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Developing an Interactive Knowledge-Based Learning Framework with Support of Computer Graphics and Web-Based Technologies for Enhancing Individuals' Cognition, Scientific, Learning Performance and Digital Literacy Competences

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1. Introduction

The knowledge related to computer graphics principles, virtual reality, web3D and other advanced information visualization tools and techniques as well as low cost, but high quality hardware and software facilities has gained growing accessibility over the last decade. However, there have been the challenges of influencing and supporting individuals' skills, cognitive competencies and learning performance enhancements based on the mentioned principles and technologies (Dede, 2009); (Franco et al., 2009); (O' Connor & Cohn, 2010); (Osberg, 1997 a, b); (Winn, 1997); (Youngblut, 1998). It includes improving citizens' traditional and digital literacy skills and scientific competences related to reading, writing, mathematics and sciences (Franco & Lopes, 2009, 2011); (OECD/PISA in focus 2, 2011); (PISA, 2010); (Mervis, 2011); (UNESCO, 2008); (Wilson et al., 2010).

Hence, there has been the necessity of improving educational policy actions for decreasing the digital divide (Nachira et al., 2007); (UNESCO, 2008); (Ronchi, 2009) and enhancing learning performance (OECD/PISA in focus 6, 2011). These problems include improving educators' professional skills and competencies (OECD, 2011) for dealing with information visualization tools such as virtual reality, interactive media and electronic technologies (Fundação Victor Civita, 2010); (Lopes et al. 2010); (Osberg, 1997a); (Winn, 1997).

In addition, it has been necessary investigating mechanisms for promoting social innovation and development, and how these can be achieved from the top down or the bottom up, involving collaboration that can be enhanced based in a context of dialogue, mutual knowledge and respect (Huws, 2011). For instance, as demonstrated on the development of the educational theory and practice related to alphabetizing citizens within a critical way in order that they can become lifelong learners with autonomy (Freire, 1996).

The development of this long-term empirical work (Franco and Lopes, 2011) and its research material (Bricken & Byrne, 1992); (Dede, 2009); (O'Connor & Cohn, 2010); (Winn, 1997) have showed that using low cost, but high quality desktop virtual reality and other advanced information visualization techniques and tools on individuals' education have the potential for supporting a culture of promoting social innovation and development as well as influencing individuals' lifelong learning attitudes with sustainability.

However, using virtual reality and computer graphics techniques for supporting individuals' education has been explored in small scale in ordinary schools and citizens' daily lives. So, this work development has contributed for decreasing the problem of influencing empirical uses of computer graphics and information visualization techniques beyond academic research to "*solve a real-world (non-computer graphics) problem*" (Potel, 2004).

Bates (1992) has investigated the concept that virtual reality can "*let us go anywhere and do anything*" and as "*language of presentation will develop over time*" (Bates, 1992).

Ahead of virtual reality allow virtual world builders enriching the experience for participants, the current state of the art of digital technology has supported going *"beyond the visual, and it seems clear that music, speech, and other sound will be similarly important to the broad success of virtual reality*" (Bates, 1992) and inspire interactive experience. For instance, this learning possibility was explored in the creative, collaborative and interactive educational information visualization experience, which integrated through VRML, video, still images and sound files at k-12 education (Franco et al., 2008).

So, based on information visualization technology potential for improving citizens' lifelong education and professional lives, this work has faced the mentioned challenges through the strategy of influencing and supporting recursively and incrementally citizens' cognitive, scientific, learning and performance enhancements related to their traditional/digital literacy competences since k-12 education (Franco, Machado & Lopes, 2011).

This work includes training citizens for dealing with the growing amount of information and computing resources in the knowledge based society of the 21st century (Computing in the Core, 2011); (CORDIS Work Programme, 2010); (UNESCO, 2008). And addressing the industry needs of a skilled workforce for dealing with simple and advanced contemporary technologies within digital ecosystems (Digital Ecosystems, 2011); (Nachira et al., 2007).

An example of such needs is the collaborative project Virtual and Interactive Environments for Workplaces of the Future, (VIEW of the Future), which has investigated how the state of the art of "*virtual environment (VE) concepts, practices, methodologies, systems and relevant application guidelines*" (Wilson, 2002) can support the industrial market. And has analyzed VE e virtual reality influence on human development (Crosier et al., 2004), considering the growing use of emerging technologies on industrial and academic research and development R&D work and in training such as in the military field (Skinner et al., 2010).

The potential for supporting individuals to deal with the challenges highlighted on this introduction via using information visualization technologies, such as virtual reality (Bates, 1992), has indicated that educational policies need to be reconsidered and/or improved, as investigated in (OECD, 2010); (U.S. DE, 2010). For instance, there has been the necessity of amplifying investments for influencing an increase on individuals' grasping and using computer science and information visualization technologies at k-12 education within more effective ways (Camera, 2011); (Dede, 2009); (Fundação Victor Civita, 2010). And supporting educators' lifelong high quality knowledge and professional development because they are *"expected to be able to adapt to new knowledge and demands during their careers"* (OECD, 2011).

Such expectative has pointed investigating and applying at k-12 education daily work a recursive and consistent educational policy involving institutions (government, universities, k-12 schools) collaborative work from the top down and or the bottom up to enhance educators' knowledge and cognition for using advanced contemporary technologies (ACT) with fluency (Franco et al., 2009); (Fundação Victor Civita, 2010); (U.S.DE, 2010).

It includes improving disadvantaged students' ACT skills and scientific knowledge competencies both at school and surrounding community accordingly to Pont (2004) in (Davis 2008). "*This involves curriculum development, teacher training and development, contributing to community development, out-of-school support, and parental support. It involves community-wide programmes that empower the students*"(Pont, 2004, p. 179) in (Davis, 2008).

1.1 An interdisciplinary and interactive knowledge-based learning framework

A way for empowering students and educators' digital literacy knowledge and skills as well as supporting a school surrounding community development can and has been through carrying out an *interdisciplinary and interactive knowledge-based learning framework* (IIK-BLF) process with support of emerging and advanced information visualization technologies. It has brought about a culture of influencing individuals' cognitive, digital literacy, scientific and learning competences enhancements. This IIK-BLF has been carried out within a multilevel approach as in (McLoughlin, Kaminski & Sodagar, 2008); (Rueda et al., 2001).

