Chapter 22
Multi-Level Adaptation in End-User Development of 3D Virtual Chemistry Experiments

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ABSTRACT

Multi-level adaptation in end-user development (EUD) is an effective way to enable non-technical end users such as educators to gradually introduce more functionality with increasing complexity to 3D virtual learning environments developed by themselves using EUD approaches. Parameterization, integration, and extension are three levels of adaptation ranging from straightforward to complex in terms of what end users have to understand in order to develop functional software applications, all within reach of end users without special training on programming. A 3D educational application EUD system proto-type, iVirtualWorld, has been expanded to support 3D virtual chemistry experiments generation using these three levels of EUD adaptation. An evaluation has been conducted on 18 participants from the education domain, and the results confirmed ease-of-learn, ease-of-use, and usefulness of this solution. Contributions of this paper are 1) a paradigm for applying EUD technologies in 3D virtual learning environment creation; 2) an easy-to-use tool for educators to build customized virtual chemistry experi-ments; and 3) empirical assessment data for the multi-level adaptation solution.

1. INTRODUCTION

Traditional on-campus hands-on experiments in physical laboratories have several limitations, such as limited resources (e.g. physical space, teach-ers and open hours) for students (Ertugrul, 2000; Lagowski, 1989), safety issues during experiments (Bell & Fogler, 2004; Chen, Song, & Zhang, 2010), expensive instruments and materials (Domingues, Rocha, Dourado, Alves, & Ferreira, 2010; Ma & Nickerson, 2006), and difficulties of implementa-tion in online or distant learning courses (Chen et al., 2010). Educators have been seeking comple-ments or substitutions for hands-on laboratories

for decades using emergent or developed computer technologies. Virtual laboratories, based on computer simulation, computer graphics and computer networking, have been proposed and studied by researchers from education and computer science. Virtual laboratories have significant advantages over traditional physical experiments: flexible accessibility, especially for distant learning students (Jensen et al., 2004); cost-effectiveness (Chen et al., 2010; Martinez-Jimenez, Pontes-Pedrajas, Polo, & Climent-Bellido, 2003); and safety (Chen et al., 2010; Martinez-Jimenez et al., 2003; Woodfield et al., 2005), to name a few. Studies provided evidences showing that using virtual laboratory could increase students' performance (e.g. problem-solving skills and cognitive skills) in the class (Woodfield et al., 2005; Martinez-Jimenez et al., 2003; Baher, 1998).

More recently, the development and the popularity of 3D virtual worlds provide platforms to extend the usefulness of virtual laboratories by putting students into multi-user virtual environments that can simulate real learning environments. Students could better develop spatial knowledge in navigable, interactive 3D environments than using non-3D, non-interactive alternatives such as photographs or video materials or panoramic photographs (Dalgarno & Lee, 2010; Trindade, Fiolhais & Almeida, 2002). Three-dimensional virtual environments also could be used to better model richer physical behaviors of objects (Dalgarno & Lee, 2010). Experiments that could not be performed or observed in the real world, e.g. molecular reactions, could be simulated in 3D virtual worlds (Trindade et al., 2002; Holloway, Fuchs & Robinett, 1992). Furthermore, 3D virtual environments could integrate hardware such as head-mounted displays (HMDs) (Holloway et al., 1992) or Cave Automatic Virtual Environment (CAVE) (Dalgarno & Lee, 2010) to form augmented reality environments. Virtual worlds also provide a social platform for users to express their creativity, share information and communi-

cate with each other. With these features, virtual worlds are ideal for creating virtual laboratories as a complement to traditional physical laboratories by overcoming the limitations of the latter.

Although 3D virtual worlds show great potential in building virtual laboratories for educational purposes, educators face difficulties when they apply 3D virtual worlds (Chou & Hart, 2010) in practice. Current virtual world building tools assume that their users have programming abilities. Nevertheless, many virtual world users (e.g. chemistry or biology teachers) have neither programming skills nor necessary resources to learn programming skills. This situation has been a barrier to broader adoption of virtual worlds in education.

End-User Development (EUD) studies to methods, techniques and tools enabling non-technical computer end-users to create or modify a software system to adapt their requirements. Research on EUD integrates Human Computer Interaction, Software Engineering, Computer Supported Cooperative Work, and Artificial Intelligence. In the domain of chemistry experimental education, educators are end-users who do not have a programming background. Their applications are 3D virtual chemistry experiments for educational use. This study will apply EUD technologies in chemistry experimental education and design a solution for educators to build and modify 3D virtual chemistry experiments easily and flexibly based on their own teaching strategies.

The remainder of the paper is organized as follows. Section 2 reviews related work of virtual laboratories in education. Section 3 introduces the application of multi-level adaptation technology of EUD in 3D virtual chemistry experiments' creation. An implementation of the solution–*iVirtualWorld*–is illustrated in Section 4. Section 5 presents a user study conducted for *iVirtualWorld* evaluation, followed by a discussion of future work in Section 6. Section 7 summarizes this paper.

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