Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.
Developing an extramural e-learning environment to bridge the digital divide

A dissertation presented in partial fulfilment of the requirements for the degree of Doctor Of Philosophy in Computer Science at Massey University, Palmerston North, New Zealand.

Russell Johnson
2005
Abstract

The research presented in this thesis conceptualises a strategy for designing e-learning systems to bridge the digital divide between those who have access to – and know how to use – high performance information technology, and those whose do not. It describes the prototyping of a system to test this conceptualisation, and the subsequent evaluation of the prototype in a realistic setting.

From a review of existing research, eight guidelines were synthesised for developing effective extramural e-learning environments. In addition, three broad user-centred strategies were identified as showing promise as possible ways to implement such an environment. These strategies emphasised localised over centralised functionality, specialised over general-purpose tools, and user-initiated adaptability over system-initiated adaptivity. It was hypothesised that by following the design guidelines and combining these three strategies – without making any presumptions about technological platform – a workable way could be found to meet all the requirements for an extramural e-learning environment that offers a significant improvement over correspondence-based courses.

Incremental prototyping was used to evaluate and refine the main elements of the design specification and then to integrate them into an operational system. This prototyping confirmed that the method proposed for developing a computer-based learning environment was workable. The prototype was then installed and tested, first over a LAN, and then over a rural telephone-based communication system where it was tested it with users.

The system performed very favourably under these conditions. The volunteers' response to the learning computer was enthusiastic, contrasting what they could accomplish with it to the difficulties they faced with conventional systems. It was concluded that the user testing gave strong support to the thesis that distributive, specialised and adaptable strategies can be successfully combined to provide a widely-accessible and usable computer-based learning environment.
Acknowledgements

There are a number of people and organisations whose advice, encouragement and support during this research I want to acknowledge.

First and foremost I would like to thank my principal supervisor, Assoc. Prof. Elizabeth Kemp, for the time and effort she has put into keeping me focussed throughout this project, but especially during the final writing up of this thesis. I would also like to warmly acknowledge the contributions of my co-supervisors, Assoc. Prof. Ray Kemp and Peter Blakey. I want to express my appreciation for the considered opinions, the constructive feedback, and, above all, the space to develop my research ideas, that I received from all of them.

There are a number of busy people from a range of disciplines who took time out to share with me their experience and knowledge of computer-based learning during the initial stages of my research. I would particularly like to acknowledge Assoc. Prof. Kinshuk, Bill Anderson and Trevor Billany, in this regard. I also acknowledge the influence of the TILE research group, led by Professor Chris Jesshope, in helping to provide an initial framework for this research.

I want to thank the school and residents of Akitio for their enthusiastic participation in this research, and for providing a real environment in which to test out my ideas.

I acknowledge the financial support of the Foundation for Research, Science and Technology through a Bright Futures Top Achiever Doctoral Scholarship.

On a personal note, I would like to thank Cheryl for her support and encouragement throughout this long process.

I would also like to acknowledge my parents, especially my late father, whose own academic aspirations were cut short by injury, illness and family responsibilities, and for whom I carried the flag on this march.
Publications

Publications associated with this research are:


# Brief Table of Contents

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapter 1</td>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Chapter 2</td>
<td>Distance education and computer-based learning overview</td>
<td>9</td>
</tr>
<tr>
<td>Chapter 3</td>
<td>Web-based e-learning: an evaluation</td>
<td>35</td>
</tr>
<tr>
<td>Chapter 4</td>
<td>Conceptualisation of an extramural e-learning system</td>
<td>67</td>
</tr>
<tr>
<td>Chapter 5</td>
<td>Towards a specification for an extramural e-learning system</td>
<td>83</td>
</tr>
<tr>
<td>Chapter 6</td>
<td>Prototyping the extramural e-learning system</td>
<td>113</td>
</tr>
<tr>
<td>Chapter 7</td>
<td>Use and evaluation of IMMEDIATE</td>
<td>175</td>
</tr>
<tr>
<td>Chapter 8</td>
<td>Conclusion</td>
<td>211</td>
</tr>
<tr>
<td>References</td>
<td></td>
<td>223</td>
</tr>
<tr>
<td>Appendix A</td>
<td>References for e-Learning Systems Reviewed</td>
<td>241</td>
</tr>
<tr>
<td>Appendix B</td>
<td>Conceptual view of learning elements and study modes</td>
<td>251</td>
</tr>
<tr>
<td>Appendix C</td>
<td>User Interfaces to Internet-based systems</td>
<td>257</td>
</tr>
<tr>
<td>Appendix D</td>
<td>Learning Shell Requirements Specifications</td>
<td>263</td>
</tr>
<tr>
<td>Appendix E</td>
<td>Learning Shell prototyping – classes and components</td>
<td>283</td>
</tr>
<tr>
<td>Appendix F</td>
<td>Learning Shell – selected class interfaces and source code</td>
<td>297</td>
</tr>
<tr>
<td>Appendix G</td>
<td>Learning Shell – screen shots</td>
<td>351</td>
</tr>
<tr>
<td>Appendix H</td>
<td>Communications Management</td>
<td>357</td>
</tr>
<tr>
<td>Appendix I</td>
<td>Course authoring and management application</td>
<td>385</td>
</tr>
<tr>
<td>Appendix J</td>
<td>Evaluation – handy hints, scenarios for user testing</td>
<td>395</td>
</tr>
<tr>
<td>Appendix K</td>
<td>Evaluation: Information sheet, questionnaire, and interviews</td>
<td>405</td>
</tr>
</tbody>
</table>
# Detailed Contents

<table>
<thead>
<tr>
<th>Chapter 1</th>
<th>Introduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>E-Learning for all</td>
</tr>
<tr>
<td>1.2</td>
<td>An issue for research</td>
</tr>
<tr>
<td>1.2.1</td>
<td>Research objectives</td>
</tr>
<tr>
<td>1.3</td>
<td>Research Methodology</td>
</tr>
<tr>
<td>1.4</td>
<td>Thesis structure</td>
</tr>
</tbody>
</table>

| Chapter 2  | Distance education and computer-based learning overview | 9 |
|------------|---------------------------------------------------------|
| 2.1        | Distance education: an historical review | 9 |
| 2.1.1      | Four threads in distance learning | 10 |
| 2.1.2      | The technology of distance education | 12 |
| 2.1.3      | The university and distance education | 14 |
| 2.1.4      | Summary | 17 |
| 2.2        | Computers in education: Milestones in computer-based learning research | 18 |
| 2.2.1      | Teaching machines | 18 |
| 2.2.2      | Thinking machines | 21 |
| 2.2.3      | Discovery learning | 24 |
| 2.2.4      | Communities of learning | 26 |
| 2.2.5      | Summary | 28 |
| 2.3        | Networked computers and distance education | 29 |
| 2.3.1      | Constraints on use of computers in distance education | 31 |
| 2.4        | Conclusion | 33 |

| Chapter 3  | Web-based e-learning: an evaluation | 35 |
|------------|-------------------------------------|
| 3.1        | Terminology | 35 |
| 3.2        | Overview of recent e-learning research | 36 |
| 3.3        | Evaluation criteria | 37 |
| 3.3.1      | A focus on extramural study in the public sector | 37 |
| 3.3.2      | End-user requirements | 37 |
| 3.3.3      | Functionality | 38 |
3.3.4 Usability
3.3.5 Accessibility
3.3.6 A student-centred learning environment

3.4 Assessment of web-based courseware
3.4.1 Courseware functionality
3.4.2 Usability concerns
3.4.3 Inaccessibility
3.4.4 Summary

3.5 Recent developments in e-learning
3.5.1 Anywhere, anytime study
3.5.2 Individualisation
3.5.3 Collaboration and Help
3.5.4 Interaction
3.5.5 Specialisation
3.5.6 Conclusion