This IIK-BLF development process has attempted to combine an increase on individuals' mentioned competences and stimulate ones' performance enhancements in the context of learning and teaching sciences concepts (Franco & Lopes, 2010 and 2011). It has used as motivation and sustainable support information visualization technologies, such as web-based and virtual reality (VR) techniques and computer graphics (CG) principles as in (Dede, 2009); (Franco, Farias & Lopes, 2010); (Osberg, 1997b); (Youngblut, 1998).

So, this IIK-BLF has focused on the problem of sharing knowledge related to information visualization technologies and on how-to-integrate and use recursively and incrementally, these and other diverse adaptive technologies (Digital Ecosystems, 2011) such as interactive media and virtual environments (NATE/LSI, 2011); (Skinner et al, 2010) within k-12 education curriculum development for enhancing individuals' computer literacy competencies as well as the teaching and learning of sciences (Davis, 2008).

For applying this IIK-BLF integration process, we have considered the growing influence of visual culture on citizens' daily life (Hernández, 2000) and on business communication processes (Bresciani, Tan & Eppler, 2011). These factors have brought about the necessity of improving citizens' visual alphabetization (Donis, 2007).

We have addressed this necessity through using interactive media and virtual environments in teaching/learning and training at k-12 education, employing lessons, which have been transferrable (Mestre, 2002), for instance, from the military training practices and reflections with virtual environments in (O'Connor & Cohn, 2010). So, this long-term IIK-BLF has applied educational actions beyond descriptions related to the necessity of improving STEM (science, technology, engineering, and mathematics) education at K-12 schools (Mervis, 2011). It includes the growing number of assessments and reflections about them such as in (PISA, 2010) and rhetorical policy and competencies guidelines in (UNESCO, 2008).

Hence, this IIK-BLF practical development has added value to investigations and reflections in contemporary R&D literature and practices related to using information visualization technologies since k-12 education (Dede, 1995, 2009); (Osberg, 1997a, b).

Both literature and practices have showed the necessity of putting into practice a long term, recursive and inclusive experiential learning work using advanced information visualization tools and techniques (Dede, 2009); (O'Connor & Cohn, 2010); (Youngblut, 1998). And influencing citizens' digital knowledge, skills and competencies enhancements, which can support individuals dealing with and learning STEM concepts (CORDIS Work Program, 2010) as well as improving their visual alphabetization processes (Donis, 2007).

1.2 This IIK-BLF long term contributions through using information visualization

This IIK-BLF has supported individuals' direct manipulating (Preece et al., 1994) interactive media technologies through influencing individuals programming computers and visualizing 2D and 3D web-based content during educational activities. It has been a long-term, recursive, incremental and spiral development strategic process, which has contributed for reducing the problem of enhancing individuals' digital literacy tacit knowledge, as exemplified in (Franco & Lopes, 2010, 2011); (Dede, 2009); (Osberg, 1997a).

This IIK-BFL development has showed that integrating low cost, but high quality information visualization systems, such as desktop virtual reality on individuals' formal and informal education has made an effective difference for influencing citizens' learning attitudes, cultural knowledge improvements and lives development in diverse ways.

So, this IIK-BFL has been an inclusive approach required for "*the interdisciplinary nature of human performance research to understanding the brain-body-environment intersection*" (Fiore, Salas & Palvas, 2010) and as a way of influencing ordinary individuals' cognitive and learning competences (Franco et al., 2009) through general and specific knowledge enhancements based on using interactive media and virtual environments (Del Nero, 1997).

Evidences for such reflections are that school and surrounding community have taken part of lifetime opportunities. For instance, the community has participated on the one-to-one learning model project from the Non Governmental Organization One Laptop per Child (OLPC), which in Brazil is called 'Um Computador por Aluno' (UCA) and carried out collaborative work with the Laboratory of Integrated Systems (LIS) from the Polytechnic School of the University of São Paulo. These actions have resulted on institutions as well as researchers and educators' cooperative work, including technical and human sustainability for developing innovative learning projects based on interactive media and information visualization technologies (Franco et al., 2009); (Franco & Lopes, 2011); (Lopes et al., 2010).

Another contribution is that this IIK-BLF has inspired individuals' development of problem solving competencies based on Wing's computational thinking concept (NRCC, 2011); (Wing, 2010) and conscious use of emerging and advanced information visualization technologies such as VRML (Nadeu, Moreland & Heck, 1998), X3D (Brutzman, 2008); HTML5/X3D (Behr, J et al. 2009, 2011) and Scratch™ (Resnick et al. 2009); (Scratch, 2011).

These contributions have supported individuals' growing awareness related to information technology (IT) marketing "demand for a variety of skills in areas ranging from website development to upgrading internal systems and meeting the needs of mobile users". Ones' computer programming (CP) skills and digital literacy knowledge enhancements have been key points for this. These skills have the potential of preparing citizens for better working life opportunities since CP will be first in line for IT jobs, accordingly to a survey (Saia, 2011).

Cognitive sciences investigation related to the ability of inventing and transmitting cultural objects has suggested that human brain is preadapted to cultural transmission, which requires minding other minds (Dehaene, 2009). Our reflections involving this IIK-BLF development and contribution have showed that this empirical work has gone beyond providing accessibility to advanced contemporary technologies such as virtual reality.

Key factors for that and this work sustainability have been ordinary individuals' mental models and cultural transformations. Citizens' have reflected and understood that dominating and using interactive media and technologies have brought about adding value to their education, citizenship, school and surrounding community development.

In addition, using contemporary information visualization technologies on individuals' interactive knowledge development processes have happened through growing collective conscience that "*a base of tacit knowledge is frequently a pre-requisite for making use of any particular bit of codified knowledge*" (Cortright 2001).

2. Individuals' tacit knowledge development based on interactive media and electronics environments and sciences support

Individuals' tacit knowledge has increased through a culture of direct manipulating, disseminating and integrating emerging visualization technologies related to interactive electronics environments (NATE/LSI, 2011) in educational activities with sustainability.

The sustainability has come from using accessible web-based technologies in this inclusive project and providing to individuals, for instance, boy and girls, equity opportunities for learning and using advanced information visualization technologies through ESB computers lab and beyond (Franco & Lopes, 2009, 2011). Examples that have supported this mood of influencing individuals' digital, scientific and tacit knowledge development with simulations are in (Dede, 2009). And in a R&D work, which has used VR, considering individuals' culture and creating a new way for engaging people with computers so that they can practice, learn and perform better (Belman, 2011); (ICT Cultural Awareness, 2011).

