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Declarations

This thesis is presented in accordance with the regulations for the degree of Doctor of Philosophy. It has been composed by myself and has not been submitted in any previous application for any degree. The work in this thesis has been undertaken by myself, except where otherwise stated.

The perspective of Empirical Modelling for educational technology is discussed in connection with constructionism in [RB02]. The restaurant manager model described in section 3.5 was discussed in [RRR00] in connection with strategic decision support systems. The digital watch model described in section 4.7 was discussed in [RBF00] in connection with engineering education. The use of Empirical Modelling to simulate LEGO Mindstorms robots described in section 6.4 was discussed in [EJR+02].

Abstract

In this thesis, we explore the extent to which computers can provide support for domain learning. Computer support for domain learning is prominent in two main areas: in education, through model building and the use of educational software; and in the workplace, where models such as spreadsheets and prototypes are constructed. We shall argue that computer-based learning has only realised a fraction of its full potential due to the limited scope for combining domain learning with conventional computer programming. In this thesis, we identify some of the limitations in the current support that computers offer for learning, and propose Empirical Modelling (EM) as a way of overcoming them.

We shall argue that, if computers are to be successfully used for learning, they must support the widest possible range of learning activities. We introduce an Experiential Framework for Learning (EFL) within which to characterise learning activities that range from the private to the public, from the empirical to the theoretical, and from the concrete to the abstract. The term 'experiential' reflects a view of knowledge as rooted in personal experience. We discuss the merits of computer-based modelling methods with reference to a broad constructionist perspective on learning that encompasses bricolage and situated learning. We conclude that traditional programming practice is not well-suited to supporting bricolage and situated learning since the principles of program development inhibit the essential cognitive model building activity that informs domain learning. In contrast, the EM approach to model construction directly targets the semantic relation between the computer model and its domain referent and exploits principles that are closely related to the modeller's emerging understanding or construal. In this way, EM serves as a uniform modelling approach to support and integrate learning activities across the entire spectrum of the EFL. This quality makes EM a particularly suitable approach for computer-based model construction to support domain learning.

In the concluding chapters of the thesis, we demonstrate the qualities of EM for educational technology with reference to practical case studies. These include: a range of EM models that have advantages over conventional educational software due to their particularly open-ended and adaptable nature and that serve to illustrate a variety of ways in which learning activities across the EFL can be supported and scaffolded.

Abbreviations

AOP - Agent-oriented parser

BBC - British Broadcasting Corporation

CAI - Computer Assisted Instruction

CPL maps - Combinatorially Piecewise Linear maps

EDEN - Evaluator of DEfinitive Notations

DMT - Dependency Modelling Toolkit

DoNaLD - Definitive Notation for Line Drawing

DTkEden - Distributed TkEden

EDDI - Eden Definitive Database Interpreter

EM - Empirical Modelling

EFL - Experiential Framework for Learning

FDL - Free Distributive Lattice

ILE - Interactive Learning Environments

IPPE - Instructive Portable Programming Environment

ISBL - Information Systems Base Language

ITS - Interactive Tutoring Systems

MIT - Massachusetts Institute of Technology

OO - Object-Oriented

OpenGL - Open Graphics Library

OXO - Noughts-and-crosses style games

P4 - The lattice of subsets of {1,2,3,4}

PENGUIMS - Programmable ENvironment for Graphical User Interface Management and Specification

RAT - Relational Algebra Tutor

RCX - Robotic Command eXplorer

RSE - Robotic Simulation Environment

S4 - The symmetric group on 4 symbols

SASAMI - Solids Animation Simulator And Modelling Interface

SCOUT - SCreen LayOUT notation

SI - Spreadsheet for Images

SIN - Situation, Ignorance, Nonsense

SIV - Spreadsheet for Information Visualisation

SQL - Structured Query Language

SQLTE - SQL to EDDI translator

SQLZERO - a variant of SQL whose semantics is consistent with relational theory

TILT - Tools / Interfaces / Learner's needs / Tasks

TkEden - Tk/Tcl EDEN interpreter

UML - Unified Modelling Language

VAT - Visual Agent Talk

VBA - Visual Basic for Applications

VCCS - Vehicle Cruise Control Simulator

ZPD - Zone of Proximal Development