Software agents support for personalised learning: Negotiating and e-contracting with multiple providers

A thesis submitted to the University of Manchester for the degree of Doctor of Philosophy in informatics,

Faculty of Humanities

2012

GODWILL IMBONZUGAH VEGAH

Manchester Business School (MBS)
Declaration

No copy of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or institution of learning.

Copyright statement
i) The author of this thesis (including any appendices and/or schedules to this thesis) owns any copyright in it (the “Copyright”) and s/he has given The University of Manchester the right to use such Copyright for any administrative, promotional, educational and/or teaching purposes.

ii) Copies of this thesis, either in full or in extracts, may be made only in accordance with the regulations of the John Rayland’s University Library of Manchester. Details of these regulations may be obtained from the Librarian. This page must form part of any such copies made.

iii) The ownership of any patents, designs, trade marks and any and all other intellectual property rights except for the Copyright (the “Intellectual Property Rights”) and any reproductions of copyright works, for example graphs and tables (“Reproductions”), which may be described in this thesis, may not be owned by the author and may be owned by third parties. Such Intellectual Property Rights and Reproductions cannot and must not be made available for use without the prior written permission of the owner(s) of the relevant Intellectual Property Rights and/or Reproductions.

iv) Further information on the conditions under which disclosure, publication and exploitation of this thesis, the Copyright and any Intellectual Property Rights and/or Reproductions described in it may take place is available from the Head of School of (Manchester Business School) (or the Vice-President) and the Dean of the Faculty of Life Sciences, for Faculty of Life Sciences’ candidates.
Acknowledgement

I would like to extend my heartfelt appreciation and gratitude to my supervisors Prof. Nikolay Mehanjiev and Prof. Trevor Wood-Harper, respectively for their invaluable guidance, support and encouragement throughout my research work. I want to especially acknowledge their day-to-day vigilance and encouragement with essential and critical feedback which was very much needed to keep me focused throughout my work.

I would also like to give special thank to my friends (Sahar, Malik and Navaab) for their helpful observations and feedback; and especially Dr. Tim Anglin and his family, for their supported and encouragement during my personal difficult moments, in the course of my research. The Divine words: ‘Man is a mine rich in gems of inestimable value …’ and ‘…a heaven of wisdom in consultation’, from Baha’i writings was a source of inspiration to me and my work.

Dedication

I would like to dedicate this work to my Mother, Mrs. Elisabeth Vumoh Vegah, for her moral support, encouragement and motherly love, throughout my studies, even when she was thousands of miles away, but very present “with me in spirit”, during the difficult times of my work; and my late father, Mr. Samuel Ngwoh Vegah, may his soul rest in peace, for his sacrifices and dedication in taking care of me, “planting the seeds of knowledge”, from early childhood, even under very adverse conditions. I want to also dedicate this to my late cousin, Dr. Hosea Mundi, as well as Mrs Regina Mundi, also know as Ma Regi, who worked ceaselessly, hand in-glove with my late father, to ensure I have a veritable educational foundation, and all family members who have been very supportive in the course of my research work.
**Author: Background and Research work**

I graduated with an M.Sc in Electrical and Electromagnetic Engineering and B.Sc, in Electronics and Communications Engineering, from the University of Wales, College of Cardiff, and North London University respectively. My masters dissertation in “Analogue/Digital card (ADDA) for the IBM PC inspired me to work with hardware/software interface systems, as well as take up teaching, lecturing and consultancy positions in the domain, for over ten years. I had since had a passion for developing “holistic engineering systems”, from hardware to software with an inclination to communications and electronic sub-systems.

I chose to carry out my research in the domain of “Software agents’ applications for e-learning” with intentions to apply “finite state machine algorithms” to capture and analyse speech and electromagnetic signals, as was the case for my M.Sc. dissertation. I found out these algorithms were not sufficient for my research work. Given new and challenging experience to deal with “continuous” needs and requirements of “Online” learners (a not so finite state scenario), investigated and applied functions and capabilities of “intelligent software agents”, to support personalised and flexible E-Learning.

This work addresses current and existing e-learning issues of personalised learning including inflexible models of learning needs, narrow coverage of learning objectives and ineffective use of Open Educational Resources (OER). Intelligent agents’ capabilities were applied to devise dynamic learning plans and corresponding electronic contracts with flexible learning terms and conditions. The approach support evaluation and feedback of learning results, options for deriving customised learning objectives through specification of learning requirements; the provision of multiple provider options in a distributed and heterogeneous learning background. With the growing need for e-learning, software agent engineering application opens an innovative discipline that contributes to enhancing human capacity development. The integration of open source CMS (Content management System) and OER (Open Educational Resources) exemplified in this work supports cost effective deployment in both academic and professional training. With the ADALP approach prototype developed in this research work, high-volume request and learning activities would require further engineering on the current agent platforms, to support data management in distributed learning environment; the development of features, such as “learning ontology”, to facilitate effective and efficient interaction and communication of the learning support agents.
Glossary

ADALP: Adaptive Agent Learner Plan
B-Model: Basic Requirement model
Co-SA: Co-Supervisor agent

DPLAN: Dynamic Learning Plan
E-Contract: Electronic Contract
EAI: Expert interface agent
ELNR: E-learning Needs and Required Features

EVA: – Evaluation Agent
IOL: Improving Online Learning
LRQ: Learning Request
LVI: Learner Evaluation Indicator

OER: Open Educational Resources.
PA: Pedagogic advice agent
P-Resource: Personalised Resource