Another foundation that has supported influencing citizens' tacit knowledge development is that this IIK-BLF has integrated engineering, pedagogy and cognitive sciences diverse concepts, methods and epistemologies. This integration has brought about individuals' collaboration and cognition development through stimulating human to human and human computer interactions (HCI) as well as provoking research, create and visualize digital content (Rogers, Brignull & Scaife, 2002).

As in (O´ Connor & Cohn, 2010) such digital and human systems and sciences integration and interactions have caused opportunities for developing multidisciplinary and interdisciplinary learning through individuals' collaborative work. It includes ones' experiencing the concept of cognitive interactivity, which "*refers to interactions between internal and external representations when performing cognitive tasks (e.g learning)*" (Rogers, Scaife & Rizzo, 2005).

In practice, cognitive interactivity has been achieved through coding virtual environments via computer programming VRML scripts and visualizing them with support of individuals' collaborative, cognitive and human computer interactions (Franco et al., 2008). In addition, sciences, HCI interactions and digital systems integration within this IIK-BLF have contributed for developing an interdisciplinary, flexible and open pedagogic and technical architecture, which has been useful at k-12 education formal learning and educators' professional development (Franco & Lopes, 2008, 2009) and on citizens' informal learning and entertaining activities (Franco, Cruz & Lopes, 2006); (Franco et al., 2009).

Such engineering, pedagogy and cognitive sciences integration has also supported advanced R&D work such as a new research model called '*convergent research model*' (Sharp et al. 2011) and practical work related to learning sciences and developing psychological and social studies based on virtual reality within a cross-disciplinary environment (ICT, 2011).

Similarly, this IIK-BLF development has used such sciences and digital integration with support of VR and interactive media electronics (NATE/LSI, 2011), including advanced information visualization technology evolutionary R&D work (Instant Realty, 2011); (X3DOM, 2011) for influencing citizens' digital literacy skills and competences as well as cultural and scientific learning and performance enhancements processes (Franco et al., 2009); (Franco, Farias & Lopes, 2010); (O' Connor & Cohn, 2010) as in figure-1.

Fig. 1. An example of how this IIK-BLF has contributed for improving individuals' tacit knowledge through direct manipulating interactive media and technologies (such as text editor, VRML code, and a web3D-based browser as BS Contact™) for programming, visualizing and reflecting about the processes of enhancing knowledge and competences.

In the above example, at the end of 2009, in the computers lab of a Primary School called Ernani Silva Bruno (ESB), students from the 7th grade level presented to a geography educator, who was finishing her initial education course, how they were using web-based virtual reality technologies for learning and doing symbolic representation (Osberg, 1997b).

Through experiential learning activities students and educators practiced their cognitive abilities such as logical reasoning skills, with support of computational thinking paradigm (NRCC, 2011); (Wing, 2010). They used computer graphics principles and information visualization tools as problem solving instruments for creating scientific visualization (Cunningham, 2007) related to cultural and spatial data acquired on ESB School surrounding community nature and researched on the web.

The data was integrated in the virtual environment through VRML textual code and its related symbolic visualization as the panoramic view showed in figure-2, with support of both, a vision that "*a virtual reality system as producing surface level phenomena via the inter-face and associated software, then the organization and content of software well behind the interface constitute a\deep structure for the virtual world*" (Bates, 1992) and of the metadata approach

(Pocsai et al., 1998). So, ones experienced "*the arrangement of code and data that produces the essential meaning of the interactive experience*" (Bates, 1992).

Paraphrasing (Pocsai et al., 1998), the metadata approach has been recognized as a feasible technique, which in bibliography has worked since years. As showed on figure-2, "*metadata is represented as a set of facts about the resource*" (e.g. language (VRML). Each fact is represented as an attribute (or element). "*An attribute contains a type identifying what information the attribute contains and one or more values*" (e.g. **PointLight { location** 0.0 500.0 0.0, **radius** 3000.0, **ambientIntensity** 0.5} and **# Commentaries** in Portuguese language **(#controle da iluminação do mundo virtual / 'controling the virtual world lighting'))**. "*Metadata may be part of the resources themselves*" (e.g. information inside of a VRML <{meta}> tag) or "*kept separately from them (e.g. index information of www-search-engines, file creation date-information in UNIX file systems*") figure-2 on the left (Pocsai et al., 1998).

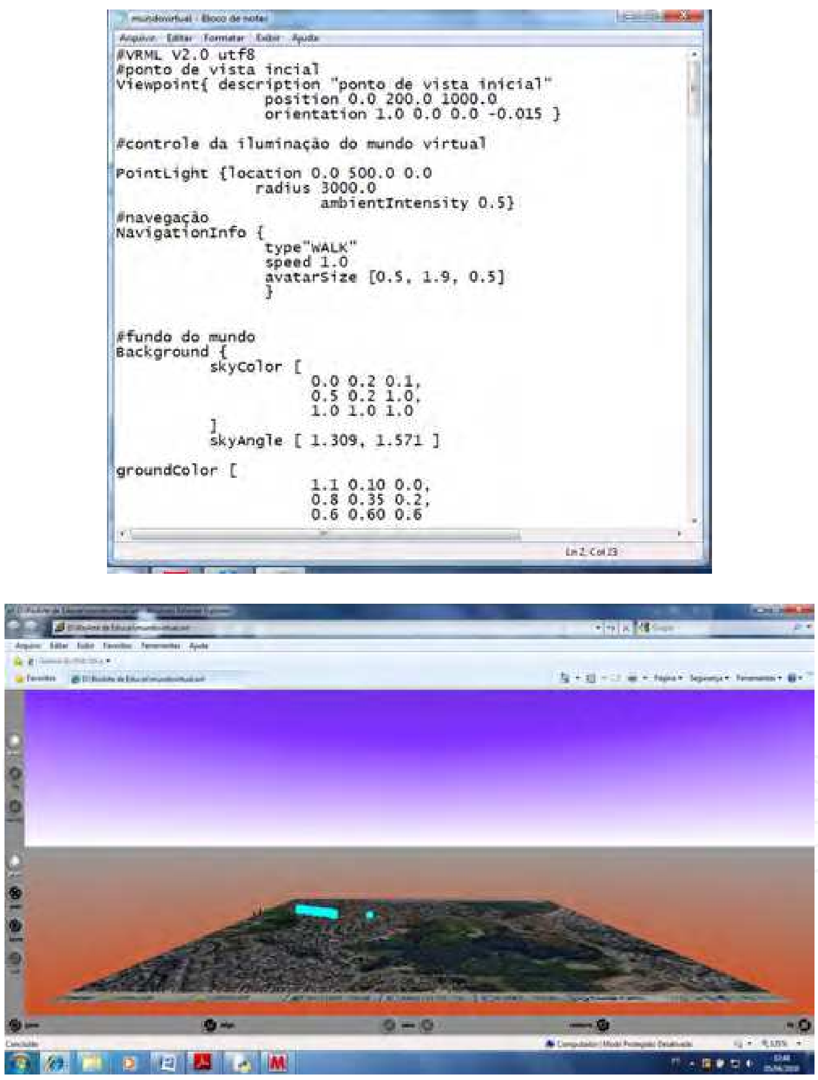

Fig. 2. VRML textual code and its symbolic representation using the concept of metadata in (Pocsai et al., 1998) and supporting individuals' tacit knowledge, digital literacy skills and cognition improvements such as attention, planning, critical thinking and memory through programming, saving and debugging the VRML file as well as enhancing ones' writing, reading and visualization abilities and competences.

