3D Immersive and Interactive Learning

Yiyu Cai
Editor

3D Immersive and Interactive Learning

Springer

Editor
Yiyu Cai
Nanyang Technological University
Singapore

ISBN 978-981-4021-89-0 ISBN 978-981-4021-90-6 (eBook)
DOI 10.1007/978-981-4021-90-6
Springer Singapore Heidelberg New York Dordrecht London

Library of Congress Control Number: 2013931273

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Foreword

The introduction of the Internet into our conscious environment brought about a transformation in the way we communicate, making it possible to exchange information and acquire knowledge with little practical delays. While this represented a tremendous increase in efficiency, it was not until the advent of Web2.0 tools, which allowed for greater interactivity and enhanced online collaboration capability, that a new frontier was reached. Such tools fundamentally alter the ways in which we interact, and more importantly, they extend the connectivity for each individual to not just sources of knowledge, but also sources of expertise. A carefully structured connectivity sphere can then allow the individual to have access to a range of diverse and enriching interactions that was not possible before. When led by pedagogically sound designs, Web2.0 tools can be meaningfully weaved into teaching and learning environment to greatly enhance the educational journey of a learner.

3D visualization technology represents an important extension of interactive tools that has potentially inordinate applicability in a wide range of areas. Over the past five decades, this technology has made significant progress, particularly in bringing about accurate visualization of concepts that are difficult to verbalize. These include the illustration of the structures of macromolecules and the simulation of the life cycles of stars and galaxies. The use of the technology enables the learner to immerse in an environment that allows for learning through an increased range of sensory experience, which can potentially deepen understanding.

While there is much to be done in effectively using 3D visualization technology for teaching and learning, this book reports on a good range of efforts toward this end. It presents the collaborative efforts from researchers and practitioners in designing 3D native content for different subject learning, setting up of 3D environments for visual learning, conducting curriculum-based 3D classroom teaching, as well as nurturing students' learning interests and curiosity through 3D innovative co-curriculum research activities. Prof. Cai, the editor of this book with over 20 years of research experience in computer graphics, visualization and virtual-reality, has put together a commendable set of findings from a wide variety of work in using 3D visualization for teaching and learning. Such efforts are invaluable toward building a greater understanding of the educational use of such technologies. It is my pleasure to congratulate the editors and researchers represented in this book for adding on to our collective wisdom.

Dr. Horn Mun Cheah
Educational Technology Division
Ministry of Education
Singapore

Contents

Chapter 1
Introduction to 3D Immersive and Interactive Learning

Yiyu Cai, Chor Ter Tay and Boon Keong Ngo

Abstract The concept of 3D is not new. But never like today, 3D is rapidly entering our life. Using 3D for education is an innovative yet challenging work. This chapter introduces the concept of 3D Immersive and Interactive Learning, which is also called In-depth Learning. In particular, the enabling technologies and the supporting learning environments behind 3D Immersive and Interactive Learning are discussed. The relationship between In-depth Learning and other Learning Paradigms, such as Visual Learning, Simulation-based Learning, Constructivism Learning, and Engaged Learning, etc., are studied. This chapter also serves as an overall introduction to the whole book which presents several efforts in Singapore using 3D for In-depth Learning. The book covers a wide spectrum of education including Gifted Program, Normal (Technical) Stream, and Special Needs Education. The author(s) of each book chapter share their experiences from different angles on 3D In-depth Learning.

Keywords 3D • Immersive and Interactive Learning Environments • In-depth Learning, Science, Technology, Engineering, and Mathematics Education • Modeling, Simulation, Visualization, Interaction, User Interface • Virtual-reality • Assessment

Y. Cai (✉)
Nanyang Technological University, 50 Nanyang Avenue, North Spine, Block N3.2 Level 01 Room 08,
Singapore 639798, Singapore
e-mail: myycai@ntu.edu.sg