PIA: Provider interface agent
TAA: Task analysis agent
RAA: Results Analysis Agent
SA: Supervisor agent
<table>
<thead>
<tr>
<th>Chapter 1: Introduction</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Motivation</td>
<td>12</td>
</tr>
<tr>
<td>1.2 Aims and Objectives</td>
<td>14</td>
</tr>
<tr>
<td>1.3 Research Hypothesis</td>
<td>14</td>
</tr>
<tr>
<td>1.4 Methodology</td>
<td>14</td>
</tr>
<tr>
<td>1.5 The Approach and Research Contribution</td>
<td>19</td>
</tr>
<tr>
<td>1.6 Evaluation</td>
<td>20</td>
</tr>
<tr>
<td>1.7 Thesis Structure</td>
<td>20</td>
</tr>
<tr>
<td>Chapter 2: The E-learning Environment and its Challenges</td>
<td>22</td>
</tr>
<tr>
<td>2.1 E-learning Issues</td>
<td>22</td>
</tr>
<tr>
<td>2.1.1 Learning issues in Real Life environment scenario</td>
<td>22</td>
</tr>
<tr>
<td>2.2 Surveys on e-learning Issues</td>
<td>25</td>
</tr>
<tr>
<td>2.2.1 E-learning Needs and Required Features (ELNR)</td>
<td>25</td>
</tr>
<tr>
<td>2.2.2 Educational Resources</td>
<td>26</td>
</tr>
<tr>
<td>2.2.3 Improving Online Learning (IOL)</td>
<td>26</td>
</tr>
<tr>
<td>2.2.4 IOL Survey Discussion</td>
<td>28</td>
</tr>
<tr>
<td>2.2.5 Expectations of E-learning Systems</td>
<td>29</td>
</tr>
<tr>
<td>2.3 Analysis on E-learning Issues</td>
<td>29</td>
</tr>
<tr>
<td>2.3.1 Guidelines for effective e-learning</td>
<td>30</td>
</tr>
<tr>
<td>2.3.2 Summary of E-Learning Issues</td>
<td>31</td>
</tr>
<tr>
<td>Chapter 3: Literature Review of E-learning Systems</td>
<td>33</td>
</tr>
<tr>
<td>3.1 The Knowledge-Tree e-learning Approach</td>
<td>33</td>
</tr>
<tr>
<td>3.2 ADELE</td>
<td>34</td>
</tr>
<tr>
<td>3.3 Intelligent Tutoring Systems (ITS)</td>
<td>35</td>
</tr>
<tr>
<td>3.4 Educational Brokerage Systems</td>
<td>40</td>
</tr>
<tr>
<td>3.5 Other Learning Approaches</td>
<td>42</td>
</tr>
<tr>
<td>3.6 Agent support E-learning Systems</td>
<td>44</td>
</tr>
<tr>
<td>3.6.1 Software Agents Applications and Systems</td>
<td>44</td>
</tr>
<tr>
<td>3.6.2 Agent characteristics and Capabilities for Learning Support</td>
<td>45</td>
</tr>
<tr>
<td>3.6.3 Justification of Intelligent Agents and online Learning</td>
<td>47</td>
</tr>
<tr>
<td>3.6.4 Distributed Learning Environments with Intelligent Agents</td>
<td>48</td>
</tr>
<tr>
<td>3.6.5 Software Agents for Co-operative learning (SACL)</td>
<td>52</td>
</tr>
<tr>
<td>3.6.6 Agent Framework for Learning Systems (AFLS)</td>
<td>53</td>
</tr>
<tr>
<td>3.6.7 The E-adviser</td>
<td>54</td>
</tr>
<tr>
<td>3.7 Summary of E-learning approaches and learning issues</td>
<td>55</td>
</tr>
<tr>
<td>Chapter 4: The ADALP Approach for Flexible and Personalised E-learning</td>
<td>59</td>
</tr>
<tr>
<td>4.1 ADALP Overview</td>
<td>59</td>
</tr>
<tr>
<td>4.2 The ADALP Structure</td>
<td>61</td>
</tr>
<tr>
<td>4.2.1 Learner Requirements</td>
<td>61</td>
</tr>
<tr>
<td>4.2.2 Negotiation with Providers</td>
<td>61</td>
</tr>
<tr>
<td>4.2.3 Learner Evaluation</td>
<td>62</td>
</tr>
<tr>
<td>4.3 ADALP Process</td>
<td>63</td>
</tr>
<tr>
<td>4.4 ADALP</td>
<td>64</td>
</tr>
<tr>
<td>4.5 E-learning issues Addressed by ADALP</td>
<td>65</td>
</tr>
<tr>
<td>4.6 The Role of Agents</td>
<td>66</td>
</tr>
<tr>
<td>4.7 Summary of the ADALP Approach</td>
<td>68</td>
</tr>
<tr>
<td>Chapter 5: The ADALP Approach Structure and Features</td>
<td>69</td>
</tr>
<tr>
<td>5.1 Design Principles</td>
<td>69</td>
</tr>
<tr>
<td>5.2 ADALP Approach Functional Specification</td>
<td>71</td>
</tr>
<tr>
<td>5.3 Agent System Design for ADALP Approach</td>
<td>74</td>
</tr>
</tbody>
</table>
5.3.1 Prometheus Methodology ................................................................. 75
5.3.2 Prometheus Methodology Steps and Results .................................... 75
5.4 Agent System Specification (with Prometheus Methodology) .................. 76
5.4.1 Key actors of agent System ............................................................. 76
5.4.2 The Agent System Goals ............................................................... 76
5.4.3 Functions and Capabilities of ADALP Agent system ......................... 78
5.4.4 Scenarios Illustrating System Operations ......................................... 79
5.4.5 External Data to ADALP Agent System ............................................ 80
5.4.6 Systems’ Interface to Learner and Provider environment .................... 82
5.5 ADALP Agent System Architecture .................................................... 84
5.5.1 Interactions of Agents and Agent Clusters ........................................ 84
5.5.2 Interactions of Key Agent Actor ..................................................... 86
5.6 Detail Agent System Design of the ADALP Approach ............................ 88
5.6.1 ADALP Agent System Flowchart .................................................. 89
5.6.2 Structures of Key ADALP Agents and Agent Behaviours .................... 90
5.6.3 Agent Behaviours Supporting Flexible and Personalised Learning .......... 93
5.6.4 Agent Plans and Triggering Conditions ............................................ 94
5.6.5 Major Agent Information Components, Goals and Messages ............... 95
5.6.6 Matching ADALP Agent System Design with JADEX Agent ............... 99
5.7 Agent Interactions Specifications for ADALP Approach .......................... 99
5.7.1 Learner Interaction with Interfaced agent, LIA ................................... 99
5.7.2 Multi-issue Negotiation of Learning Requirements ............................. 101
5.7.3 Negotiation Messages Sequence of ADALP approach ......................... 104
Chapter 6: Feasibility Implementation ..................................................... 106
6.1 ADALP Prototype ............................................................................. 106
6.1.1 Agent Beliefs and Beliefsets for ADALP approach .............................. 106
6.1.2 Summary of Agent Support Model .................................................. 106
6.2 Implemented Features of ADALP Approach Agents .............................. 107
6.2.1 Requirements Composition and Negotiation Activities ....................... 107
6.2.2 Course Negotiation Criteria ............................................................ 108
6.2.3 Feedback and learner performance (Re-Negotiation Criteria) ................ 109
6.2.4 Typical Reject Criteria ................................................................. 110
6.2.5 Provider and Broker agent behaviours ............................................. 110
6.2.6 Negotiation Criteria Summary ....................................................... 111
6.3 Walkthrough .................................................................................... 111
6.3.1 Learning support multi-issue Negotiation ........................................ 111
6.3.2 Two way evaluation of Learner performance and Provider capabilities .... 115
6.4 Real Life Application of ADALP: Scenario in schools and colleges ........... 119
6.4.1 Typical Learner Requirements Capture in Schools and Colleges .......... 119
6.4.2 Course Negotiation with Schools and College Providers .................... 121
6.4.3 Learning Evaluation: A Real life Learner Performance Scenario ........... 122
6.5 ADALP Approach prototype results and analysis ................................... 124
6.5.1 Prototype Results Analysis .............................................................. 124
6.5.2 ADALP Contribution Analysis ........................................................ 125
6.5.3 E-learning issues addressed by ADALP Approach and Contributions ...... 127
6.6 Future Agent Behaviours of ADALP Prototype .................................... 127
6.7 Conclusion ....................................................................................... 128
Chapter 7: ADALP Evaluation ................................................................. 129
7.1 Introduction ...................................................................................... 129
7.2 Comparison of ADALP and other approaches ..................................... 129
7.3 Negotiation of courses with providers (C1) ........................................ 131
7.4 Re-Negotiating courses based on learning performance; aligning DPLAN and E-Contract (C2a) ........................................... 132
7.5 Two-way evaluation of learning performance and provider capabilities (C2b) . 132
7.5.1 Evaluation of the ADALP Model and Concepts ........................................ 133
7.6 Revisiting Hypotheses and Research Questions ........................................... 134
7.6.1 Evaluation of ADALP Hypotheses .................................................. 135
7.6.3 Evaluation of ADALP Research Objectives ........................................... 136
Chapter 8: Conclusion and Future Work ............................................................ 137
8.1 Summary .............................................................. 137
8.2 Applications of ADALP Approach in Real Life Situations ............................ 138
8.3 Conclusion .............................................................. 141
References: .................................................................................................... 142
Appendix ....................................................................................................... 148
Appendix A ..................................................................................................... 148
A.1 DfES e-Learning Strategy Summary .................................................... 148
Appendix B ..................................................................................................... 150
B.1 ADALP Agent collaboration ................................................................. 150
B.2 Provider Capabilities .............................................................................. 153
B.3 Summary of designated agent activities and codes .................................. 154
Appendix C: Sample Agent Functions ............................................................ 155
C.2 Agent platforms ......................................................................................... 157
C.2.1.1 Jadex Agent Structure ................................................................. 157
C.2.1.2 Agent Plans .................................................................................. 159
C.3 Database tables for agent activities .......................................................... 160
C.4 Agent platforms ......................................................................................... 162
List of Figures
Figure 1.1: Key actors in a sample e-learning model (Courtesy http://www.johnstephenson.net/jsdownloads.htm) ........................................................................................................13
Figure 1.2: Design Science methodology .................................................................................................................................15
Figure 1.3: Design Methodology Details for ADALP Approach .........................................................................................................16
Figure 1.4: Thesis Organisation .........................................................................................................................................................20

Figure: 3.1 Classification of Learning Systems - illustrating gaps addressed by proposed agent-based system – ADALP (an intelligent Brokerage System for online learning support) ........................................................................................................56

Figure: 4.1 ADALP Approach Block Diagram ..............................................................................................................................60
Figure: 4.2 Typical Agent Activities of ADALP Approach ................................................................................................................63
Figure: 4.3 Classifications of ADALP Contributions ........................................................................................................................65
Figure: 4.4 Expanded ADALP Agent Activities .............................................................................................................................67
Figure: 4.5 AI Learner Interface Agent Activity ................................................................................................................................68

Figure: 5.1: Schematic representation of the ADALP approach process ...............................................................................................73
Figure: 5.2: Learners-Providers and Learning Centre Scenarios ........................................................................................................80
Figure: 5.3: Sample Learner Requirement Template ........................................................................................................................82
Figure: 5.4: Sample DPLAN Template .............................................................................................................................................83
Figure: 5.5: Sample E-Contract Template ........................................................................................................................................83
Figure: 5.7: Agent System Architecture: (Demonstrating agent collaboration, Generating Learning Task, learner plan and e-contract) ..................................................................................................................85
Figure: 5.8: Highlight of an Instance ADALP Approach Agent System ................................................................................................88
Figure: 5.9: Flowchart giving details of the ADALP Approach .........................................................................................................90
Figure: 5.10: ADALP information components ................................................................................................................................95
Figure: 5.11: Relationship of key Agents (LIA, SA and PIA) and Core information components of the ADALP approach with associated Data Structure ..................................................................................97
Figure: 5.12: EAI support in Learner Requirement Specification ..................................................................................................100
Figure: 5.13: Multi-Issue (LO1, LO2) Negotiation and Contracting Courses with Providers (PIA) based on learner Requirements of Courses, LO1 and LO2 ...........................................................................101
Figure: 5.14: Adapting and Re-Negotiating Issues of Learning Plan and E-contract based on learning performance .................................................................................................................................102
Figure: 5.15: Two – Way evaluation Rules-Flowchart .......................................................................................................................104