Beyond the interactive learning processes of researching, reading, writing, creating the virtual environment and improving individuals' tacit knowledge, the educators and students meeting was an effective opportunity for developing collaborative work. The interactive meeting supported author1 and students' needs for preparing the digital artwork for a presentation in the city of Rio the Janeiro (Franco, Farias & Lopes, 2010). It brought about the possibility of sharing information visualization knowledge, via covering geography educator's lack of digital literacy skills. Including her interest in knowing how accessible and advanced interactive information visualization technologies can enhance educational activities related to acquiring geography concepts and supporting students' spatial thinking skills development based on information visualization technology (Chen, 2006) used for representing ESB surrounding community's urban life and natural resources as explained in (Franco, Farias & Lopes, 2010) and visualized in figures-1 and 2.

The human to human, and human computer knowledge based interactions exemplified above have been ways, which this IIK-BLF has contributed for developing students and educators' digital literacy skills and competencies beyond their initial education, and can serve a range of purposes, including to: "*update individuals' knowledge of a subject in light of recent advances in the area; update individuals' skills and approaches in light of the development of new teaching techniques and objectives, new circumstances, and new educational research; enable individuals to apply changes made to curricula or other aspects of teaching practice; enable schools to develop and apply new strategies concerning the curriculum and other aspects of teaching practice; exchange information and expertise among teachers and others, e.g. academics and industrialists; or help weaker teachers become more effective*" (OECD, 2011).

3. Related work

There have been several efforts for diffusing information visualization tools, techniques and knowledge and using them on individuals' education and training (Chen, 2006).

Roussou (2004) has carried out long term R&D work, for instance, through the NICE (Narrative-based, Immersive, Constructionist/Collaborative Environments) an interactive virtual learning environment for young children that has served as a test bed for exploring virtual reality (VR) as a learning medium. Her work has integrated psychology, cognitive sciences and learning theories as active learning theory, constructivism and constructionism, focusing on using the sensorial possibilities related to VR possibilities for supporting individuals' learning through interacting with 3D computer generated environments. Roussou et al. (2006) have created and compared interactive immersive and non-immersive VR environments potential for educating. The work has expanded through designing and offering children exploratory learning activities via 3D interfaces. And analysing children' tasks based on Vygotsky's Zone of Proximal Development (ZPD), which concerns the internalisation of social rules. For instance, taking in consideration that an individual using a 3D virtual environment can collaborate and learn with support from a more able peer, "*but is not yet able to complete the task unaided*" (Roussou et al. 2008).

Bricken & Byrne (1992) have developed experimental study using VR for conducting a summer course with k-12 education students. Students' activities have centred on hands-on exploration of new technology. Researchers have created virtual worlds and explored human's sensorial capabilities, which permit step inside to see, hear, touch and modify them. The investigation has evaluated *VR's usefulness and appeal to students ages 10 - 15 years, documenting their behavior and soliciting their opinions as they used VR to construct and explore their own virtual worlds*. As tools individuals have worn a head-mounted, audio-visual display, position and orientation sensors, and tactile interface devices, which allow inhabit actively an inclusive computer-generated environment.

Bricken (1992) has outlined a spatial algebra by mapping the structure of commutative groups onto the structure of space, considering interactions with spatial representations through natural behaviour in an inclusive environment that enforces the transformational invariants of algebra, which the spatial representation affords experiential learning. Experiential algebra permits algebraic proof through direct manipulation and can be readily implemented in virtual reality. The techniques used to create spatial algebra have brought about supporting to explore experiential learning of mathematics in virtual environments.

The Laboratory for Virtual Reality, Psychology, Rehabilitation, and Social Neuroscience at the University of Southern California's Institute for Creative Technologies has engaged in a broad program of R&D applying computer-mediated instruction for learning sciences, taking into account ways how people learn and methods of teaching that facilitate more effective learning experiences (VRCPAT, 2011). "*This is where ICT's learning sciences are making a difference. Through design, guidance, mentoring, and assessment -- we provide education that is both useful and unforgettable*" (ICT Learning Sciences, 2011). The research has also investigated human brain mechanisms that underlie neurocognitive functioning and emotion regulation in persons throughout the life course using as tools a cross-disciplinary environment and an interdisciplinary team integrated by computer scientists, writers, engineers, producers, administrators and artists, including a combination between virtual and augmented reality, psychology and social neuroscience. In addition, ICT's researchers have experienced and reflected that using virtual and augmented reality is an essential component in the evolution of medical and psychological sciences in the digital age. As any technology applied in these areas, both challenges and opportunities have emerged in how virtual and augmented reality are usefully applied and validated. For instance, the Virtual Reality Cognitive Performance Assessment (VRCPAT, 2011) has made "*use of virtual environments to create a battery of neuropsychological measures to assess the ways in which the structure and function of the brain relate to specific psychological processes and evident behaviors: attention-vigilance, effort, abstraction-flexibility, executive functioning, spatial organization, visual-motor processing, processing speed, visual memory, verbal abilities, and verbal memory and learning*" (ICT, 2011).

4. IIK-BLF Strategy and Information Visualization Technologies

As mentioned on this chapter introduction and tacit knowledge sections and exemplified in figures-1 and 2, this IIK-BLF strategy development has used advanced information visualization technologies and concepts (Duralach & Mavor, 2001); (CORDIS Work Program 2010) such as VRML (Nadeu, Moreland & Heck, 1998) and X3D (Brutzman, 2008) for supporting individuals acquiring tacit knowledge and developing cognitive, scientific and digital literacy skills and competencies.

