had on the body image of children and adolescents with physical disabilities. The study examined the different effects of the virtual experience on the body image of different groups of subjects. It compared the body image of children with the body image of adolescents. It compared the body image of subjects with cerebral palsy (CP) from birth with that of subjects who contracted muscular dystrophy at a young age. It also compared the improvement of girls' body image to boys' body image.

Various studies have attempted to examine the question of how body image affects the personalities, behavior and self-image of people with physical disabilities. It was found that body image has implications regarding various personality disorders, depending on the severity of the impairment and the surrounding circumstances.

Among different programs for evaluating and enhancing body image that were developed during the years for handicapped children, one can find various programs in which the individual is shown a one-dimensional representation of his or her image in the form of a picture, a drawing, a shadow, via a mirror, in television and through different software packages. However, in this study the researcher used a Desktop VR application to enhance the participants' body image.

The subjects in this study were children and adolescents, aged 10-18, with physical disabilities (CP or muscular dystrophy) who attended special education schools. The researcher designed the study in several stages. First, the subjects completed a Body Cathetix questionnaire (body image questionnaire), and were photographed using a digital camera (full face only). Then virtual 3D entities were created depicting an accurate likeness of the subject. Following, the researcher introduced each subject to his or her 3D virtual body for about 20 minutes. The subject was able to change his/her virtual body's clothes and accessories, and select a movement for his/her virtual representation from a selection of 'healthy' movements ranging from passive to very active. At the end, the subjects were asked to complete again the Body Cathexis questionnaire for comparative purposes.

The main hypothesis of this study was that children and adolescents with physical impairment usually have a more negative body image than non-handicapped people, and that one reason for this is the way they perceive their image is reflected by society in mass media. The assumption was that since handicapped individuals extrapolate themselves from such representations, having an opportunity to see themselves with different gazes, using a technology that portrays them positively, would directly affect their body image.

Other hypotheses were that subjects with CP would have a different body image compared with subjects with muscular dystrophy, and that girls' body images would improve more significantly than boys. The results were compelling. The interaction with a self fully functional body had a significant impact on body image of adolescents. Their body image improved dramatically. The interaction improved also the body image of subjects with CP. Curiously, no significant change was observed in this study in the girls' body image, while in the case of the boys, the interaction with a self 3D virtual body had a significant impact on their body image.

To the best of my knowledge, very few VR studies were conducted with CP children. This study, however, similar to the above studies, investigated an existential aspect of mental health. Therefore, this kind of study could advance the theory and practice of using VR to support a more positive mental state at least for people with disabilities.

Enhancing cognitive skills with VR

In recent years, I have been conducting with colleagues a cluster of studies to test whether VR could enhance a variety of cognitive skills, and whether it could improve the awareness of teachers and parents to a variety of cognitive difficulties and impairments. Here are just some representing studies that can account for a growing category of research.

Enhancing induction and deduction skills with VR

In studies that have been carried out over the years, many theories have been presented on the cognitive development and performance of the deaf and hard of hearing. Many researchers have found that regarding reasoning and reaching a logical conclusion, particularly when the process of induction is required, deaf and hard-of-hearing children usually have difficulties.

One study (Passig & Eden, 2000) investigated whether the practice of rotating VR objects will have a positive effect on the ability of deaf and hard-of-hearing children to use inductive processes when dealing with shapes.

Three groups were involved in that study. An experimental group, which included 21 deaf and hard-of-hearing children who played a VR game, one control group, which included 23 deaf and hard-of-hearing children who played a similar 2D game (not VR game), and a second control group of 16 hearing children for whom no intervention was introduced.

The results clearly indicated that practicing with immersive VR spatial rotations significantly improved the inductive thinking used by the experimental group, as compared with the first control group, who did not significantly improve their performance. Also, while prior to the VR experience, the deaf and hard-of-hearing children attained lower scores in inductive abilities than the children with normal hearing, (control group II). The results indicated that the inductive abilities of the experimental group, after the VR experience, improved to the extent that there was no noticeable difference between them and the children with normal hearing.