Figure: 6.1: Requirement composition and Provider offers ..................................................................................................................112
Figure: 6.2: Course negotiation – Supervisor Agent Request Courses from Providers using Request Protocol conversation ID ....................................................................................................................113
Figure: 6.3: Course Negotiation Details – Provide resources matching learner requirements; and proposed courses from provider agent .............................................................................................................113
Figure: 6.4: Matching learner requirements with provider resources ................................................................................................114
Figure: 6.5: Matching requested Course fields (Course attributes) with available provider courses) .................................................................................................................................114
Figure: 6.6: Three matching fields – 206 201 and 304…found from provider resources ..............................................................................115
Figure: 6.7: Processing Performance Score Results .........................................................................................................................117
Figure: 6.8: Details of learner performance score processing .............................................................................................................117
Figure: 6.9: Supervisor Agent – Captures performance results ........................................................................................................118
Figure: 6.11: Expert Agent Interface Activity – Learning Tasks (Courses) Allocation, based on Learner Request ...............................................................................................................................121
Figure: C2.13 Structure of a Jadex agent: The Supervisor Agent .........................................................................................................158
List of Tables

Table 2.1: Components that create successful online learning environments (percentage of respondent with satisfactory statement) ................................................... 27
Table 2.2: Components that create barriers in online learning environments (Percentage of respondent with satisfactory statement) ................................................... 27
Table 2.3: E-learning Issues, Expected Benefits and Observations ........................................ 29
Table 2.4: JISC VLE design guidelines .................................................................................. 31
Table 2.5: Grouping e-learning issues .................................................................................. 32

Table: 3.1 Summary of adaptive e-learning and personalised issues ........................................ 57
Table: 3.2 Learning approaches and identified issues ................................................................ 57

Table: 4.1 ADALP Features and Process Steps ........................................................................ 63
Table: 4.2 ADALP contributions and addressed learning issues ............................................. 66

Table: 5.1: ADALP Functional Specifications, Demonstrations and Contributions ......... 71
Table: 5.2: Key Agent Actors Supporting Functional Specifications of ADALP approach ................................................... 77
Table: 5.3: Sample Learner Performance Table - External data ................................................ 81
Table: 5.4: Sample Learner Evaluation Indicators Table - External data ................................ 82
Table: 5.5: Target Scores Table - Internal Data .......................................................................... 82
Table: 5.6: Key Agent Structures .......................................................................................... 91
Table: 5.7: Corresponding agent goals and plans ................................................................... 92

Table: 6.1: Reject and Acceptance Criteria ............................................................................ 110
Table: 6.2: Evaluation of Learning Performance ..................................................................... 116
Table: 6.3 Expected learning target scores .......................................................................... 122
Table: 6.4 Performance results of learner activity ................................................................. 122
Table: 6.5 Learner Evaluation Indicators (LVI) ..................................................................... 123

Table: 7.1 Classification and Evaluation method of ADALP contributions ......................... 129
Table: 7.2: Summary issues of Adaptive E-learning Approaches ......................................... 130
Table: 7.3 ADALP Features and issues addressed, compared to other Learning Approaches ............................................................................................................ 131
Table: 7.4 Summary of ADALP E-learning Model and Concepts Evaluation .................. 133

Table B.1: ADALP agent analysis and design: BDI Model Perspective ............................... 150
Table B.2: ADALP agent activity and events code table ..................................................... 154
Abstract

E-learning is increasingly adopted to support face-to-face classroom-based learning or implemented as a complete standalone learning system. It’s inherent adaptable nature and ability to provide learning anywhere, everywhere and anytime makes it a versatile tool for access to basic, professional and higher education.

This research proposes and develops an adaptable e-learning approach, focusing on the learner’s requirement specification and negotiation of course with multiple providers to improve online learning. This addresses issues of inflexible learning model, narrow coverage of subject domains in existing systems and ineffective use of educational resources, using design research methodology (DRM).

The proposed Intelligent Learning approach provides learning support by applying collaborative and deliberative capabilities of software agents to e-learning systems. Designated learning support agents negotiate with providers on behalf of the learner for courses, matching specified requirements. This is achieved through agent negotiation strategies, devising dynamic learning plans (DPLAN) and online learning contract (or E-Contract) between the system and a range of providers, to harness the changing needs of the learner, hence, providing an Adaptive Agent Learner Plan (ADALP) approach. It develops and applies a “Basic Requirements Learning” model, addressing specific learning objectives, supported by a two way evaluation process that enforces learning flexibility, empowering learners and accommodating a wide spectrum of learning needs.

Unlike traditional Intelligent Tutoring System (ITS), learning objectives are not fixed and are constituted dynamically from learner specifications. The ADALP approach provides multiple provider support options, generating learner feedback for goal oriented, but flexible learning. This deviates from the traditional “top-down” approach, where instructors and designers create fixed models of different categories of learners and their needs.

The prototype of multi-agent system (MAS) demonstrates contributions of the approach, applying Multi-issue-Negotiation and Contracting Courses with Multiple Providers; devising dynamic personalised learning plans and learning commitment (or e-contracts) between learners and providers. It implements designated agents which generate tasks and sub-tasks corresponding to the learners’ goals and objectives; “biding” for learning and tutoring resources from multiple providers to deliver on the derived tasks. Personalised learning plan aligned with online learning contract is generated for each learner based on the specified requirements and learning goals, as a result. It is argued that the ADALP approach empowers learners and improves on similar approaches, in comparison to existing adaptive learning systems.

Key words: Intelligent and Adaptive learning system, Dynamic learning plan, Agent support learning, e-Learning and e-Contracts, learner-provider negotiation.
Chapter 1: Introduction

Learning and training increase human potential and productivity for industry and sustainable development. Hence the role and importance of research into flexible and customised learning approaches, is essential for academic, professional and economic growth.

The Adaptive Agent Learner Plan (ADALP) approach employs software agents to investigate, design and implement a flexible e-learning approach, focusing on personalised learning requirements. In this approach, a Dynamic Learning Plan (DPLAN) and E-Contract (learner commitment between with providers), is generated for each learner. Software-agents, with specialised functions, analyse and interaction with providers, match and assign courses to learners which meet their learning requirements.

1.1 Motivation

There is a growing need to develop more effective adaptable learning systems to reach a wide spectrum of learners and cater for personalised needs. This is supported by (Massey J, 2003; Anthony Basiel, 2006), ‘finding appropriate tools to support e-learning and learner activities in VLE …and developing innovative learning processes that take advantage of emerging technologies’. With emerging technologies, various approaches have been tried with varying degrees of success. A wide range of issues arise from e-learning (also known as Virtual Learning environment, VLE). Given the capabilities of intelligent software agents and the need for versatility of e-learning and training support, the ADALP approach applies features of the former to address personalised learning issues in e-learning environments.

DfES (England’s Department for Education and Skills), emphasis the importance of e-learning and the need to improve existing systems, providing an E-Learning Strategy which identifies barriers to distributed learning. It proposed and developed a sustainable long-term strategy (DfES 2004). The HE strand encourages a collaborative approach to personalised learning activities where E-Learning exploits interactive technologies and communication systems to improve the learning experience. From DfES recommendation, E-learning, along with existing teaching methods, enhances the quality and reach of teaching and learning. Also according to the Quality Assurance Agency (QAA 2006) guidelines, the design of VLE system delivery learning
programmes, student development, learning support and assessment, brings to question the quality of the provision of academic standards, managing teaching and learning to ensure learning needs are met (DfES, Towards a Unified e-Learning Strategy, 2003).

ADALP is developed to contribute in addressing existing barriers (e-learning issues) of VLE and provide flexible and customisable e-learning system, in line with DfES recommendation. Universities and higher institutions of learning (e.g. Middlesex University 2006), have policies in place addressing the institution’s e-learning strategy alongside home-working provision. This involves corporate plans with new approaches employed to teaching and learning using web technology for higher productivity; increase access to higher education for people previously excluded by barriers of time, place and finance.

Typical existing e-learning approach (Basiel A, 2006) proposes access and increased training of staff and trainees using e-learning platform such as WebCT or Blackboard. Figure 1.1 shows “Key Participants” of the existing e-learning framework.