This IIK-BLF has approximated recursively and incrementally individuals from web-based electrical engineering techniques (Pressman, 2006) and information and communication technologies (ICT) through hands-on work approach, which has allowed individuals' direct manipulating (Preece et al., 1994) digital technologies and creating microworlds for developing scientific knowledge as explained in (Bates, 1992); (Papert, 1993).

Hence, this IIK-BLF has also investigated an evolutionary R&D work, which integrates Hypertext Markup Language (HTML5) and X3D (Behr & Jung 2010). Such integration has been designed to allow interoperating diverse open-standard formats and using advanced web-browser capabilities for visualizing, interacting with and creating 3D web-based content without necessity of employing a plug-in (X3DOM, 2011), (Behr et al., 2011).

However, according to our empirical tests, in a computer without or using older consumer graphics card capability as GeForce FX 5200 (Chrome Help, 2011); (X3Dom Platform Notes, 2011), it has not been possible to visualize X3D content embed in HTML5.

On the other hand, having a capable consumer graphics card such as Intel™ GMA 4500M in a computer, the design of the X3DOM integration model and its tools can amplify the ways of using interactive media and electronic environments, computer science, computer graphics, scientific, cultural and digital arts knowledge integration through creating simple and complex applications as in figure-3. This integration has the potential of contributing for solving real world learning problems, for instance, related to enhancing students' math and geometry competences at primary education in third grade level. They have had difficulties for developing math abilities such as adding, subtracting, problem solving and recognizing geometric shapes accordingly a math research in Brazil (G1 Jornal Nacional, 2011).

With the growing accessibility to mobile devices and computers at schools and surrounding community, through using web-based information visualization technologies, as VRML in (Franco et al., 2009) and (X3Dom, 2011), a culture of creating symbolic representation based on scripts and its visualization can and has been diffused (Franco & Lopes, 2011). This kind of culture can support individuals deal with abstraction during simple and complex tasks (Wulfeck & Wetzel-Smith, 2010) through learning activities involving computer programming, describing and visualizing geometric shapes and colors, calculating shapes areas and moving them around the computer screen.

Fig. 3. Demo related to testing evolutionary R&D work, the X3DOM integration model that has been based on HTML5/X3D and supports diverse file formats such as MPG., PNG. JPG. and WAV. HTML5/X3D has been embedded in web browsers capabilities such as in Google Chrome™ and FireFox ™, allowing technology accessibility to all citizens.

These activities can happen through 'learning by doing', across reusing and adapting X3D scripts, in figure-3. So, as in (Bricken, 1992) individuals' interactions with spatial representations onto the structure of space and natural behaviors for carrying out such actions can lead citizens to live experiential learning processes related to *"attention-vigilance, effort, abstraction-flexibility, executive functioning, spatial organization, visual-motor processing, processing speed, visual memory, verbal abilities, and verbal memory and learning"* (ICT, 2011).

Due to their enormous potential for motivating learner and support active education related to exploratory and experiential learning (Osberg, 1997 a, b); (Youngblut, 1998), learning-by-doing (Walczak, Wojciechowski & Cellary, 2006), exploring and applying in practice active learning theory (Roussou, Oliver & Slater, 2008), interactive electronic environments, virtual reality techniques and 2D and 3D web-based formats such as HTML5/VRML/X3D have been objects of education, training and R&D work (Behr et al., 2011); (X3Dom, 2011).

Hence, these technologies can and have been lightweight enable virtual reality solutions for enhancing individuals' cognition, digital literacy competences, learning sciences and entertaining in great scale (Franco, Machado & Lopes, 2011). For instance, through using as media *"web-based I3D (interactive 3D) or emerging 3D TV systems, which may drastically speed up the adoption of VR technology in education. Both the end-users and the client infrastructure are ready for this change"* (Walczak, Wojciechowski & Cellary, 2006).

An example of interactive electronic system that has supported such concept is the integration involving Ginga, the Brazilian DTV system, and the X3D format, which has brought about X3D-GINGA architecture investigated in (Tavares et al., 2007). Another example of evolutionary R&D work using 3D environments by combining web-based standard description languages, such as X3D/VRML and Ginga Digital TV system integration has been carried out in (Souza, Machado & Tavares, 2010). They have proposed a specification that incorporates modules that can enable the implementation, development and execution of 3D applications. Souza, Machado & Tavares's (2010) implementation and comparative tests between a (OpenGL ES API, 2011) in Java and Nested Context Language (NCL), whose main characteristic is the mechanisms for synchronization of multiple media, with X3D have showed advantages in using X3D/VRML as demonstrated in table-1.

Characteristic	Ginga-J (Java) – JSR239	Ginga-NCL (NCL+X3D)
Collision Handling	Implemented by the developer - customizable	Supported in the browser - Predefined
Event Handling	Implemented by the developer - customizable	Supported in the browser - Predefined
Texturing	Implemented by the developer	Supported in the browser - Predefined
Lighting Techniques	Fully Supported	Partially supported
Robust techniques (Ray trace, Fog, Bump Mapping and so on.	Partially or not supported	Partially supported
Time to develop	Three days	One day

Table. 1. It shows a comparison between OpenGL ES API in Java and NCL with X3D based on empirical work developed by (Souza, Machado & Tavares, 2010).

This kind of comparative work has showed that through applying accessible web-based standard languages such as VRML/X3D and a web browser as tools for creating and visualizing information, it is possible developing an inclusive digital literacy, scientific, educational and cultural artwork, because such technologies have become available in great scale on ordinary personal computers and mobile devices as showed in (X3Dom, 2011).

Hence, even ordinary individuals, with low level of technical abilities as well as reading and writing competences can afford to understand how these digital systems work and use them for lifelong learning with autonomy. So, they can apply digital systems as a motivational and sustainable support for enhancing cognitive competences and learning performance.

Step by step, with support of the brain plasticity concept (Sharp et al., 2011) and hands on information visualization technologies, individuals can and have transformed their mental models and engaged in a culture of developing technical knowledge and autonomy for researching, appropriating themselves from digital systems and exploring their learning possibilities (Franco et al., 2009); (Franco & Lopes, 2010); (Franco, Machado & Lopes, 2011).

Influencing these individuals' mental and learning attitudes has been expected to be carried out at k-12 education as in guidelines (UNESCO, 2008); (U.S.DE, 2010) and can bring about citizens'scientific and digital literacy competences enhancements for transforming and creating digital content. For that, we take in consideration the visual culture influence in the knowledge-based society and the competences that have been expected from the workforce (Digital Ecosystems, 2011); (Nachira, 2007). For example, ones be able of doing complex tasks through using advanced technology with fluency and developing abilities for programming computers (Colson, 2007); (Fleming, 2011).