C. T. Tay · B. K. Ngo
ZEPTH Pte Ltd, Singapore, Singapore
e-mail: chorter@zepth.com

B. K. Ngo
e-mail: boonkeong@zepth.com

Y. Cai (ed.), *3D Immersive and Interactive Learning*,
DOI: 10.1007/978-981-4021-90-6_1,

1.1 Introduction

In early 2003, Singapore was hit by an invisible invader—the coronavirus of the Severe Acute Respiratory Syndrome (SARS). The SARS outbreak was a timely reminder of the importance of education on virus infected communicable diseases. In Sept 2003, a one-year permanent exhibition—Convergence of Art, Science and Technology (CAST) was open to the public in the Singapore Art Museum. At the Gallery #10, a 3D Protein Roller-coaster was designed by the first author and his students [1, 2] aiming to have an innovative, intuitive, and interesting way for the public to understand SARS-related viruses and their protein structures (Fig. 1.1a). The exhibition received good response. Based on the same concept, a Bio X-game was designed and exhibited in Oct 2005 at the China Science and Technology Museum in Beijing (Fig. 1.1b). In this game, the protein ribbon structure was

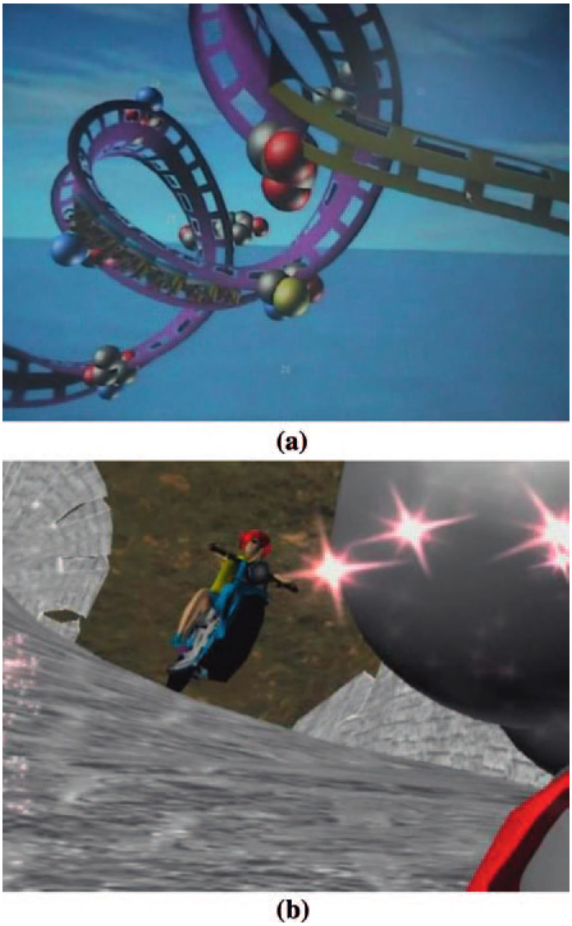


Fig. 1.1 Interactive and Immersive 3D Visualization: **a** a protein roller coaster; and **b** a protein X-game

modeled following the Chinese Great Wall. Players can learn molecular structures through riding on a virtual motorbike along the virtual Great Wall. In Dec 2005, Protein Rendition, the redesigned Bio X-game incorporating the protein sonification, was officially launched by Science Centre Singapore as part of the permanent Genome Exhibition [1, 3].

Around the same time, the high school section (also known as Chinese High School) of Hwa Chong Institution (HCI) in Singapore started to explore the use of 3D technology for learning applications. A small and simple Virtual-reality (VR) room was set up in the school in 2003 enabling the In-depth Learning through gaming. Students from the school formed a Special Interest Club. They organized workshops in their campus as well as in other schools to promote the concept of Learning Life Science through VR Gaming (Fig. 1.2a). River Valley High (RVH) is another Singapore school pioneering the use of 3D for In-depth Learning. A VR classroom was set up in the school in Feb 2007 (Fig. 1.2b). Since then, the school has organized various learning activities with their 3D learning environment. Mr Chow Ban Hoe from RVH will share his experience in Chap. 4 on 3D In-depth Learning in his school.