![Key Actors in E-learning](http://www.johnstephenson.net/jsdownloads.htm)

Figure 1.1: Key actors in a sample e-learning model (Courtesy http://www.johnstephenson.net/jsdownloads.htm)

From sample e-learning Models as shown in Figure 1.1 (and www.mdx.ac.uk), the key participants of the e-learning framework include trainees (learners), the suppliers (teachers, lecturers and various subject experts), administrators, managers, designers and technicians. This research work re-groups these key participants into three categories: learners, suppliers (providers), and advisers; and focus on personalised and flexible learning where the learner takes advantage of multiple providers. It submits that
software agents approach facilitates effective collaboration between learners and providers for mutual benefit, focusing on learner requirements.

1.2 Aims and Objectives
The research objectives are formulated with the focus on the learning goals of the learner are as follows:

1. To provide flexible and personalised learning with an agent approach, applying software agent “reasoning”, “planning” and “collaboration” capabilities, in mentoring, tracking learning performance, learning goals and objectives.
2. Generate learning options; enabling learners make the best use of available courses (resources) from multiple providers matching their learning goals and objectives.

The Research Question
With the above research objectives the question to address is:

1) Could software agent’s Belief-Desire-Intentions (BDI) model, support specification and negotiation of learner requirements, in a multiple provider environment?

2) Could software agent technology help learners, of heterogeneous background, in flexible and personalised learning, in a multiple provider environment?

1.3 Research Hypothesis
With emerging learning theories, increasing need for pedagogic support for online learners, growing demand for specialised skills development in various domains, and the need to merge technology and pedagogy for effective learning; The research work is driven by the Hypotheses that: the Believe, Desire, Intention, (BDI), model support learning processes by: 1) Negotiating learner requirements with multiple providers (HP1); and 2) Matching learner requirements with provider resources for effective learning, (HP2).

The agent characteristic of the approach, is believed, would improve targeted and flexible achievement of learning goals, for the mutual benefit of learners, learning facilitators and learning providers.

1.4 Methodology
A key process in the research involves design and implementation of a proposed artefact to address identified learning issues and gaps of existing systems. This also necessitates the demonstration of the Artefacts’ (or prototype’s) contribution to knowledge in the
domain of software agent support for e-learning. With these considerations, The Design Research Methodology is found to be suitable, compared to others which do not focus on design and implementation of a prototype approach (system).

Design science research methodology (Owen (1997), Takeda, et al. (1990), which consists of seven (7) phases [(1) Problem Awareness, (2). Suggestions, (3) Development, (4) Evaluation, (5) New Knowledge, (6) Conclusion, (7) Adoptions and deductions] is applied in the investigation and development of the Adaptive Agent Learner Plan (ADALP) approach (Figures 1.2a and Figure 1.2b). Figure 1.2a shows the basic research paradigm where knowledge is acquired and applied in a chosen domain; that is, the research work leads to acquired knowledge through a knowledge using and knowledge building process.

![Figure 1.2: Design Science methodology](image)

**Figure 1.2: Design Science methodology**

Figure 1.3 illustrates the specific application of the methodology (general paradigm); Knowledge of existing e-learning approaches and e-learning issues lead to knowledge building of the specific artefacts (ADALP), which addresses the gaps of existing systems and current learning issues. The research methodology framework is further, detailed as follows:

a) Current / existing e-learning issues (inflexible learning models, limited options and inefficient use of online resources) from surveys and real life learning environment scenarios motivating the research, (elaborated in Chapters 2 and 3), provides awareness of the problem addressed in this research;
An operational principle can be defined as “any technique or frame of reference about a class of artifacts or its characteristics that facilitates creation, manipulation and modification of factual forms” (Dasgupta, 1996; Purao, 2002).

**Figure 1.3: Design Methodology Details for ADALP Approach**

b) The identified issues (or acquired knowledge of the problem) are highlighted in existing systems, establishing the extent to which the issues have been addressed or unaddressed (This is elaborated in Chapter 3);

c) Suggestions for a new system (i.e. proposed solutions to identified issues) are explored and specified (elaborated in Chapter 4 and 5);

d) The proposed solutions are developed and implemented to show their advantage over existing ones and support the claims/contributions in addressing the identified learning issues (this is presented in Chapter 6);

e) Evaluation of the new system (Chapter 7) is carried and new knowledge acquired - A BDI agent model is adopted and developed to support flexible and personalized learning.
A block diagram of the research process and phases illustrating details of the research cycle from investigating e-learning issues and challenges to a proposed solution of dynamic learning plans and formalised e-contracts, are shown in Figure 1.4, which outlines the research process in developing a flexible learning approach in a “knowledge building and Knowledge using” cycle, merging pedagogy and technology.

Figure 1.5 elaborate specific details of the knowledge building process and illustrates the application of software agents to improve existing e-learning approaches. Knowledge is generated and accumulated from e-learning theories, learning barriers as well as agent capabilities (i.e. agent planning and negotiation techniques); and from e-learning surveys, reports and existing system, (E-Adviser and Knowledge-Tree) in the “knowledge using process”, to design the research artefacts (an agent-support learning approach).

From the development stage of the artefacts, partial or fully successful implementations are evaluated (according to the functional specification implicit or explicit in the suggestion). Development, Evaluation and further Suggestion are (iteratively) performed in the course of the research (design).

New knowledge is acquired in the process of implementing and evaluating the proposed artefact (a flexible and personalized e-learning approach, with dynamic learning plans and formalised contracts, applying BDI agent planning futures of Jadex, Figure 1.5), according to the suggested solution, earlier discussed.

Figure 1.4: Outline of Research Process – Artefacts from Knowledge Using/Building Process
Figure 1.5: Details of Knowledge Building and Knowledge Using Cycle

The Research Artefacts

The research artefacts produced by the work of this thesis comprise solutions to identified learning issues in particular, which help in addressing gaps in existing systems through negotiation with learning providers, devising learning plans and online contracts with multiple provider options. The artefacts also addresses e-learning issues in Virtual Learning Environments (VLE) arising from surveys on existing e-learning platforms, by negotiating learner requirements with providers to formalise personalised learning contract and learning plan, as well as constituting suitable courses from specified learner requirements that reflect heterogeneous background of learners.

ADALP (a software agent-support learning approach) is based on emerging learning theories, combining pedagogy and technology; employing agent support tools which are underpinned by AI planning techniques. It establishes a dynamic “Bottom-Up”, Basic Learning Requirements Model, which deviates from the existing Top-Down models that employ fixed and pre-designed objectives, and so can caters for learners from a diverse background.

The artefacts and contribution are also based on interactive and collaborative learning theories (Stephenson J, 2001) as well as software agent technology theories on “reasoning” and “deliberation” (Jennings and Wooldridge, 1998). The learning
approach demonstrated by a prototype, illustrates typical learning processes, applying the BDI agent model, with suitable characteristics which are modelled on human mental states of Belief, Desire and Intentions. This is implemented using an example agent development platform (JADEX).

It also examines the concepts of Learning Feedback for learners, Personalised and Updatable Learning Objectives, Dynamic Learning Plans, Support for multiple learning providers, Fixed and Dynamic learning models, considered measuring criterion for existing system.

The artefacts is evaluated and compared with similar research works in adaptive learning such as Knowledge-Tree, ‘A distributed architecture for adaptive e-learning’, (Brusilovsky et al. 2004); Intelligent Tutoring Systems (Lesgold, Eggan, Katz and Rao, 1992; Koedinger, Anderson, Hadley and Mark, 1995); ADELE (ADELE Graz, 2005) – Eye Tracking technology for adaptive learning, E-Adviser, (Hawryszkiewycz’s, 2004) – Task intensive e-learning approach, and “Intelligent educational systems of the present and the future”, (Arroyo, Greaser and Johnson 2007), further discussed in Chapter 3.

1.5 The Approach and Research Contribution

The learning support approach proposed in this thesis relies on the dynamic alignment between a learning plan and e-contract for each learner. The Dynamic Learning plan, helps to keep learners (or trainees) focused on their desired learning goals and objectives; the formalised E-Contracts, dynamically linked to learning plan, provide the basis for feedback and the evaluation of both learners and providers. This approach enables learners to take advantage of multiple providers with the support of agent collaboration capabilities, where agents adopt learners’ objectives and negotiate with multiple providers to obtain best learning options and flexible learning.

This approach underpins the following contributions to knowledge:

C1) Applying software agent multi-issue negotiation capabilities to negotiate learner requirements, extended beyond cost and course title, to constitute personalised courses, with multiple provider, which ensures specified learning objectives are met; This is demonstrated by applying a user-interface template to capture learner requirements and designated learning support agents which calls for bids (proposals) from provider for courses on behalf of the learner.
C2a) Re-negotiation of courses based on learning performance scores and specified learner requirements, hence updating learner plan with learning targets and aligning DPLAN and E-Contract. This is effected through message(s) communicated between designated learning support agents.

C2b) Two-way evaluation of learner performance and provider capabilities, demonstrated by an evaluation process that involves analysis of learning performance scores and learners choices.