This study focused on a specific field of thinking—Structural Induction (ISI). The underlying assumption of the study was that, while deaf and hard-of-hearing children have difficulty in inductive processing, this type of thinking can be improved. The assumption was based on various studies that had found that although the deaf resembled the normal hearing in most thinking-related tasks, the auditory and language deficiencies lead to lower verbal functioning and to lower results in tasks requiring inductive thinking.

The improvement of the structural inductive skills of the experimental group, while exploiting a VR game, was such that no distinct difference remained between them and the normal hearing control group after the intervention. The deaf and hard-of-hearing control group, however, who had no VR training, still maintained low scores. The gap between them and the normal hearing group remained the same even after the 2D practice.

Enhancing awareness to toddlers' cognitive state with VR

This study (Passig, Klein, & Neuman, 2001) used VR to simulate a toddler's experience during the first few days in daycare and improve the caregiver's understanding of the toddler's state of mind. The virtual worlds were developed in accordance with the toddler's way of thinking and from her/his cognitive and visual viewpoint. The aim of the study was to investigate whether the caregiver's awareness of the cognitive experiences that the toddler undergoes in his or her first days in kindergarten improves through a VR simulation of a toddler's world. We simulated six cognitive elements of a toddler: Object constancy; trial and error; perspective of height; perspective of things; egocentricity; and imagination. The participants in this study were 40 (female) caregivers who worked with infants aged 6 months to 4 years old in private daycare. The findings indicated that experiencing a virtual world that reflects the real world of children improves the caregiver's awareness of the cognitive experiences that the toddler undergoes in his/her first days in a kindergarten or daycare.

Former studies reported that the chronic shortage of manpower, unattractive salaries, and the expenses of in service training for caregivers have an impact on the quality of their teaching. This study, therefore, first confirmed that the participating caregivers' awareness to the cognitive experiences of an infant attending the initial days in day care is indeed low. Based on this validated assumption, the purpose then was to test whether using VR to train caregivers would make an impression on the caregiver, and influence his/her attitude towards toddlers. The research aimed to test whether a very small time investment (10 minutes in the toddler's virtual worlds) would produce significant training results for the caregivers.

To the best of our knowledge, this was the first study to report positive results for such a hypothesis. Many other studies have proved the effectiveness of VR in other training situations, but our review of the literature did not reveal any use of VR with cognitive and emotional aspects related to toddlers.

All the more so, we could not find any reliable tool in the literature in order to carry on with this study. Therefore, we investigated with different "childhood experts" the feasibility to draft a list of questions that will represent (somehow) the toddlers' cognitive way of thinking. It was quite an experience to draft this list. The "experts" (faculty members of the Baker Center for Early Childhood Education, School of Education, Bar-Ilan University http://www.biu.ac.il) recommended a short list that will be simple enough for the participants to follow. We believe that for an initial attempt to simulate the cognitive state of a toddler and test its efficiency this list was sufficient. Following the exercise in the virtual worlds, the most noteworthy improvement in the caregivers' awareness was in relation to the cognitive elements of perspective (objects) and the toddler's egocentricity.

The levels of awareness of the cognitive experiences a toddler undergoes in his or her first days at kindergarten improved most significantly amongst those caregivers that showed the least understanding of the element of separation. This was also the case in relation to awareness of the various elements of the child's cognitive stage, apart from the elements of trial and error and perspective (height). For these elements, there were no significant differences in levels of improvement between caregivers who demonstrated different stages of awareness before the experience.

We believe that this type of research opens a new path into uncharted territories—worlds that we could not easily and quickly touch and demonstrate. As opposed to the majority of studies using VR, this study did not simulate situations or worlds familiar to subjects, but rather created abstract scenarios from a human brain, and tested the efficiency of another person's interaction with them.