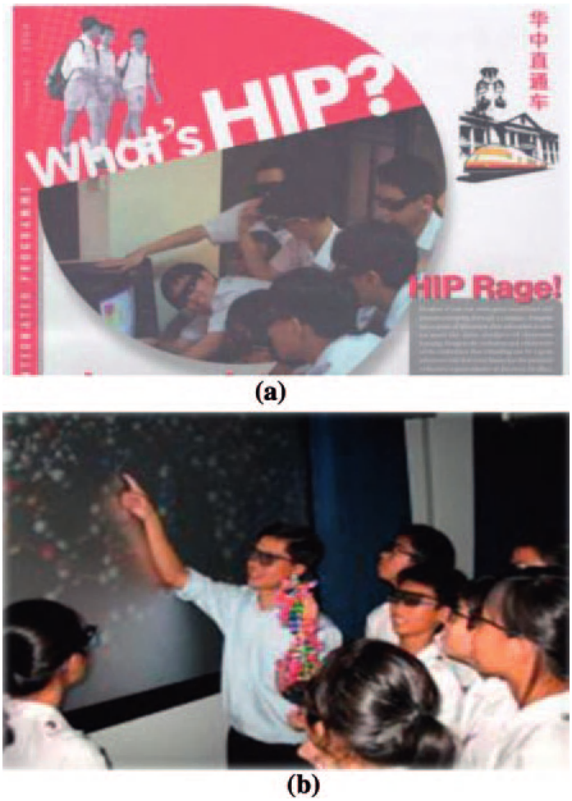


Fig. 1.2 **a** In-depth Learning in Chinese High School; and **b** In-depth Learning in River Valley High School

In 2008, the Singapore Ministry of Education (MOE) and Infocomm Development Authority (IDA) of Singapore launched the FutureSchools@ Singapore [4] project. The initiative aims to develop a peak of excellence in an ability-driven education paradigm and to encourage innovation in schools:

> These schools will not only enhance the diversity of educational offerings to cater to learners' needs but also provide possible models for the seamless and pervasive integration of infocomm technology (ICT) that includes interactive & digital media (IDM). By harnessing ICT in the education sector through innovative pedagogies and flexible learning environments, schools will be able to achieve higher levels of engagement of their students who already have an infocomm-integrated lifestyle. Thus, students will be equipped with the essential skills to be effective workers and citizens in the globalised, digital workplace of the future.

Among the five FutureSchools@Singapore, Crescent Girls School (FS@ CGS) and Hwa Chong Institution (FS@HCI) have set up their 3D Labs for In-depth Learning. CGS students attend Geography lessons in their Immersive and Interactive VR space. By virtual flying over the Victoria Falls in Africa, they learn map reading through gesturing with the aid of 3D technology (Fig. 1.3). At FS@

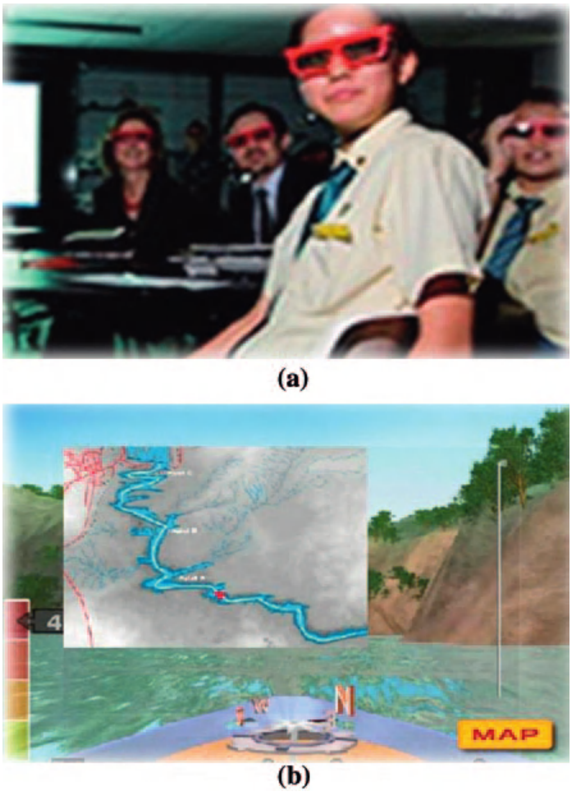


Fig. 1.3 In-depth Learning in FS@CGS: **a** the CGS's Immersive and Interactive VR space; and **b** learning victoria fall and map reading in the VR space