This long-term and recursive IIK-BLF inclusive approach development processes have showed that is feasible to address such society needs since the k-12 education. For instance, through influencing sixth grade level students' learn information visualization techniques for supporting their digital literacy skills. It includes grasping arts and math concepts and using their knowledge and imagination for creating digital content as showed in figure-4.

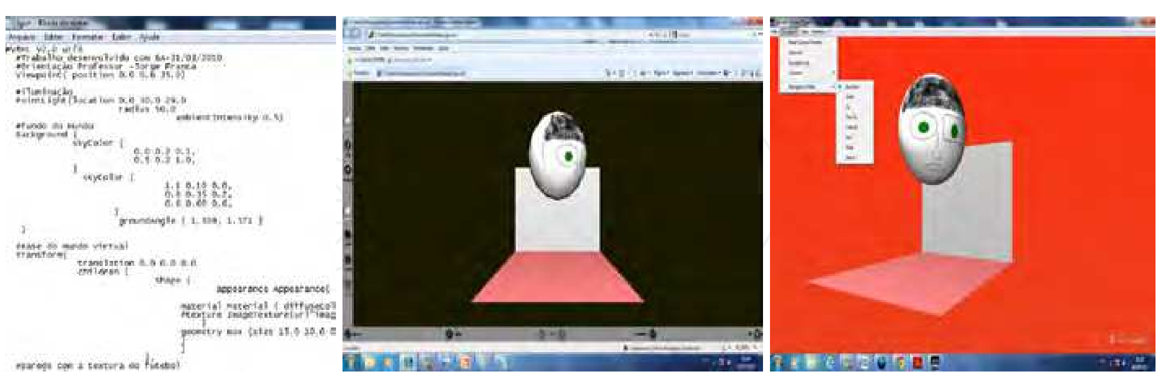

Fig. 4. The two pictures on the left and middle are part of the work carried out with and by sixth grade level students aiming to representing human body in the first semester of 2010. The picture on the right is part of our recent research for learning X3D tools and techniques and it is not implemented at school yet. However, as in the picture on the right, using the InstantReality Player™ can support a more inclusive and evolutionary work based on Extensible Markup Language (XML), virtual and augmented reality and JavaScript technologies (InstantReality, 2011), bringing about approximating individuals from more advanced computer programming skills development (X3Dom, 2011).

Back to ESB School learning and teaching of arts concepts based on information visualization, students from the sixth grade level used paper and pen in the classroom, including computers, virtual reality and web3D technologies inside the computers lab.

Students direct manipulated technologies such as a notepad for programming and debugging VRML code. These learning actions influenced students reading through writing; applying paint software for creating textures; knowing and employing a web-based language VRML; and using 2D and 3D web-browsers such as Internet Explorer™ and Cortona 3D Viewer™, bringing about enhancements on their digital literacy and tacit knowledge.

It was a collaborative work involving ESB School ICT Facilitator and Arts Educator, who participated from a small scale workshop, which the ICT Facilitator conduct for her understanding how advanced information visualization technologies could support students' further learning arts and math concepts initially investigated in the classroom.

During the knowledge-based interactions the educators reflected about the relevance of using such technologies for motivating and teaching students. After that, they used at school the same media and communication tools that entertainment and cultural industry such as movie, video and computer games ones have used to attract and maintain citizens' attention and consuming, for instance, 3D computer games and movies.

Using visual communication tools at school has been a relevant way of expanding a culture of researching and learning that can be linked with storytelling and movies characters, such as the princess Lea in the movie Star Wars. For instance, some physics concepts showed during the mentioned film have inspired information visualization R&D and a holographic system development based on fictional and storytelling culture as well as in the conceptual scientific knowledge applied on the artwork (3-D Teleconference, 2011).

In addition, cognitive sciences research related to brain development and neuroesthetics based on Jean Pierre Changeaux in (Dehaene, 2009, p. 309) has suggested that the culture of observing and creating artwork can support understanding that human brain as the synthesis of multiple evolutions "*harbors a wide selection of mental operations that can explain the complex emotional reactions brought on by a work of art. In neuronal terms a paint is broken down into many parts that are conveyed to numerous brain areas. Each of these regions processes one of the artwork attributes: color, texture, faces, hands, emotional expression. A work of art becomes a master piece when it stimulates multiple distributed processors in a novel, synchronous, and harmonious way*"(Dehaene, 2009, p. 309).

Through influencing hands on desktop virtual reality techniques on individuals' education across writing and reading VRML code and visualizing its symbolic representation, as in the empirical collaborative k-12 education artwork example above, we have addressed Dehaene's investigation about mental operations. Hence, this IIK-BLF development based on direct manipulating numbers through VRML/X3D coding, for instance '**translation 0.0 2.0 15.0**', which is related to Cartesian plan (**X (0.0), Y (2.0)** and **Z(15.0))** and subsequent virtual navigation using mouse/keyboard/other device and web browser interface has supported individuals' approximation from "*mathematical influence on basic and universal competences of the human mind, through structured mental representations of space, time and number that we inherit from our evolutionary past, and that we learn to recombine in novel ways with the help of written and spoken symbols*" (Dehaene, 2009 p. 309).

5. Incremental and spiral information visualization knowledge diffusion

In the course of applying information visualization technologies, this IIK-BLF has supported pedagogy empowerment as practical R&D work (Dede, 1995); (Osberg 1997 a, b) and school surrounding community collective intelligence development related to individuals become aware, understand and use interactive technology on their educational processes (Franco et al., 2008b); (Franco et al, 2009); (Franco, Machado & Lopes, 2011).

Our practical work and reflections have showed that diffusing within recursive, incremental and spiral ways interactive information visualization, media and technologies knowledge and practices can and have been a relevant approach for engaging individuals in a culture of knowledge-based development processes as in (Dede, 1995); (Osberg, 1997).

This research has focused on disseminating advanced information visualization technologies such as web3D and virtual reality and their pedagogical use as showed in sections 2 to 4.

However, as we have carried out work within a primary school, this IIK-BLF has also applied 2D web-based digital technologies such as Hypertext Markup Language (HTML), Scratch™ and blog, broadening the range of possibilities for using human and digital systems integration and interactions for supporting individuals' learning performance enhancements at ESB Primary School and surrounding community in figure-5.