Enhancing awareness to dyslexia with VR

That conclusion brought others to further investigate this new territory. One such study was conducted by Shavit (2005), who tested whether we can enhance the awareness to dyslexia. She looked into the question of the impact VR can have on the degree of teacher's awareness of the cognitive experiences dyslectic pupils encounter while trying to read. The participating teachers were divided into an experimental and a control group. In the experimental group the teachers were exposed to ten immersive virtual worlds which simulated ten dyslectic students' cognitive experiences. The teachers in the control group watched a film which elaborated on similar experiences with audiovisuals. All the subjects filled out questionnaires before and after the intervention. The questionnaires tested the teachers' level of cognitive awareness of the dyslectic student's experience on meeting the written word. The research results indicated that experiencing a variety of simulated types of dyslexia with VR can bring about greater improvement in teacher awareness of the dyslectic pupil's cognitive experiences than is achieved by watching a film about dyslexia.

Enhancing awareness to test anxiety with VR

We have conducted another somewhat similar study (Passig & Moshe, 2008) to test whether we can enhance the awareness of test anxiety. Ninety subjects participated in that study, and were divided into three groups. The experimental group experienced a VR immersive simulation which made tangible the cognitive aspect of test-anxiety. One control group watched a video film on the subject, while the second control group read statements by pupils who suffer from that syndrome. The level of awareness was tested four times: Two weeks before the VR experience, one week before and immediately after the experience, and two weeks later. During each stage the subjects filled out an Awareness of Test Anxiety Questionnaire (ATAQ), which was composed expressly for this study.

A recent study funded by the Department of Education (TENDS, 2007) in the US, for example, found that 61% of all students reported being affected by test-anxiety, with 26% experiencing high levels of test anxiety often or most of the time. The study also found that girls were twice as likely to experience test-anxiety as were boys.

As a result of studies like this over the years, many programs of intervention have been developed to help students overcome their anxieties. These programs, to one extent or another, provided the teachers with means for helping students for whom exams are a great cognitive obstacle. Still, it has long been known that the teacher can have a marked effect on the students' level of anxiety during an exam, beyond the subjective conditions which arouse test-anxiety. Some studies pointed out that raising the teachers' awareness of test anxiety in its various manifestations can help the teacher understand and take better care of the students in the classroom.

This study therefore has been conducted to test whether a VR experience simulating the cognitive sensations perceived by a student who suffers from test-anxiety would improve pre-service teachers' awareness of the phenomenon.

Surprisingly, while examining the awareness to symptoms of the phenomenon it turned out that there was a significant rise in the level of awareness in the video control group immediately after watching the movie. Two weeks later, however, when the level of awareness of the symptoms of the phenomenon was tested, a significant drop in the level of awareness was measured. The experimental group, on the other hand, who were exposed to the VR experience, showed a rise in their awareness to the complexity of the phenomenon two weeks later, and not immediately after the intervention.

We suggested an explanation connected to the nature of memory. Studies have long noted that perceptions absorbed with great force can influence memory over an extended period of time. Many studies have found that a memory lasts longer if it is recorded at times of greater, as opposed to lesser, excitement. We then suggested that since VR is capable of providing a more powerful sensory experience than other technologies, it evidently etches its impressions into the memory of the person using it, so that she or he remembers them over a longer period of time.

This study demonstrated again that VR is significantly more effective than other technologies in increasing knowledge of highly abstract, hard-to-grasp cognitive states.

Enhancing abstract perceptions with VR

The most unusual studies in VR and education, to the best of my knowledge, have involved the endeavor to teach abstract concepts with VR. In recent years, I have been engaged with colleagues in this fascinating endeavor. Here are two examples that represent this track of research.

Enhancing time perception

Usually, the process of developing the perception of time continues from five to eleven years of age. This study (Eden & Passig, 2007) sought to test the most effective representation mode in which children could best express time concepts, especially the proper arrangement of events in a logical and temporal order. Most of the time, temporal order is examined and taught by 2D pictorial scripts. However, in this study we used Bruner's (1990) representation stages and tested the comparative effectiveness of VR as a mode of representation of children's conception of sequential time with the pictorial representation mode as well as the oral and textual modes.

The study involved 65 participants, aged 4 to 10, divided in two groups: kindergarten and school children. The study examined their ability to arrange episodes of a scenario in which a temporal order exists, using the different modes of representation.