1.6 Evaluation

ADALP Prototype is evaluated with scenarios highlighting functional specifications with unique features (DPLAN and E-Contracts) that contribute to e-learning. Other aspects of ADALP that are evaluated include its application to learning and teaching activities and how ADALP addresses real-life learning issues. The comparison of ADALP to similar existing systems and related adaptive learning approaches focus on the differences and similarities of ADALP, compared to "Extended ITS" and Intelligent Tutoring Systems (ITS), demonstrating the advantage of ADALP over existing approaches.

1.7 Thesis Structure

The structure of the thesis is demonstrated in Figure 1.5. The arrows indicate the link between the chapters as well as the associated appendix.

---

Figure1.4: Thesis Organisation
Chapter 2 analyses surveys and e-learning reports, identifying e-learning issues. It investigates and outlines the challenges of flexible and personalised learning. Chapter 3 reviews existing research work on adaptive and flexible learning, identifying addressed and unaddressed e-learning issues; and concludes by focusing on gaps in the existing and e-learning approaches. Chapter 4 presents an outline of ADALP, a proposed solution to issues of current e-learning approaches. Chapter 5 elaborates and discusses details of the ADALP approach and contributions. In Chapter 6, a prototype implementation is presented. The implementation is demonstrated with the BDI agent model of Jadex-agent-development platform. Chapter 7 carries out evaluation of the ADALP approach and the research contributions. In Chapter 8, the results of the research and future work on the ADALP approach are discussed. Appendix A provides details of learning theories and elaborates further on the gaps of existing e-learning systems discussed in Chapter 3. Additional details of the ADALP approach system, presented in Chapters 4 and 5, is provided in Appendix B; while programming code snippets of the ADALP prototype discussed in Chapter 6, is provided in Appendix C.
Chapter 2: The E-learning Environment and its Challenges

Case studies and surveys show that e-learning promises to transform the educational sector, thereby advancing the knowledge economy; but significant challenges persist. Online learning issues, particularly on flexible and adaptive e-learning, are identified and discussed from various surveys with e-learning practitioners and researchers.

2.1 E-learning Issues

From surveys (Massey J. 2003, Bonk C. 2006), it is found that existing commercial learning systems such as WEBCT, Blackboard and others, are increasingly being adopted by a growing number of learning institutions. There is a growing need to develop adaptable learning systems to reach a wide spectrum of learners and cater for personalised needs. With emerging technologies, various approaches have been tried with varying degrees of success. As shown in Figure 1.1, key actors of typical existing e-learning Model, www.mdx.ac.uk (Basie, 2006) include the Learners, learning providers (or suppliers), Administrators, Managers, Designers and Technicians. This research re-groups these key participants into three categories: learners, suppliers (providers), and advisers; focusing on personalised and flexible learning where the learner takes advantage of multiple providers.

While e-learning has already significantly improved overall learning (and teaching), critical pedagogic innovations are yet to be developed. The following survey highlights the challenges for innovation and development of e-learning technology and examines existing learning systems and theories.

2.1.1 Learning issues in Real Life environment scenario

In rural Africa, issues of learning in schools and colleges amongst others include limited learning resources and the need for specialised knowledge and skills; hence there is a ‘...desperate need for resources for education and teaching’. Jurie Joubert, 2009. Access to resources for learning, capacity building and skills development at individual or collective level is required. Whereas in inner city schools, colleges and community centres of London or Manchester in the UK, there are diverse cultural background and a wide range of learning needs within the same age group, raising the need for...
personalised learning (for learners with heterogeneous background (See Key reasons for supporting student diversity, Page 4, ‘adjusting methods of learning, teaching and assessment to meet the needs of a wide range of students, in practice, benefits all students’, HEFCE (2002) http://eprints.ucl.ac.uk/2314/1/StudentDiversity.pdf).

In typical learning environment, common activities include: 1) Course selection and enrolment by students, learners or trainees; 2) Teaching, mentoring and facilitation of learning/training on a specified subject or range of subjects; 3) Assigning Lecturers, Teachers, supply teachers, instructors and facilitators to a class (or group) of students.

The supply teacher or mentors (who are sometimes graduate volunteers) are recruited to support learning, while educational establishments (schools, colleges and teaching agencies) are learning providers that: a) provide a range of courses, that is hoped, would match students (learners) needs, b) establish learning contracts between learners and the supply teacher or mentor, c) establish higher level contracts between teaching agencies and the providers (i.e. schools and colleges), as well as teaching contracts between supply teachers and the teaching agencies (middle level suppliers).

As expected, the principal goal of the system is to provide learners (pupil and students) with optimal and efficient learning support options to enable the learner to acquire various skills. But there are drawbacks, restrictions and limitations with the legacy system in place such as: Predefined and inflexible courses that do not match the diversified learning needs of inner city learners of developed countries like UK nor sufficient resources for rural African environment, that need addressing.

Even with the involvement of existing teaching and educational agencies, to recruit instructors, supply teachers and mentors, (in addition to regular teachers / Lecturers), to help teach for example the Sciences, Maths and ICT, within schools and colleges; to meet the demand for a wide range of learning needs of inner city learners for developed countries such as UK (and lack of resources for rural Africa learners); Traditional or legacy systems in place fall short of addressing these issues due to limitation of fixed learning models in place or inadequate application of emerging technology.

Learning and training providers as well as agencies need to consider a flexible learning support system that could meet not only a wide range of subject domains but also
specific learning requirements for learners. This includes addressing infrastructural and resource limitation of existing learning environments, including time constraints (for example the regular teaching times for UK schools and colleges). Open Educational Resources (OER), are now available and this could be harnessed to provide systematic and relevant learning resources to learners. From teaching experiences and day-to-day observations in learning environments, a flexible and personalized learning system for students, trainees and learners could take into consideration key learning elements such as:

a. A series of learning tasks (courses), based on the learning need and background
b. Specialised subject (domain) resources for diversified learning needs
c. Envisaged Enterprise / institutional needs in training

Educational training and processes must be of a quality to lead to specific learning outcomes in the form of capabilities (Hoffman, 2006). Education and learning should thus enhance capability, taking into account the interrelatedness of teaching, learning and human development; critical areas to focus on, for successful schools and colleges include: Resources and physical inputs, of programmed learning materials, local and regional support networks’, (Pillay J 2004 Experiences of learners from informal settlements. South African Journal of Education, 24:5-9).

Learning Issues
From the example of existing educational systems, it could be deduced that the following are common issues that needs to be addressed: i) Limited Access and insufficient or non-available options of learning providers (or resources) on existing systems for learners; ii) inadequate coverage (or provisions) on existing systems to cater for diverse learning objectives that meet heterogeneous learning requirement of learners and iii) Non-optimal usage of Open Educational Resources (OER). Typical scenario that further illustrates the above aspects is a learning environment that includes "supply teaching" and student mentoring, in schools and colleges.

In addition to the above issues, concepts and features such as: Useful Learning Information Feedback for learners, Updatable Learning Objectives and Learning Plan, Personalised Learning Objectives, Support for Multiple Learning Providers, Fixed or Dynamic Learning Models, amongst others, could be considered measuring criterion in
assessing existing system. These are later used to evaluate the proposed agent-support approach (see Chapter 4) for flexible and personalized learning.

2.2 Surveys on e-learning Issues

The first survey, ELNR (OECD, 2005), looks at the promises of existing e-learning systems to transform education in general and tertiary education in particular. The question “Could e-learning expand and widen access to tertiary education and training; improve the quality of education; and reduce its cost?” was examined.

The second survey, IOL (Song et al., 2004), based on learner comfort and satisfaction with style, preferences, and useful technology, looks at the aspects of what makes a learner successful, confident, and motivated in an online environment (VLE). The survey identifies broad issues involved with e-learning.

2.2.1 E-learning Needs and Required Features (ELNR)

This survey highlights the challenges for further developments of e-learning. It points out the need for innovation and development of “new knowledge management practices”, and more team work as necessary conditions for tertiary education institutions to be able to move to e-learning adoption cycles (or phases).

The cycles of e-learning systems include updates of innovative e-learning tools, learning models and emerging technologies. A related survey has identified a number of lessons learnt by institutions that are in the forefront of e-learning development (OECD, 2005):

- A paradigm shift in the way academics think of University teaching e.g. a shift away from “scepticisms about the use of technologies in education” and “teacher-centred culture”;
- A need to move towards a facilitator role of learning processes, team worker, and learner-centred culture;
- Targeted e-learning and training relevant to the faculty’s teaching programmes as well as ownership of the development process of new e-learning material by academics.
2.2.2 Educational Resources
The above ELNR survey identifies the need for Open Educational Resources (OER), a potentially innovative practice, providing an example of current opportunities and challenges that could trigger radical pedagogic innovations.

Digitalisation and the potential for low-cost global communication have opened tremendous new opportunities for the dissemination and use of learning material. This has spurred an increased number of freely accessible OER initiatives on the Internet including: 1) open courseware; 2) open software tools (such as course content management systems); 3) repositories of learning objects (e.g. MERLOT learning objects repository) and other “free” educational e-learning courses.