HCI, Mathematics and Biology teachers use their VR Lab to teach Trigonometry and Cell Biology. They also conduct pedagogical research on the impact of 3D for visual learning. Ms. Sandra Tan and Ms. Gwee Hwee Ngee from HCI will share their experiences in Chaps. 2 and 3 on 3D In-depth Learning of Biology and Mathematics, respectively. In Chap. 5, Mr. Joseph Tan et al. will share their interesting 3D sabbaticals conducted in HCI for students to learn Science, Technology, Engineering, and Mathematics (STEM) (Fig. 1.4).

Several other schools in Singapore have embarked on the journey of 3D for educational applications. The 3D Hub with the National Junior College (NJC) offers their students a platform to do various projects under their Science Training and Research (STaR) program. Figure 1.5a shows one of the projects—Sonar Terrestrial Observatory (STEREO). The same platform is also used to support their International Exchange Program (Fig. 1.5b) between NJC and Korea Science Academy (KSA). Mr. Nick Chan and his colleagues from NJC will share their story on 3D In-depth Learning in Chap. 6. In Chap. 7, Ms. Clara Wang and her team from Jurong West Secondary School will share their experience in teaching Nutrition with their Normal (Technical) stream using 3D Serious Games. Professor Noel Chia from the National Institute of Education and his collaborators will share in Chap. 8 their project on 3D virtual pink dolphins for special needs education.

In April 2011, the authors of this chapter organized a Symposium on 3D Learning in Singapore. This book is based on some of the selected papers presented at the symposium.

The remainder of the chapter is organized as follows. Section 1.2 discusses the enabling technologies for In-depth Learning in 3D Immersive and Interactive Environments. Section 1.3 investigates In-depth Learning with an emphasis on its relationship to Visual Learning, Simulation-based Learning, Engaged Learning, and Constructivism Learning. Section 1.4 gives the concluding remarks of this chapter.

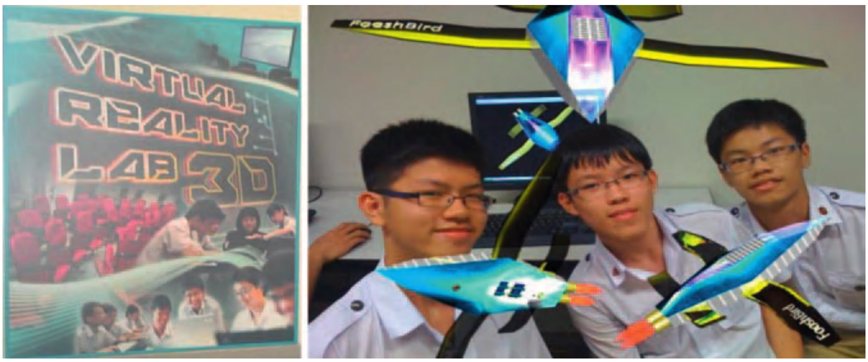
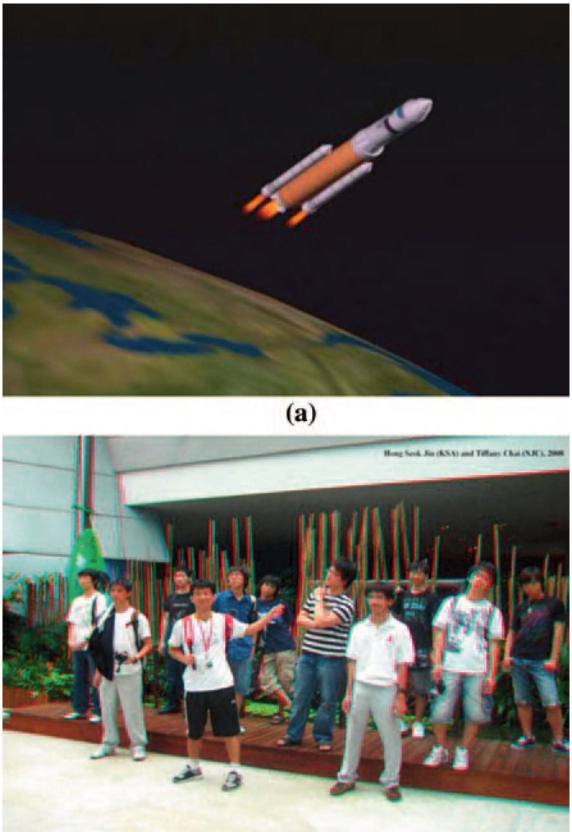