3.6 Designing for extramural e-learning
3.6.1 Prioritising the student interface
3.6.2 Adaptation in a learning environment approach:
3.6.3 Guidelines for designing extramural e-learning environments

3.7 Concluding the literature review – a hypothesis

Chapter 4 Conceptualisation of an extramural e-learning system

4.1 A computer for learning
4.1.1 Everyday activities imbuing the conceptual model
4.1.2 Making learning possible
4.1.3 A reusable educational resource

4.2 Specialised interface
4.2.1 E-learning metaphors
4.2.2 A modular approach
4.2.3 Rendering the interface invisible

4.3 Individualised interface
4.3.1 Adaptation strategy
4.3.2 Integrated Support, Communication and Collaboration

4.4 Integrated network user interface
4.4.1 Network characteristics
4.4.2 A networked extramural e-learning system
Chapter 5   Towards a specification for an extramural e-learning system  

5.1 Network User Interface  
5.1.1 Alternative network user interfaces  
5.1.2 Integrated Interface  

5.2 Network Architecture  
5.2.1 Architectural style  
5.2.2 Communication Style  
5.2.3 Connection style  

5.3 Development platform  
5.3.1 Multi-platform  
5.3.2 PC-based  
5.3.3 Windows-based  

5.4 A Specialised User Shell  

5.5 Modular construction  
5.5.1 System Components  

5.6 Adaptable environment  
5.6.1 Student Model  
5.6.2 Integrated Learning Support  
5.6.3 Individualised Support  

5.7 IMMEDIATE specification  

5.8 Summary- Prototype Focus  

Chapter 6   Prototyping the extramural e-learning system  

6.1 Functional requirements for student user  

6.2 Component-based approach  
6.2.1 Study modes  
6.2.2 Learning elements  
6.2.3 Delphi code modules  
6.2.4 Reusable learning components  
6.2.5 Learning Shell assembly  
6.2.6 Refinements to promote consistency and modularity  
6.2.7 Feasibility of component-based approach  

6.3 System level support
6.3.1 System Tree
6.3.2 System level operations
6.3.3 Reference model specification
6.3.4 Implementation of data structures
6.3.5 Refinements to system modules
6.3.6 Embedded operating system

6.4 Interface Design
6.4.1 Learning Shell look and feel
6.4.2 Interface Refinement

6.5 Integrated learning support and communications
6.5.1 The system database
6.5.2 Communications and Group Work
6.5.3 Extramural Support
6.5.4 Coarse-grained learning help
6.5.5 Individualisation

6.6 Communications management
6.6.1 Repository Manager
6.6.2 Asynchronous messaging
6.6.3 Procedures for Resource Updating over the network
6.6.4 A challenging task

6.7 Authoring application
6.7.1 Course Authoring and Re-use
6.7.2 Authoring mechanism
6.7.3 Implementation
6.7.4 Evaluation of authoring tool

6.8 The IMMEDIATE prototype
6.8.1 Modifications to the prototype
6.8.2 Debugging

6.9 Conclusion

Chapter 7 Use and evaluation of IMMEDIATE

7.1 Goals of evaluation phase
7.2 The Evaluation Strategy
7.2.1 Focus on student as user
7.2.2 Testing for functionality and accessibility
7.2.3 Usability testing
Appendix E  Learning Shell prototyping – classes and components  283
E1  Prototyping basic component types  284
E2  Component dependencies  285
E3  Inheritance hierarchy  287
E4  Class Hierarchy  288
E5  Delphi Object Hierarchy  294