The OER initiatives are a relatively new phenomenon in tertiary education. The open sharing of one’s educational resources implies that knowledge is made freely available on non-commercial terms. The innovation impact is considered to be of great value when it is shared, where users freely reveal their knowledge and thus work cooperatively. Inventors of OER benefit from increased “free distribution” or from distribution at very low marginal costs. The main motivation or incentive for people to make OER material available freely is that the material might be adopted by others and even modified and improved. This could be harnessed and made more useful to learners, to suit their particular needs. The downside of this is that learners may be lost in a sea of learning resources, without the necessary tools to focus on what is pertinent or relevant to their needs.

This introduces an important challenge, which is to adapt “global OER initiatives” to local needs and to provide a dialogue between the producers/creators and users of the OER. This challenge demonstrates a need not only for “pedagogic online advisers”, but also an approach that would empower the learners to make adequate and efficient use of OER. This is further addressed in chapter 4. From ELNR, it can be deduced that effective use of online learning resources, learning technologies and overall management, demand careful consideration.

2.2.3 Improving Online Learning (IOL)
The survey ‘Student perceptions of useful and challenging characteristics’, (Song et al., 2004), looks at the aspects that makes a learner successful, confident, and motivated in
an online environment. The survey examines learners’ comfort in VLE – style, preferences, and useful online technology.

The majority of the participants in this survey identified the following components as helpful in their online learning: design of the course, the online technologies used, and time management (see Table 2.1).

**Table 2.1: Components that create successful online learning environments (percentage of respondent with satisfactory statement)**

<table>
<thead>
<tr>
<th>Level of Satisfaction</th>
<th>Design</th>
<th>Comfort</th>
<th>Motivation</th>
<th>Time management</th>
</tr>
</thead>
<tbody>
<tr>
<td>More satisfied with online learning</td>
<td>87%</td>
<td>5%</td>
<td>62%</td>
<td>62%</td>
</tr>
<tr>
<td>Equally Satisfied with online learning and face-to-face-learning</td>
<td>82%</td>
<td>82%</td>
<td>77%</td>
<td>80%</td>
</tr>
<tr>
<td>Less satisfied with online learning</td>
<td>89%</td>
<td>82%</td>
<td>82%</td>
<td>75%</td>
</tr>
<tr>
<td>Overall</td>
<td>83%</td>
<td>78%</td>
<td>76%</td>
<td>75%</td>
</tr>
</tbody>
</table>

The survey data shown in Table 2.2 attempts to answer the question “what creates barriers or challenges to online learning?”

**Table 2.2: Components that create barriers in online learning environments (Percentage of respondent with satisfactory statement)**

<table>
<thead>
<tr>
<th>Level of Satisfaction</th>
<th>Technical problems</th>
<th>Lack of Community (learning) support</th>
<th>Difficult goals / objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>More satisfied with online learning</td>
<td>75%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Equally Satisfied with online learning and face-to-face-learning</td>
<td>54%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Less satisfied with online learning</td>
<td>50%</td>
<td>71%</td>
<td>60%</td>
</tr>
<tr>
<td>Overall</td>
<td>58%</td>
<td>50%</td>
<td>-</td>
</tr>
</tbody>
</table>

Online learning participants compared to traditional classroom learning felt that a lack of community (71%) within the online environment was a challenging factor in online courses. Sixty percent of the participants reported having difficulty understanding the goals/objectives of the course and fifty percent indicated technical problems as a barrier. The biggest challenge reported by study participants were technical problems (58%). Technical problems were a challenge to participants who were more satisfied with online learning (75%) and those that were equally satisfied with online learning (54%) as compared to traditional classroom learning. Technical problems were more significant for some participants than others. As commented by participants of the
above survey for online-learning, “so many technical things … seemed to take up the whole focus of the course”.

Hence with the above barriers and challenges, Flexibility learning systems are needed to address them.

2.2.4 IOL Survey Discussion

Instructional design was one of the primary factors identified as helpful for online learning by the respondents of the IOL survey. It is not surprising that this element would rank in the top three, regardless of the mode of delivery. As stated by Dempsey and Van Eck, 2002, ‘…it takes a good design to make good online instruction…’ There exist several models upon which to base the designs of effective online environments. From the survey ‘…The challenge that remains is one of examining the current models and processes of face-to-face instruction; examining how well they work for online instruction and/or how they might be adapted’.

Previous research related to Web-based learning has also indicated the importance of the technology factor (e.g. Hill J, 2002). How to best facilitate the building of skills and comfort, remains a challenge for facilitators and learners.

The issues associated with lack of understanding learning goals and objectives link back to good instructional design which the learners stated as helpful. This study indicates the important of clarity in learning goals and objectives, for learners to better understand what is expected of them. Again, there are many models and processes that can be used to assist with the creation of learning goals and objectives, particularly as they link into a larger course infrastructure (Dick et al., 1999). Providing mechanisms where learners can ask questions and obtain feedback / recommendation to improve their understanding and expectations would assist learning efforts.

The survey 'Learning Components that create successful online learning environments' (listing technical problems were a challenge to participants who were more satisfied with online learning (75%)’ and the ' lack of community (71%) within the online environment was a challenging factor in online courses …’ identifies a need for personalized online learning support.
From the 'Components that create successful online learning environments' survey, online learning tools such as chat, e-mail, and bulletin boards, a primary forms of communication, also demonstrates the need for flexible and personalized learning approach.

### 2.2.5 Expectations of E-learning Systems

One of the main expectations (Dempsey and Van Eck, 2002) is that professional experts can deliver training/learning materials and courses from wherever and whenever, without the need for physical presence; learning should be effectively managed and monitored for optimum results for individuals and institutions with affordable expert input, utilising emerging advanced technology and “well-managed and distributed” learning provider network.

Other expected significant benefits of e-learning systems (see Table 2.3 below) include: affordable cost for both learners and providers and hence a cost-effective e-learning system; a pool of online learning resources and experts from which the community can benefit; a dynamic sustainable skills development and online learning support environment; autonomy of learners, institutions and communities to manage e-learning courses and effective skills development.

| Table 2.3: E-learning Issues, Expected Benefits and Observations |
|----------------------------------|---------------------------------|--------------------------------------------|
| **S/N** | **Issues** | **Participants’ Comments** | **Observation** |
| 1 | Face-to-face compared to online learning | Complementary role | Equally satisfied with online as well as face-to-face (82%) |
| **Overall learning:** | | | |
| 2 | Comfort with online technology | Reported that comfort with online technology (75%), impacts success | The majority of participants agreed comfort with online technologies (82%) was necessary |

It is found from this survey, that online learning tools such as chat, e-mail, and bulletin boards were the primary forms of communication in the online courses taken by the interviewees. Comments, especially on “one-to-one feedback/chat”, suggest it’s a useful feature for e-learning.

### 2.3 Analysis on E-learning Issues

From e-learning reports and surveys (Dempsey and Van Eck, 2002), it is found that there is an increasing need for innovative technology to improve learning in general as
well as specialised learning and training in various subject domains. Also there is the
need to address pedagogic support for online learners, inflexible student modelling
based on learner preferences and anticipated behaviour; restrictive access to proprietary
learning systems and narrow coverage of learning objectives.

Examining e-pedagogy of (Garrison’s, 2004), distance learning model brings out pros
and cons of VLE systems. In critically comparing the online learning theories and VLE
design principles put forth in that review, it can be seen that it is possible to design a
purposeful, creative learning environment with the appropriate adaptable learning tools.
This review also brings out the need of distributed learning and decentralisation for
customised and personalised learning systems; the need for innovative learning and
development processes to exploit interactive technologies and communication systems
to improve the learning experience; and a suitable learning approach for student/learner
development and assessment that takes care of particular questions for institutions and
learners alike that encourages a collaborative approach to personalized learning
activities. It has also been observed from this analysis that there is a need for Open and
Distance Education policy with objectives such as:

- Setting a proportion of course modules to have VLE support at least at the level
  of having module handbooks online;
- Increased number of modules to be more substantially supported by online open
  learning;
- Increased proportion of enrolled students in each school undertaking Web
  supported modules;
- Integration of VLE with student management system;
- Online pedagogical principles linked to appropriate software tools and learning
  approaches that would help course providers and learners better understand how
  to produce e-learning content and personalised learning activities, respectively.

The above e-learning needs and requirements currently exist in varying degrees in the e-
learning and training plans of various educational enterprises; and e-learning is expected
to support formal and informal learning.

2.3.1 Guidelines for effective e-learning

From the UK Joint Information Systems Committee (JISC) report of 2004, effective
practice in e-Learning should include, but not limited to, the following key factors:
Connectivity, or global access to information; Flexibility, anytime/place; Interactivity,
or immediate and autonomous assessment; Collaboration, through online discussion
tools; Extended opportunities, to reinforce classroom learning; Motivation and enjoyable learning. This is summarised in Table 2.4.