Fig. 5. On the top left an informal collaborative learning work at ESB computers lab addressing student's HTML knowledge; top-right a student showing an example of how to use Scratch™ applying the laptops related to UCA project; bottom-left internal use of blog as learning resource; on the bottom-right using blog at an external event called Brazilian Fair of Science and Engineering 'Feira Brasileira de Ciências e Engenharia' (FEBRACE, 2011).

Through these ways of using interactive media and information visualization technologies we have avoided misusing computer graphics and the mentioned technologies in just one mood as investigated in (Skinner et al., 2010). Hence, step by step, this framework has influenced individuals' cognitive domain and cultural engagement for using information and communication technologies addressing ones' digital literacy, scientific, citizenship and lifelong performance enhancements within multimodal and formative ways as (Dede, 2009).

The information visualization technologies used by children during their formative years can and have influenced their learning strengths and preferences. So, as in Dede's thoughts (2009) "*an increasingly prevalent type of media, immersive interfaces, can aid in designing educational experiences that build on students' digital fluency to promote engagement, learning, and transfer from classroom to real-world settings*".

This IIK-BLF development has been a real world proof of such concept application. It has showed that learning the mentioned information visualization technologies integrated with educational activities involving k-12 curriculum sciences amplifies the potential of spreading advanced computer graphics principles and web-based technologies and scientific knowledge beyond the classroom environment (Franco et al, 2008, 2009).

Expanding this kind learning activities can and has achieved school surrounding community through individuals' knowledge-based interactions and better use of computers and digital media (Franco and Lopes, 2009, 2010, 2011) as well as supporting ones' lifelong learning attitudes and citizenship actions.

For instance, since 2007, after interactions with ESB ICT facilitator for learning to use (Blender™, 2011) 3D software as in (Franco et al, 2008), through first applying instrumental reading for grasping Blender tutorials, a student has developed further his English language skills. During September 2011, by e-mail, the former student wrote to the ICT Facilitator informing he has done an English language course and has planned to do as graduation course digital design. The former student has gained autonomy for researching further other computer graphics and information visualization possibilities such as creative design through image processing applying software such as GIMP™ that we have used at ESB computers lab. Examples of his digital artwork have been on the web-blog (Garrido, 2011).

Fig. 6. On the left a web3D-based environment using VRML, which first was developed at ESB Primary School as a virtual museum by a former student, and has been reused at his middle school for presenting a science work related to artificial insemination and sharing computer graphics knowledge with educators and classmates; on the middle his art work with GIMP™; on the right using Blender™ (Borsato, 2011) supporting his lifelong learning as well as scientific knowledge-based learning attitudes.

Another former student has developed his lifelong learning attitudes based on computer graphics using VRML, GIMP™ and Blender™ as educational resources in figure-6. These learning attitudes have brought about his research, reading, writing and communication skills and competences enhanced. It includes practicing his citizenship with conscience through sharing knowledge with other educators and students at the school environment, in which he has done his secondary education course.

5.1 Information visualization knowledge diffusion to educators and ordinary citizens

Although this IIK-BLF development has opened training opportunities to educators from diverse sciences areas (Franco et al. 2008a, b, 2009), including the geography and arts educator in sections 2 and 4, it has remained the problem of educators developing digital literacy skills for applying with fluency and autonomy advanced information visualization technologies (IVT) such as the ones used on this framework, during their teaching actions. Improving individuals' IVT tacit knowledge can and has been influenced formally and informally at school and home with support of standard web-based technologies. However, as in the military filed (O'Connor and Cohn, 2010), there has been a lack of technology specialists for supporting educators' training in large scale for learning how to deal with advanced digital technologies.

So, for instance, it has been relevant during schools district formative meetings as (IISEDJ, 2011), a seminar for enhancing educators' knowledge, which happened in September 23, diffusing ICT knowledge through direct manipulating technology and reflecting with other educators ways of using IVT for supporting citizens' problem solving and inquiring-based learning lifelong (Thirteen, 2004) in figure.7. It includes influencing interdisciplinary socio-technical and digital literacy competences, learning performance and cognition enhancements (Franco et al., 2009); (Franco and Lopes, 2011); (Skinner et al., 2010).

In addition, this IIK-BLF has addressed the concept that "it is very important that knowledge be transmitted to all the members of society. This transmission takes place through structures like schools, families, and training courses" (Thirteen, 2004) as in figure-7.

Fig. 7. On the left and middle left part of the information visualization and cultural material based on minimalism art concept used as content support for contextualizing a digital workshop with educators during the (IISEDJ, 2011), in which they direct manipulated VRML files and reflect how to interrelating the bits on the code with k-12 sciences curriculum development; on the middle right and right pictures an adult in the process of developing her digital skills based on informal education and lifelong learning concepts with support of games and simulation technologies (Honey & Hilton, 2011).

6. Reflections and conclusions

Based on the challenges mentioned on this chapter introduction, this IIK-BLF development, strategy and outcomes have highlighted empirical actions we have carried out for integrating technology, human knowledge, educational and sciences paradigms as well as enhancing individuals' learning performance and competences.

This work has showed and reflected about a conceptual and practical educational infrastructure that has been formed. It includes practical and propositional examples of using information visualization technologies attempting to approximate k-12 students and educators as well as ordinary citizens from spiral, incremental and agile programming techniques with support of low cost and free software and web-based engineering approaches (Pressman 2006).

These work strategies have addressed features such as problem solving, inquiring-based learning and exploring scientific models and visualizations with support of the computational thinking concept and its interdisciplinary application with great focus on K-12 education (Wing, 2010). These were demonstrated within our work examples in sections 2, 4 and 5, through applying diverse computer graphics simulations, advanced web-based tools and languages as well as other digital resources for stimulating young students learning sciences as in (Philip, 2007), (Rusk, Resnick & Cooke, 2009).

As has been showed, this IIK-BLF development has influenced early independence of youths' high potential for learning and researching using digital technology and capturing their creative potential. It has fostered youths' leadership and participation in collaborative research projects targeting first-ever and exploratory, multi-disciplinary research (CORDIS Work Program 2010) covering the problem of disseminating to and supporting citizens' access to innovative services and direct manipulate emerging digital technologies (Kaplan, 2010); (Jacobi et al., 2011); (VILNIUS, 2010).

In addition, this IIK-BLF has served as a base for developing a flexible, open technical and pedagogical architecture able to support interdisciplinary and interactive academic and popular evolutionary R&D work (Franco et al., 2009).

