

Chapter 31

A Reference Architecture for Game-Based Intelligent Tutoring

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ABSTRACT

Educational computer games may improve learning experiences and learning outcomes. However, many off-the-shelf games still fail at smoothly integrating learning content into gameplay mechanisms. In addition, they do make an effort at adapting educational content to individual learners. Learner models and adaptivity, as applied by Intelligent Tutoring Systems (ITSs), address this problem. A solution to the integration dilemma would ideally be found at the software architecture level. Assuming the perspective of the software engineer, this chapter reviews published game-based ITS architectures. The most promising approaches are partially integrated architectures, which replace sub-systems of Clancey's (1984) classic ITS architecture with corresponding game elements. In order to provide a reference to developers, this chapter follows up on these ideas and proposes a unifying game-based ITS architecture based on genre studies of computer role-playing games.

INTRODUCTION

Learning by playing educational computer games may improve learning experiences and learning outcomes. When designers combine immersive virtual worlds or challenging puzzles with edu-

cational content, they hope to stimulate intrinsic motivation, encourage playful experimentation, and to support knowledge construction by illustrative, interactive visualisations. While this sounds promising in theory, the effects cannot be taken for granted. Many off-the-shelf games are simply not good enough yet.

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First, commercial educational games tend to fail to integrate learning content into gameplay mechanisms smoothly. This chapter seeks to improve learning-gameplay integration, starting at the software architecture level. Consequently, the authors will examine software architectures for game-based learning.

Second, games try to be one-fits-all solutions, neglecting the fact that learners, even from one age group, can be significantly different. Learner models and user-adaptive systems solve this problem. These have been the focus of research since the 1970s, in the form of so-called *Intelligent Tutoring Systems* (ITSs). Yet, as of now, they have not found their way into commercial educational games. The chapter will therefore take a specific look at game-based ITS architectures that are currently emerging from research.

The next section details the problems of learning-gameplay integration and lack of adaptivity. A review of published game-based ITS architectures follows. None of the approaches seems to solve the learning-gameplay integration problem in adaptive educational games in a way that would suit a larger number of developers. We address this by proposing a reference architecture. It is based on genre studies of computer role-playing games (RPGs) and backed up by a component-based framework and a growing component library. To illustrate the benefits of using the architecture as a reference, we instantiate it with an educational quest on predator-prey dynamics. A conclusion sums up our argumentation and outlines future work.

PROBLEM ANALYSIS

Integration of Learning and Gameplay

One does not find many empirical evaluations of off-the-shelf educational computer games (i.e. no academic prototypes). Yet, there are a few studies

that highlight the prevalent discrepancy between learning and gameplay. Table 1 presents three investigations of the learning content and gameplay of some successful games that sold well and/or won a variety of awards.

All games investigated in the studies mentioned above consist of separate learning and game parts. The designers had to connect these by more or less artificial mechanisms: puzzle content, virtual money, and quotes to be collected. In *Physikus* and the *Genius* games, this means that the player can ignore large parts of the instructional content. *Palestine* is superior in that it immerses the player in a virtual Jerusalem and its social conflicts, yet it destroys the immersion in instructional content by the primitive exercise that concludes each mission. Summing up, learning and gameplay are often not well integrated.

Adaptation to Individual Learners

Commercial games rarely suit individual learners. Sometimes, learning content seems to be arranged in a completely arbitrary order. The first puzzle in *Mathica* (2002, © Braingame), the maths equivalent of *Physikus*, requires solving a Diophantine equation system. This task is actually the last one explained in the educational part. Some younger members of the target group “9–99 years” (stated on the box) will not get past this first puzzle. Besides, the educational presentation manages a fine integration of learning content and story – buying different numbers of animals at the cattle-market –, whereas the presentation in the game uses an abstract combination lock on a shop door.

If there is a well laid-out course structure, there are usually no alternative entry points for advanced learners. An older student with previous knowledge in physics may not be motivated to play *Genius – Tech Tycoon*, as the game always starts off in the 19th century. It then offers novice exercises such as naming states of aggregation or weighing coins. While a session of *Palestine* starts off with a mission selection screen, an advanced

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