Table 2.4: JISC VLE design guidelines

<table>
<thead>
<tr>
<th>S/N</th>
<th>Six key dimensions of e-learning</th>
<th>Guidelines for effective e-learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Connectivity: global access to information</td>
<td>Engage learners in the learning process</td>
</tr>
<tr>
<td>2</td>
<td>Flexibility: anytime/place</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Interactivity: immediate and autonomous assessment</td>
<td>Encourage independent learning skills</td>
</tr>
<tr>
<td>4</td>
<td>Collaboration: through online discussion tools</td>
<td>Develop learner’s skills and knowledge</td>
</tr>
<tr>
<td>5</td>
<td>Extended opportunities: reinforce classroom learning</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Motivation: enjoyable learning</td>
<td>Motivate further learning</td>
</tr>
</tbody>
</table>

The suggested VLE guidelines and design principles are not meant to act as a constraint to e-learning pedagogical design creativity; nor is a VLE architect required to use all of the suggestions above. The six key dimensions of e-learning recommended by JISC could be extended to include: the option of Basic learning information feedback (FBG), composing customised (or personalised) courses and modules, with Updatable Learning Objectives and Learning Plan (FBO), from various VLE sites, to meet specific learning needs; the provision of Dynamic learning model (DLM) and options of choice to subscribe to more than one learning provider (VLE) at a time, with a single sign-on ID.

2.3.2 Summary of E-Learning Issues

Table 2.5 groups and summarises existing e-learning issues into five categories: 1) Issues of E-learning tools & E-learning Technology, 2) Issues of adequate and appropriate Online Learning Support, 3) Issues of Targeted and Customised Learning, 4) Issues of Effective use of available resources and 5) Issues of Defining and clarifying learning goals.
Table 2.5: Grouping e-learning issues

<table>
<thead>
<tr>
<th>Notes</th>
<th>Grouped Issues</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General Issues</strong></td>
<td>1) Issues of E-learning tools &amp; E-learning Technology</td>
<td>The need for new and innovative e-learning tools and technologies for time management and course design; Combination of robust online learning tools and pedagogy; Supportive and reliable learning and educational technology; Improving expectations of e-learning systems</td>
</tr>
<tr>
<td>(not addressed in thesis)</td>
<td>2) Issues of adequate and appropriate Online Learning Support</td>
<td>Inadequate online learning support; A role of a ‘facilitator’ for online learning processes, ‘team worker’, and a ‘learner-centred support culture’.</td>
</tr>
<tr>
<td><strong>Focus issues addressed in the thesis</strong></td>
<td>3) Issues of Targeted and Customised Learning</td>
<td>The necessity for targeted e-learning and training relevant to learners, departments and faculties of various disciplines, as well as ownership and/or development of new learning resources.</td>
</tr>
<tr>
<td></td>
<td>4) Issues of Effective use of available resources</td>
<td>Effective use of open source material as well as available pedagogic, professional and academic learning resources; Adapting “global OER initiatives” to local needs and providing dialogue between the doers and users of the OER; Finding better ways of sharing and re-using e-learning material.</td>
</tr>
<tr>
<td></td>
<td>5) Issues of Defining and clarifying learning goals</td>
<td>Improving perception of learning goals and objectives; Problems with understanding and defining learning goals and objectives on existing systems.</td>
</tr>
</tbody>
</table>

The survey reveals the challenge to design and create a context of learning levels of achievements congruent with and reinforcing educational and learning goals and the realisation of higher order learning outcomes (Garrison, 2004). Full analyses of learning issues are elaborated in Table A3 in the Appendix.

In the next chapter, existing e-learning systems and approaches are presented. It further examines how the grouped issues of Table 2.6 are fully or partially addressed in existing systems, as well as examines the strengths and weakness of existing learning systems, in terms of flexible learning, from a learner’s perspective.
Chapter 3: Literature Review of E-learning Systems

In this chapter, review of existing e-learning approaches uncovers how some of the issues outlined in Chapter 2 have been dealt with and the gaps that still persist. This chapter focuses on existing e-learning systems and approaches, particularly intelligent and adaptable e-learning systems.

3.1 The Knowledge-Tree e-learning Approach

Peter Brusilovsky and colleagues, in Knowledge-Tree (Brusilovsky et al., 2004), present an architecture for adaptive e-learning based on distributed reusable intelligent learning activities, component-based development of adaptive systems and teacher-level reusability, implementing core functionality of the system within a local group by using simple communication protocols. The goal of Knowledge-Tree is to bridge the gap between the currently popular approaches to Web-based education, centred on learning management systems versus the powerful but underused technologies in intelligent tutoring and adaptive hypermedia. It has features for both teacher-centred and learner-centred learning activities used as a primary tool in supporting practical courses.

The Knowledge-Tree approach developed the first comprehensive student modelling servers, CUMULATE and Personis (Brusilovsky, 2004). It has an architecture for adaptive e-learning, based on distributed reusable intelligent learning activities, integrating benefits of modern LMS and educational material repositories, with the power of ITS and Adaptive Hypermedia (AH) technologies. It uses a student model server to separate the student modelling from reusable educational activities. Different servers can support different student modelling approaches and different domain concepts for the same activities.

Its communication frameworks such as OKI, (http://web.mit.edu/oki/) and the Portal (http://www.uportal.org/), champion the ideas of component-based, distributed e-learning. But does not address issues of targeted and customised learning and the range of learning resources are limited. Learning goals of the system are pre-determined and may not meet the requirements of learners with heterogeneous background.
3.2 ADELE

Adaptive e-Learning with Eye Tracking, (ADELE Graz, 2005), is a research project with the aim of developing and implementing a framework of personalised adaptive e-learning based on real-time user behaviour. It examines the learner-centred aspects of adaptive e-learning and their support. For this purpose, indicators for adaptation criteria are derived from the learner’s physical characteristics and exemplary adaptive methods for e-learning environment.

Adaptability is achieved by tracking and capturing user behaviour (using physical sensors) in real time. It carries out the challenging task of setting up and retrieving appropriate personalised learning content of fine-grained user profile. The ADELE technology-based approach of “enhanced adaptive e-learning framework” is accomplished by exploiting real-time eye-tracking and content-tracking analysis supported by a dynamic background library. Some results of the ADELE project contribute to finding new ways of making advanced adaptive environments for teaching and learning feasible and affordable for institutions in the relatively near future.

Potential target groups that could benefit from the ADELE research and proposed innovations are as follows:

- Support of 100% knowledge acquisition in application fields such as aviation, traffic, different complex procedures, risk management, decision support, research on learning, and others;
- E-learning platform and knowledge management platform developers;
- Content publishers: improvement of content structuring, development of user-centred contents and contents supporting various learning styles;
- Eye-tracking system producers: development of low-cost eye-tracking systems, or application in a standard computer working place.

This is an e-learning environment that gives users a high degree of freedom in following a preferred educational path, together with control to explore effective paths. This combination of freedom and control is beneficial for students/learners, resulting in a deeper understanding of the instructional material.

Sometimes, this type of e-learning environment is problematic, since some students are not able to explore resources effectively. Based on “data from physical sensors attached to the learner”, ADELE customises and adapts the e-learning environment by planning a
personalised path for each user based on his or her needs, which is the degree of Eye Movements and Time spend per page by the user captured by the sensors, with the aim of improving the learning process.

The focus is on student modelling, a system for automatically generating the profiles of an e-learning user. Once these profiles have been created ADELE proceeds to solve the problem of how to efficiently use predictive information in order to plan a personalised educational path. The student model constructed initially can be refined and/or reviewed on the basis of new inputs to the system.

The drawbacks of the ADELE approach include the physical reliability of “sensors” on which the adaptive system is based. Physical (or hardware) sensors, which are critical to the effectiveness of this approach, are subject to accidental damage through physical movement of the learner and possible electrical/electromagnetic interference of the environment.

3.3 Intelligent Tutoring Systems (ITS)

Existing Intelligent Tutoring Systems (ITS), though automated, may or may not be online; most are designed for restricted or specific domains, e.g. designing and testing electronics circuit systems, ‘Graphical user interface of an interactive system for schemes design’, (Plamen Manoilov, Vladimir Mateev, 2004), studying specific topics of a subject such as fractions, algebra or equations in maths, e.g. ‘On-line tutoring for math achievement testing: A controlled evaluation] Beal, C. R., Walles, R., Arroyo, I., & Woolf, B. P. (2007).’, or the theory of relativity in physics ‘Andes Physics Tutor’, 2006, (http://www.andes.pitt.edu/) . This approach is inflexible in the sense that they are pre-designed for specific subject domains.