Fig. 1.4 FS@HCI uses their VR lab for In-depth Learning of STEM



(a)

(b)

Fig. 1.5 In-depth Learning in NJC: **a** the research project STEREO; and **b** the NJC-KSA international exchange program

1.2 Enabling Technologies for In-Depth Learning in 3D Immersive and Interactive Learning Environments

This section discusses the enabling technologies and 3D Learning Environments for In-depth Learning. In this study, 3D Immersive and Interactive Learning Environments are defined as Learning Spaces seamlessly integrated with 3D hardware, 3D software, 3D native learning contents, and pedagogy in the classroom or laboratory setting. Of specific interest, 3D modeling, 3D visualization, 3D interaction, and user interfaces are examined. These are four major enabling technologies for In-depth Learning in Immersive and Interactive Learning Environments (Fig. 1.6).

1.2.1 3D Modeling

3D modeling plays a fundamental role in creating objects with geometric shapes and physical behaviors in 3D spaces (Fig. 1.7). Rigid or deformable geometric

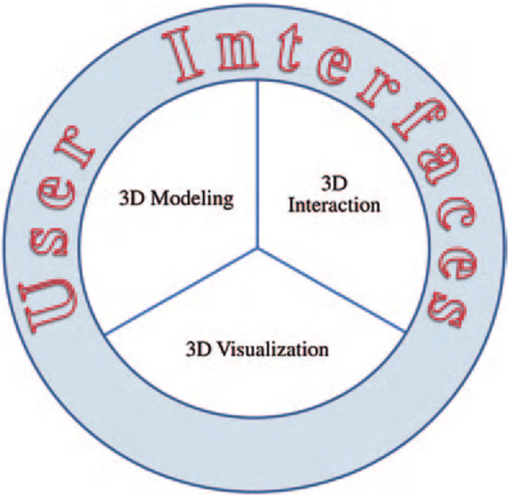


Fig. 1.6 Enabling technologies for In-depth Learning

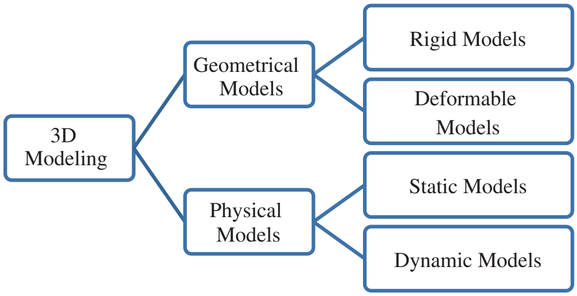


Fig. 1.7 3D modeling for In-depth Learning

shapes can be typically represented by polygons (meshes) or freeform surfaces. Meshed geometry is a popular representation widely used today in animation and games. On the other hand, objects' physical behaviors should be modeled as well for the purpose of illustrating their physical properties and dynamic change processes. The particle system is commonly used to simulate various physical phenomena like fluid, fire, etc.

Any objects in Immersive and Interactive Environments can be 3D modeled. The process of 3D modeling sometimes can be complicated. For instance, to model a protein molecule, one needs to deal with hundreds or even thousands of amino acids. Fidelity modeling, therefore, requires intensive domain knowledge about the context. It is highly important to create scientifically accurate models when describing and modeling learning content.