The findings demonstrated substantial differences in the temporal order arrangement between the modes of representation. In the VR representation, the subjects had fewer errors than in the other representations. These findings suggest that even though the pictorial mode is the most common way of examining and expressing temporal sequence, we should establish new ways of presenting sequencing so that children will be better able to achieve their full cognitive and academic potential.

Prior to this study, to the best of my knowledge, the literature does not record other attempts to verify whether time perception is dependent on the mode of expression being employed. Therefore, the results of this study could open a new venue of research in order to better understand the potential and pitfalls of the modes of representation we use in educating our children. This study, above all, suggested that virtual reality technology is an important and efficient mode of representation in attaining a higher level of abstraction when compared to other modes.

Enhancing time perception of mentally retarded children with VR

Following the previous study, in which we found that VR is the most effective mode of representation for normative children to develop and express temporal order, Bezer (2007) investigated whether this will apply to mentally retarded children as well.

People with mental retardation present different cognitive difficulties which include slow and imprecise processing of information, difficulties with memory tasks, difficulties with the use of cognitive strategies, difficulties with the perception of abstract concepts, and so forth. In the past, some studies have examined time perceptions within this type of population. Researchers reported that time perception among children with mental retardation is developed later in comparison to the population of normative intelligence, if at all. Especially, they described how this population has significant difficulty in carrying out sequential tasks. Thus, Bezer (2007) engaged in testing whether VR can improve their time perception.

Eighty-seven participants aged 9 to 21 with mild and moderate mental retardation took part in this study. They were divided into three groups: An experimental group and two review groups. The participants from the experimental group and from the first review group exercised the same sequential task scenarios. The sole difference between these two groups was the representation mode. The experimental group underwent a VR intervention program twice a week during one month. The participants of the first review group exercised the same scenarios with 2D pictures. Each participant from both groups received a measure of mediation according to his/her needs. The second review group included children with mental retardation who did not undergo an intervention program, but participated in two unique meetings. In those two meetings, the participants arranged scenarios of 2D pictures without any mediation. Those two meetings were conducted one month apart. The second review group constituted a rating scale for the difference of sequential time perception without an intervention program.

All the subjects have been examined through "Photo Series" Sub-tests taken from Kaufman's test (K-ABC) for children (Kaufman, 1990) before and after the intervention, while the goal was to see if any improvement occurred at the end of the intervention. The assumption was that a difference would be found on sequential time perception between children with mental retardation who exercised VR sequential task scenarios (the experimental group), and children who exercised 2D pictorial sequential task scenarios (the first review group), when VR representation would bring more successes. This assumption was reinforced and found to be significant. Moreover, the results also indicated that VR representation required less mediation for greater success than the 2D representation.

A wild future for VR in education

Following the procedure mentioned above for identifying wild futures, one can suggest that these studies and others alike can account as early indicators to a wild paradigm of VR in education. However, to validate this assumption one needs to describe a possible cultural and economic background in which these indicators can prosper and be nurtured to evolve into an actual future. One such cultural paradigm is in the making in recent years that could nurture these indicators to enter the main stream and become a dominant paradigm in using VR in education. It is called the Flynn effect.

Flynn effect

In the early 80s, Flynn (1980) looked into the issue of race and IQ in ways that stirred amazement at the time. His inquiry led him to believe that an environmental, not genetic, cause is at the root of the black-white IQ gap, which was suggested earlier by Arthur Jensen (Miele, 2004). Jensen, a scholar of high repute at the time, actually thought that blacks on average were genetically inferior. That determination sent shock waves around the world and generated intense political and academic debates. After finishing his first book on the issue, Flynn decided that he would look for evidence that blacks were gaining on whites as their access to education increased, and so he began studying US military records, since every incoming member of the armed forces takes an IQ test.