It has brought about stakeholders and partners together in order to provide innovation and equitable use of Information and Communication Technology (ICT) in education (Computing in the Core, 2011). For instance, the UCA project at ESB Primary School (Franco et al. 2009) has allowed reaching with effectiveness low achievers and disadvantaged students (Davis, 2008); (ECS, 2011) and increasing the participation of young girls and women in information technology field (Franco and Lopes, 2010 and 2011); (Franco, Machado and Lopes, 2011); (NCWIT, 2011).

Our empirical work has showed that this kind of socio-technical action can be deepened and disseminated in large scale through using emerging technologies such as the integration model HTML5/X3D that have been embedded in recent web browsers developments as in Google Chrome™ and Firefox ™, allowing technology accessibility to all citizens (Behr, J et al., 2009); (Behr and Jung 2010); (X3DOM, 2011).

These kinds of electrical engineering and technical support facilities have influenced carrying out interdisciplinary and interactive learning/teaching practices as in science and technology museums (Ronchi, 2009). Applying interactive media and technologies in museums has increased possibilities of citizens' scientific learning and entertaining experiences going beyond 2D and 3D interfaces enjoyment. At some extent, individuals have experienced *explorative and cognitive trails based on user profiles and the advice of communication experts and cognitive scientists* (Ronchi, 2009).

Interactive technologies, learning and cognitive sciences integration has been used on interdisciplinary scientific research, which has investigated *"from the movement of the ions at the individual neuron level up through learning in the service of complex cognitive functions such as planning"* encompassing *"an interactive, balanced approach that emphasizes connections between neurobiological, cognitive, and computational considerations"* (O'Reilly and Munakata, 2000). Although it is simplified, the above description is referent to neurons acting like detectors and working together synaptic processes related to brain plasticity/neuroplasticity (Brain plasticity, 2011); (Macher, 2004); (Wikipedia neuroplasticity, 2011). The synaptic processes are part of a wired network, in which detectors working together *"can exhibit useful collective properties that provide the building blocks of cognition"* (O'Reilly and Munakata, 2000).

A possibility of improving individuals' learning performance and cognition can be supported by educators' deepen knowledge on the brain plasticity. A current neuroscience research has attracted and integrated researchers from divergent backgrounds such as electrical and computing engineering and chemistry. The investigation has addressed how "*adult brain constantly adapts to different stimuli. This plasticity not only appears on learning and memory, but also as dynamic in information transmission and processing*". And the research model, which has supported it, is an interdisciplinary *new research model – convergence – which draws on an ongoing merge of life, physical and engineering sciences* (Sharp et al. 2011).

The concepts of brain plasticity and neuronal synaptic have supported the use of information visualization technologies such as VRML and computer programming techniques via text and its symbolic representation such as in section 4.

Applying these techniques has contributed for k-12 individuals and ordinary citizens amplifying their knowledge and competences for dealing with advanced emerging technologies. It includes learning how to work together and integrating their knowledge related to sciences, through collaborative teaching/citizenship actions as the work proposal and practice described in the convergence model (Sharp et al. 2011).

This IIK-BLF development processes have influenced individuals' cognitive enhancements involving fluency building, cognitive, refinement and sense-making processes investigated through the knowledge-learning-instruction (KLI) framework aiming to bridge the science-practice chasm to enhance robust student learning (Koedinger, Corbett & Perfetti, 2010).

Accordingly to psychological assessments related to comparing low-end personal computer based information visualization/simulations with high-end/realistic graphics visualizations *robust learning* can occur in both types of virtual environments (VE). Researchers have showed that what has influenced individuals' better cognitive and learning performance is the quality of tasks they have to accomplish within a VE (Skinner et al., 2010).

For instance, Wulfeck & Wetzel-Smith (2010) have demonstrated that a strategy for enhancing individuals' cognition can be developing visualizations, which make sciences concepts relationships observable. Through developing a relatively simple 3D box model using a web-based script language such as VRML/X3D, individuals can explore concepts related to point, lines, hypotenuse, angles, how calculating the box area, reflecting about attention processes referent to upper and lower cases during the writing and debugging of programming code.

This IIK-BLF has been carried out focusing on "how-to-integrate" information visualization technology and computer literacy skills for enhancing the teaching and learning of sciences (Davis, 2008) with support of adaptive technologies (Digital Ecosystems, 2011).

As exemplified through the empirical work in sections 2, 4 and 5 of this chapter, the mentioned information visualization technologies have supported individuals' learning performance, traditional and digital literacy skills and competences enhancements.

It includes individuals' cultural and cognition development through formal and informal learning activities within a recursive, spiral, incremental and hands on learning strategy (Franco et al., 2009); (Franco & Lopes, 2010 and 2011); (Pressman, 2006); (Ronchi, 2009).

There has been cultural and educational support for developing this IIK-BLF encompassing the visual and digital culture aspects. The visual culture has influenced from pre-historic to 21st century sculptures, paintings, artistic installations and digital art (Colson, 2007); (Graham-Dixon, 2008). And among other applications, emerging information visualization technologies have been used in the state-of-the-art of investigation related to applying games and simulations in education (Honey & Hilton, 2011) and in high risk environments such as military training (O'Connor & Cohn, 2010).

Finally, this IIK-BLF long-term development process with support of computer graphics, virtual reality, other diverse information visualization tools and advanced web-based technologies has brought about diverse individuals benefiting from the learning and teaching actions. It has showed that step by step this kind of inclusive and multilevel educational work has achieved its goals and worth it (Franco et al., 2009); (Franco and Lopes, 2011).

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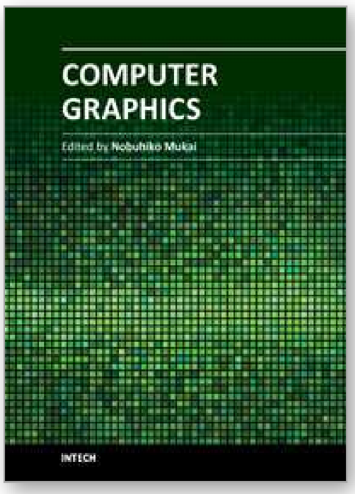

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Computer graphics is now used in various fields; for industrial, educational, medical and entertainment purposes. The aim of computer graphics is to visualize real objects and imaginary or other abstract items. In order to visualize various things, many technologies are necessary and they are mainly divided into two types in computer graphics: modeling and rendering technologies. This book covers the most advanced technologies for both types. It also includes some visualization techniques and applications for motion blur, virtual agents and historical textiles. This book provides useful insights for researchers in computer graphics.