1.2.2 3D Visualization

Realistic visualization can assist students to better understand learning objects, concepts, and processes, especially the difficult ones. Visualization, however, is

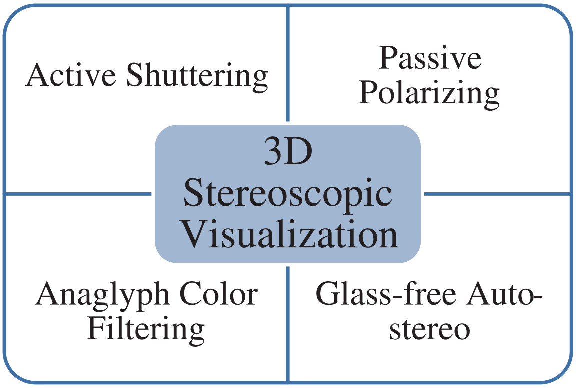


Fig. 1.8 Stereoscopic Visualization for In-depth Learning

traditionally 2D based. Objects or models in the 3D world of learning context are usually projected to 2D flat surfaces of printed textbook pages, blackboards, or projection screens. This projection could cause difficulty for students to figure out (or reconstruct) the disappeared third dimension of the original objects. Often, students are asked to use their imagination when dealing with 3D objects, or dynamic processes. This certainly poses challenges to many students (especially visual learners) when learning 3D based concepts using traditional 2D based learning paradigms.

Human beings live in the 3D world. Stereopsis is a human visual function. By processing a pair of images from the left and right eyes, the depth information can be perceived by viewers [5]. Based on the principles of human stereopsis, different types of 3D stereoscopic vision techniques (Fig. 1.8) are developed. Most of them synthesize the 3D perception by providing a pair of computer-generated images (one for the left eye and another for the right eye) with parallax information to produce the illusion of depth. While 3D modeling is a necessary task to develop Immersive and Interactive Environments, 3D visualization of 3D models is absolutely imperative in In-depth Learning. Stereoscopic visualization can produce realistic 3D effects' value added to Visual Learning.

1.2.3 3D Interaction

Interactions exist ubiquitously in real worlds between objects, between objects and users, and between users. In 3D Immersive and Interactive Environments, physical objects in real worlds are mapped onto virtual objects in virtual worlds, and interactions between physical objects are mapped onto interactions between virtual objects. Interactions between users and physical objects in real worlds are mapped onto interactions between users and virtual objects in virtual worlds (Fig. 1.9). It is therefore crucial to have interactions implemented in Immersive and Interactive Learning Environments.

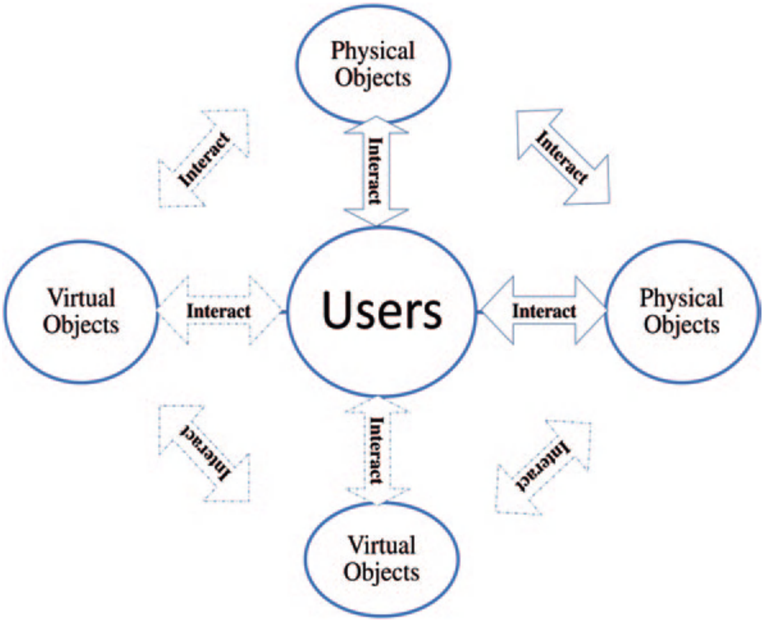


Fig. 1.9 Ubiquitous interactions for In-depth Learning

Benefiting from the advanced VR technology [5], users are able to experience or feel the interactions in virtual worlds. As such and ideally, in Immersive and Interactive Learning environments, students should be able to construct primitives when learning geometric shapes and feel the gravitation when learning Newton's Law of Universal Gravitation.