Sure enough, he found that blacks were making modest gains on whites in intelligence tests, confirming his environmental explanation. But something else in the data caught his eye. Every decade or so, the testing companies would generate new tests and re-normalize them so that the average score was 100. To make sure that the new exams were in sync with previous ones, they would have a batch of students take both tests. They were simply trying to confirm that someone who tested above average on the new version would perform above average on the old, and in fact the results confirmed that correlation. But the data also brought to light another pattern, one that the testing companies ignored. Every time kids took the new and the old tests, they did better on the old ones, Flynn claimed.

The testing companies had published the comparative data almost as an afterthought. It did not seem to strike them as interesting that the kids were always doing better on the earlier test, he argued. And so Flynn dug up every study that had ever been done in the US where the same subjects took a new and an old version of an IQ test. After examining that huge collection of data, it revealed a 14-point gain between 1932 and 1978. According to Flynn’s numbers, if someone testing in the top 18 percent in 1932 were to time-travel to 1978, he or she would score at the 50th percentile.

When Flynn finally published his work in 1984, Jensen objected to the fact that Flynn's numbers were drawing on tests that reflected educational backgrounds. He predicted that the Flynn effect would disappear if one were to look at tests, such as the Raven Progressive Matrices, that give a closer approximation of the 'general intelligence' (g), by measuring abstract reasoning and pattern recognition and eliminating language altogether. And so Flynn dutifully collected IQ data from all over the world, all of which showed dramatic increases.

The trend Flynn discovered in the mid 80s has been investigated extensively, and at present there is little doubt that he is correct (Murdoch, 2007). In fact, there is even evidence that the Flynn effect is accelerating. US test takers gained 17 IQ points between 1947 and 2001. The annual gain from 1947 through 1972 was 0.31 IQ point, but by the '90s it had crept up to 0.36.

Flynn effect's causality debate

Though the Flynn effect is now widely accepted, its existence has in turn raised new questions (Flynn, 2007). The most fundamental: Why are measures of intelligence going up? The phenomenon would seem to make no sense in light of the evidence that g is largely an inherited trait. We're certainly not evolving that quickly.

Lately, Flynn and William Dickens (Dickens & Flynn, 2001), a Brookings Institution economist, proposed one explanation made apparent to them by the Flynn effect. Imagine somebody who starts out with a tiny little physiological advantage: He's just a bit taller than his friends, Dickens says. That person is going to be just a bit better at basketball. Thanks to this minor height advantage, he tends to enjoy pickup basketball games. He goes on to play in high school, where he gets excellent coaching and accumulates more experience and skill. And that sets up a cycle that could, say, take him all the way to the NBA, Dickens says.

Now imagine this person has an identical twin raised separately. He too, will share the height advantage, and so be more likely to find his way into the same cycle. And when some imagined basketball geneticist surveys the data at the end of that cycle, he will report that two identical twins raised apart share an off-the-charts ability at basketball. If you did a genetic analysis, you'd say: Well, this guy had a gene that made him a better basketball player, Dickens says. But the fact is, that gene is making him 1 percent better, and the other 99 percent is that because he's slightly taller, he got all this environmental support. And what goes for basketball goes for intelligence: Small genetic differences get picked up and magnified in the environment, resulting in dramatically enhanced skills. The heritability studies weren't wrong, Flynn says. We just misinterpreted them.

Dickens and Flynn (2001) showed that the environment could affect heritable traits like IQ, but one mystery remained: What part of our allegedly dumbed-down environment is making us smarter? It's not schools, since the tests that measure education-driven skills haven't shown the same steady gains. It's not nutrition—general improvement in diet leveled off in most industrialized countries shortly after World War II, just as the Flynn effect was accelerating.

Most cognitive scholars remain genuinely perplexed. "I find it a puzzle and don't have a compelling explanation," said Harvard's Steven Pinker in an interview with Steven Johnson from Wired Magazine (Johnson, 2005). "I suspect that it's either practice at taking tests or perhaps a large number of disparate factors that add up to the linear trend."