Appendix F  Learning Shell – selected class interfaces and source code  297
F1  Controller object – interface and selected source code  298
F2  Course Explorer object – class interface, selected source code  306
F3  System Dictionary – constants  311
F4  System Utilities – class interface  315
F5  Resource Model Manager – interface and selected source code  316
F6  Student Model Manager – class interface  317
F7  System Model Manager – class interface and selected code  318
F8  System Tree Manager – class interface  320
F9  Sample reference model implementation – System Tree  321
F10  Sample learning component implementation  325
F11  Extramural Support – class interface and selected source code  327
F12  Concept Map – class interface and selected source code  338
F13  System Models – Models directory and selected model files  344

Appendix G  Learning Shell – screen shots  351

Appendix H  Communications Management  357
H1  FTP Server – Screen shots  358
H2  Repository Manager – Screen shots  360
H3  Repository Manager – interface and selected source code  362
H4  Learning Shell: Update Resources – interface and selected code  374
H5  Learning Shell: Update Extramural Support – interface, selected code  379
Appendix I  Course authoring and management application  385

I1  Authoring application – screen shots  386
I2  Add Learning Material – screen shot and class interface  393

Appendix J  Evaluation – handy hints, scenarios for user testing  395

J1  Handy Hints sheet  396
J2  Initialisation (Scenario 1)  397
J3  Start-up, browse the Study guide (Scenario 2)  399
J4  Work on an Assignment (Scenario 3)  400
J5  Access a Lecture, Ask for Learning Support (Scenario 4)  401
J6  Monitor group discussion, get assignment feedback (Scenario 5)  402
J7  Exploring a Topic (Scenario 6)  403
J8  Completing an interactive tutorial (Scenario 7)  404

Appendix K  Evaluation: Information sheet, questionnaire, and interviews  405

K1  Information sheet for participating volunteers  406
K2  Questionnaire for participants  408
K3  Outline for semi-structured interviews with each participant  409
K4  Interviews with participants  411
Figures and Tables

**Figures**

- **Figure 1.1** Research methodology 5
- **Figure 2.1** Innovations in distance learning technology 12
- **Figure 3.1** Courseware environment marked by visual clutter 47
- **Figure 4.1** Each study mode contains a unique set of learning elements 73
- **Figure 4.2** Learning computer shifts weight of system to learner 78
- **Figure 4.3** Networked extramural e-learning – conceptual view 79
- **Figure 5.1** Three basic types of web documents 85
- **Figure 5.2** Enhanced web browser components 86
- **Figure 5.3** Integrated Interface 89
- **Figure 5.4** IMMEDIATE accommodates diverse communication media 91
- **Figure 5.5** Gartner Spectrum of Network Styles 92
- **Figure 5.6** Modes implemented from pre-installed components 101
- **Figure 5.7** Learning Shell System components 102
- **Figure 5.8** System Tree models table of contents and student’s progress 103
- **Figure 5.9** Knowledge-based system components 108
- **Figure 5.10** IMMEDIATE network components and configuration 110
- **Figure 6.1** Start-up scenario 116
- **Figure 6.2** Interface components of the Learning Shell 118
- **Figure 6.3** Message List component encapsulates multiple forms 119
- **Figure 6.4** Code to wrap Feedback learning element as Delphi component 121
- **Figure 6.5** Shell assembled by dragging components onto Desktop form 121
- **Figure 6.6** Desktop encapsulates all Shell components 122
- **Figure 6.7** System Tree with additional concept level 125
Tables

Table 3.1  Contrasting properties of adaptable and adaptive systems.  52
Table 3.2  Forms of adaptation in learning systems.  52
Table 4.1  Individualisation dimensions supported by the learning computer  75
Table 4.2  Requirements for network components  80
Table 5.1  Some higher-level protocols implemented over TCP/IP.  93
Table 5.2  Possible methods for rendering the interface invisible.  98
Table 5.3  The four dimensions of the Integrated Help system.  107
Table 6.1  Basic learning element categories  118
Table 6.2  System level operations defined from use cases.  126
Table 7.1  Summary of Participant Profile Questionnaires.  183
Table 7.2  Scenarios covered all e-learning enhancements and dimensions.  185