1.2.4 User Interfaces

In VR, interactions can be implemented via suitable devices and user interfaces (Fig. 1.10). Graphic user interfaces (GUI) are most commonly used in software applications together with the mouse and keyboard. The Natural Interface (NI) is getting more and more popular especially after Microsoft successfully launched their Kinect product for gesture-based human–computer interaction. Tactile/Haptic User Interfaces (T/HUI) emphasize the experience of touch or force feedback. Today, several haptic or tactile devices such as phantom and cybergloves are commercially available in the market.

It is possible to have the above three major types of user interfaces integrated in a 3D Immersive and Interactive Learning Environment. Complementary to each other, GUI, NI, and/or T/HUI will provide different ways for human–computer interactions depending on different needs in different situations.

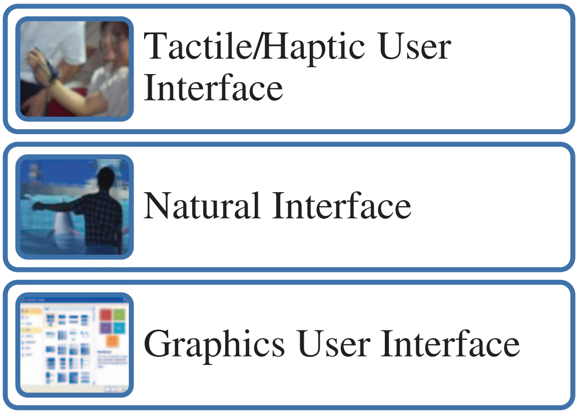


Fig. 1.10 User interfaces for In-depth Learning

1.2.5 3D Immersive and Interactive Learning Environments

Figure 1.11 shows an overall view of 3D Immersive and Interactive Learning Environments which are an integration of hardware, software, pedagogy, and contents. Construction of Virtual Environments, however, has a number of technical challenges which are beyond the scope of this chapter and more information can be found in [5, 6]. Here, we will give a brief discussion of the architecture of the environments (Fig. 1.11).

From the hardware perspective, 3D Immersive and Interactive Learning Environments are typically equipped with high-end computers, high-performance graphic processing units (GPUs), high-end projection systems, various interactive devices, and network facilities. From the software perspective, the environments usually have suitable software for modeling and simulation, interaction, graphics and visualization, and optimization. Different contents should be designed and developed for teaching and learning purposes. Content development, however, is a lengthy and challenging process. Without pedagogy, an Immersive and Interactive

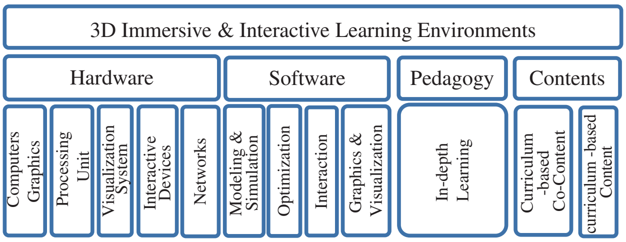


Fig. 1.11 3D Immersive and Interactive Learning Environments

Environment will never be a Learning Environment. Enabled by 3D technology; In-depth Learning is built upon Visual Learning, Simulation-based Learning, Constructivist Learning, and Engaged Learning.

1.3 In-Depth Learning in Immersive and Interactive Environments

Section 1.3 discusses 3D Immersive and Interactive Learning Environments and the enabling technologies behind the environments. This section will investigate In-depth Learning in 3D Immersive and Interactive Environments more from the pedagogical point of view. Specifically, efforts will be made to study the use of Immersive and Interactive 3D technology to enhance Visual Learning, Simulation-based Learning, Constructivist Learning, and Engaged Learning (Fig. 1.12).