Flynn has his theories, though they're still speculative. "For a long time it bothered me that *g* was going up without an across-the-board increase in other tests," he said in the above mentioned interview. If *g* measured general intelligence, then a long-term increase should trickle over into other subtests. "And then I realized that society has priorities. Let's say we're too cheap to hire good high school math teachers. So while we may *want* to improve arithmetical reasoning skills, we just don't. On the other hand, with smaller families, more leisure, and more energy to use leisure for cognitively demanding pursuits, we may improve, without realizing it, on-the-spot problem-solving, like you see with Ravens."

When you take the Ravens test, you're confronted with a series of visual grids, each containing a mix of shapes that seem vaguely related to one another. Each grid contains a missing shape; to answer the implicit question posed by the test, you need to pick the correct missing shape from a selection of eight possibilities. To "solve" these puzzles, in other words, you have to scrutinize a changing set of icons, looking for unusual patterns and correlations among them.

This is not the kind of thinking that happens when you read a book or have a conversation with someone or take a history exam. But it is precisely the kind of mental work you do when you, say, struggle to program a VCR or master the interface on your new cell phone.

Over the last 50 years, we've had to cope with an explosion of media, technologies, and interfaces, from the TV clicker to the World Wide Web. And every new form of visual media—interactive visual media in particular—poses an implicit challenge to our brains: We have to work through the logic of the new interface, follow clues, sense relationships. Perhaps unsurprisingly, these are the very skills that the Ravens tests measure—you survey a field of visual icons and look for unusual patterns.

The best example of brain-boosting media may be videogames. Mastering visual puzzles is the whole point of the exercise—whether it is the spatial geometry of *Tetris*, the engineering riddles of *Myst*, or the urban mapping of *Grand Theft Auto*.

The ultimate test of the "cognitively demanding leisure" hypothesis may come in the next few years, as the generation raised on hypertext and massively complex game worlds starts taking adult IQ tests. This is a generation of kids who, in many cases, learned to puzzle through the visual patterns of graphic interfaces before they learned to read. Their fundamental intellectual powers were not shaped only by coping with words on a page. They acquired an intuitive understanding of shapes and environments, all of them laced with patterns that can be detected if you think hard enough.

A wild VR future paradigm: Inducing cognitive skills

Now imagine that a major player in the gaming industry will pick up this paradigm to be his marketing motto. Supported by some initial evidence that 3D in general and VR in particular could enhance some cognitive skills or even better could open the minds of students to uncharted concepts and abstract perceptions, the industry would generate intense pressures and incentives to further study and develop VR in that direction.

By definition, a wild future's probability has between 20-30 percent chance to materialize. Therefore, it is not farfetched to assume that someone would indeed follow this trail after some more studies of the above sort were conducted and the idea better validated.

In a world of global intense competition, such a marketing message can deliver great competitive edge to multibillion dollar industries. In a world in which parents are ever concerned about the mental well being of their offspring, the falling standards of education and the eagerness of children to spend ever growing hours in virtual games and spaces, it could be a promise no one would be able to resist, not even schools. In that case, a paradigm that promises its followers great intellectual gains and an edge over competitors in the classroom and the entry levels in the market place would be too hard to ignore.

Of course, as any other technology, it will see after a few short years of hype its disappointment. Other models in futures thinking like the *S model* have already established that after a few years of hype there are always the comedown years in which many more serious studies are conducted to better develop and validate the paradigm. However, since this article aims at looking at a wild possibility of the state of VR in education by the mid to the end years of the second decade of the 21st century, I assume that the hype stage could surround those years up to the end of the decade.

If this scenario would indeed materialize one should expect to see a growing industry and academic work that will deliver a vast variety of applications that would aim to target disorders from specific mental disabilities to sophisticated spatial as well as cognitive traits. Today, VR is poised to change the way we demonstrate ideas and familiarize children with some difficult to explain knowledge. In a wild future, VR could be a viable tool and driving force to accelerate the evolution of humankind, since it falls right under the ultimate characteristics of the Flynns' *cognitive demanding leisure hypothesis,* as reflected in its highly rich visual patterns of graphic interface. It sounds wild at the moment but there is a chance for such a trend if we are reading correctly the initial indicators as demonstrated in the above studies.

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