1.3.1 In-Depth Learning is 3D-Enabled Visual Learning

Electromagnetism (EM) is a difficult topic in Physics for many students to learn due to its invisibility of the EM field. In Geometry, the concept of skew lines (SL) and shortest distance of a pair of skew lines are hard for students to understand because of the limitation of visualization using the traditional blackboard or printed papers of textbooks as major teaching media.

In-depth Learning is 3D-enabled Visual Learning which is different from conventional Visual Learning where usually seeing is believing. In 3D Immersive and Interactive Environments, students can view objects in true 3D without heavily relying on "imagination". With the third dimension easily available in immersive visualization, students can better understand difficult concepts like EM (Fig. 1.13a) and SL (Fig. 1.13b) avoiding imagination-caused spatial misunderstanding.

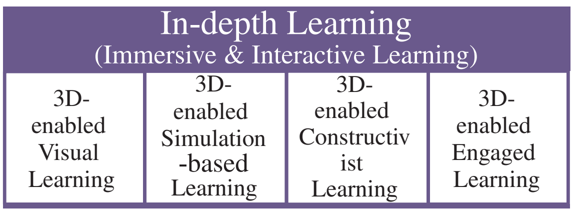


Fig. 1.12 In-depth Learning versus Visual Learning/Simulation-based Learning/Constructivist Learning/Engaged Learning

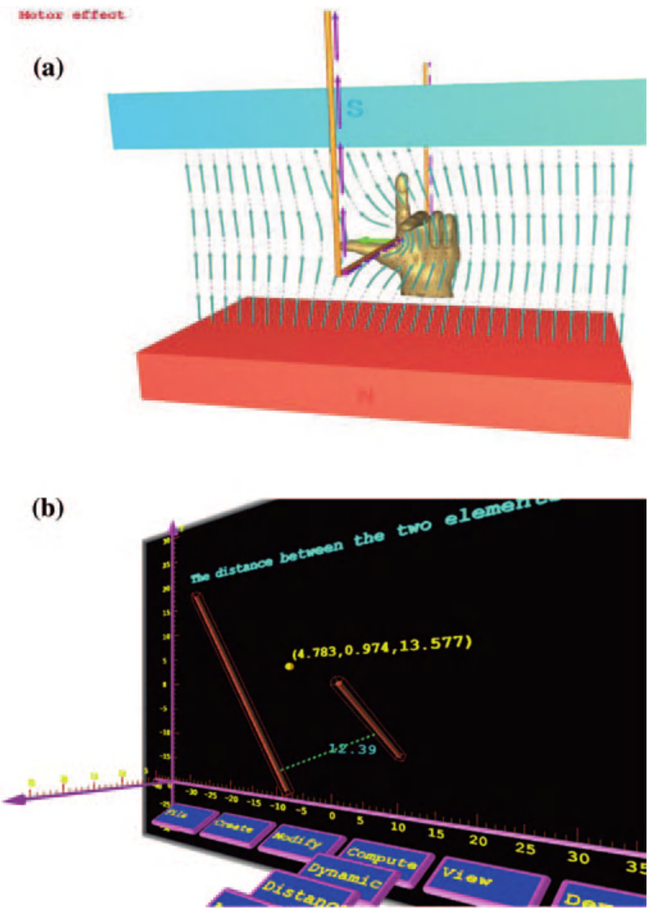


Fig. 1.13 **a** In-depth Learning of electromagnetism in Physics; and **b** In-depth Learning of shortest distance and skew lines in Trigonometry (Images courtesy of ZEPTH, CGS and HCI)

1.3.2 In-Depth Learning is 3D-Enabled Simulation-Based Learning

River formation is a process that takes a long time to develop. It is difficult, if not impossible, to show the real and dynamic processes of river formation to students when they are learning these topics. Mitosis and meiosis are two different types of cell divisions that often confuse students when learning Cell Biology. It is practically infeasible to show these two dynamic and real processes of cell division when students are comparing them. Simulation offers an alternative solution by providing realistic and dynamic processes to mimic the real situation. In-depth Learning uses 3D-enabled simulation technology to enhance learning.