From Helande M et al, in ‘Handbook of Human Computer Interaction, 1997’, the goal of intelligent tutoring systems (ITS) is to engage learners and students in sustained reasoning activity and to interact with the student based on a deep understanding of the students behaviour. Research efforts have yielded notable successes in achieving the promise of intelligent tutoring (Lesgold, Eggan, Katz and Rao, 1992; Koedinger, Anderson, Hadley and Mark, 1995).

To demonstrate the usefulness as well as limitation of intelligent tutoring systems (in terms of subject domain flexibility), two ITS projects, the Algebra Tutor (PAT),

**The Algebra Tutor Project (PAT):** Intelligent tutoring systems for mathematics and programming has been around for a little over a decade (Anderson, Corbett, Koedinger and Pelletier, 1995). Only about two-thirds of high school freshmen take algebra I and among students who enter the academic mathematics track (algebra I, geometry, algebra II, pre-calculus), about 40% drop out each year. Mathematics achievement levels are appreciably below the national average. A maths curriculum was used as starting point for an Algebra Tutor (PAT). PAT is an algebraic problem solving environment. Each task presents a problem solving situation that describes the relationships among two or three quantities and presents from three to six specific questions to answer. Students are asked to represent the quantities as spreadsheet columns, answer the questions in the spreadsheet rows, induce an algebraic description of the relationships and graph these relationships. The student constructs mathematical expressions for deriving quantities with variable (e.g. 0.2 lx + 525 and 0.13x ± 585), where x is a variable and enters them into columns. Finally, the student enters example values into the remaining rows in response to specific queries in the exercise description. Having constructed this table, the student also graphs the equations; generates an appropriate scale and label for each axis, and identifies the intersection of the two lines. Thus, the student gains experience with alternative representations.

With the help of this system, the algebra students performed 10-15% better on standardized mathematics tasks, e.g., Math SAT exercises. In this case, it is difficult to separate the impact of the intelligent tutoring system from the impact of the curriculum. Similar effects of intelligent tutoring results have been achieved with other curriculum (Anderson, Boyle, Corbett and Lewis, 1990; Corbett and Anderson, 1991; Koedinger and Anderson, 1993a). However, the PAT project that began with an assessment of educational needs rather than concern with artificial intelligence innovation, resulted in an integrated package that yielded better results compared to traditional practice.

PAT reflects the cognitive ACT-R theory of skill knowledge (Anderson, 1993). This theory assumes a fundamental distinction between declarative knowledge and procedural knowledge. Declarative knowledge is factual or experiential.
ACT-R also assumes that skill knowledge is encoded initially in declarative form through experiences such as reading. While such declarative knowledge is a prerequisite of domain expertise, efficient problem solving requires the encoding of goal-oriented procedural knowledge.

Like many cognitive theories (cf. Kieras and Bovair, 1986; Newell, 1990; Reed, Dempster and Ettinger, 1985), ACT-R assumes that procedural knowledge can be represented as a set of independent production rules that associate problem states and problem-solving goals with actions and consequent state changes. Goal-oriented production can be derived from the declarative example above through practice in solving equations: IF the goal is to solve an equation for variable X and the equation is of the form $aX = b$, THEN divide both sides of the equation by $a$, to isolate $X$.

PAT contains many rules, for labelling table columns, entering problem givens and computing results, inducing algebraic expressions from examples, solving equations, labelling and scaling graphs and placing points. A set of programming rules are built into the tutor (representing the ideal student model), embodies the knowledge that the student is trying to acquire.

The tutors provide feedback message if the student appears confused about the nature of the current problem state or a problem solving action. For example, the tutor will point out if the student has entered the right answer for one cell in the wrong cell of a table. The tutors provide goal-directed problem solving advice upon request.

Three general levels of advice are provided: a reminder of the current goal, a general description of how to achieve the goal, and a description of exactly what problem solving action to take. Each of these three levels may be represented by multiple messages.

In summary, PAT as an Intelligent Tutoring System, is very useful and focussed on a defined domain. Its limitation is that the ‘ideal model’ applied in the system is predefined, in a “Top-Down” approach. As an ITS system, it is a “hard-wired model” which is inflexible and not transferable to other subject domain. A new model and knowledge base is required for the approach to be applicable for another topic or subject domain and would require an elaborate “ITS management system”, implementing a
diversified range of models, to accommodate and support learners with varying backgrounds and requirements.

**The SHERLOCK Project:** SHERLOCK is a practice environment for electronics troubleshooting commissioned by the Air Force (Lesgold, Laioie, Bunzo and Eggan, 1992; Katz and Lesgold, 1993). While PAT represents one of the mainstreams in intelligent tutoring, mathematics problem solving (Sleeman, Kelly, Martinak, Ward and Moore, 1989 ;) SHERLOCK represents a second main stream, in the diagnosis domain (Brown, Burton and Zdybel, 1973; Clancey 1982; Gitomer, Steinberg and Mislevy, 1995; Tenney and Kurland, 1988).

SHERLOCK is designed to give technicians practice in troubleshooting the F-15 Avionics Test Station. The test station is itself an electronic system for diagnosing failures in F-15 electronic equipment. However, the test station may malfunction and this poses an interesting problem. While there are detailed procedures for using the test station to diagnose failures in the F-I5, there are no fixed procedures for troubleshooting the test station. Since the test station breaks down infrequently, there is limited opportunity for technicians to learn troubleshooting heuristics on the job. Many of the technicians are in the relevant maintenance position for a limited time, so there is scant opportunity to build up expertise.

SHERLOCK addresses this problem by providing ample troubleshooting opportunities. In a characteristic simple problem solving scenario the trainee is informed that the test station was used to measure an F15 electronic component and the meter reading indicated component malfunction. However, when the suspect F15 component was replaced the meter reading still indicated component malfunction, suggesting that the test station itself is malfunctioning. The problem solving goal is to track down the source of the test station malfunction. SHERLOCK presents a visually realistic simulation of the external control panel of the avionics test station and the student can manipulate the controls. The internals of the test station are represented by schematic diagrams. Student can take measurements by indicating the points on simulated schematic diagram to attach leads; and the student can manipulate components, by tightening connections or ‘swapping-in’ a replacement for suspect components in the schematic diagram. The student communicates an intended action category and test station component through a set of hierarchical menus.
Independent field tests of SHERLOCK were conducted by the Air Force, comparing three groups: (1) an experimental group of relative novices who completed 20-25 hours of coached practice with SHERLOCK, (2) a control group of similar novices who continued with usual work activities, and (3) a group of experienced technicians. The two novice groups completed pre-tests and post-tests of their diagnostic skills while the expert group completed a single test. The two novice groups performed equivalently on the pre-test, while the expert technicians scored about 40% higher. On the post-test the experimental group scores rose about 35%, essentially overtaking the expert technicians, while the control scores did not rise significantly. A regression analysis indicates that the 20-25 hours of practice with SHERLOCK had an equivalent impact to 4 years of on-the-job experience. SHERLOCK achieves this result in two ways, by affording the opportunity for extensive practice and by creating educationally effective instructional conditions. But basic key learning activities such as evaluation of learning performance and strategies based on learning objectives, availability of providers and the diverse background of learners, is not catered for in this system.

In summary, unlike PAT, SHERLOCK generally does not provide immediate feedback on problem solving actions. Like PAT, SHERLOCK provides advice on problem solving steps upon student request. But the content of feedback is an issue for most systems. SHERLOCK has its limitation of predefined learning model, not transferable to other topics or subject domains.

**Intelligent Tutoring Architecture**

While some intelligent tutoring project (e.g. SCHOLAR) employed a conversational dialogue the overwhelming majority of intelligent tutoring systems employ a different tutoring model as exemplified in PAT and SHERLOCK. In these environments instruction is delivered in the context of students engaged in problem solving tasks. There are pedagogical reasons for the dominance of this paradigm: It embodies the “learning-by-doing” model of cognitive skill acquisition. There are also computational advantages associated with this paradigm. Many problem solving domains provide a problem solving formalism that is easier to parse than natural language. As might be expected, the earliest problem solving tutors focused on such formal domains as mathematics (Brown, 1983; Burton and Brown, 1982), programming (Johnson and
Summary of ITS: Existing intelligent tutoring systems (ITS) are designed for restricted “tutoring” in limited topics such as “adding fractions in Maths”, carrying out diagnostics and maintenance of electronic systems as in SHERLOCKS, or “configuring a CISCO 2500 router, in network Communications Engineering”; all of which involve pre-fixed and specified problem domain. The Traditional ITS system have fixed learning resources (without the flexibility of multiple resource suppliers or providers), with fixed learning and training objectives. The question is, “Could the later issues be addressed to make the systems more dynamic and flexible?’

3.4 Educational Brokerage Systems
The Educational Brokerage System, ‘Electronic Markets for Learning: Education Brokerages on the Internet’, Matti et al, 1996, specifies and describes an electronic educational product from virtual Universities, through intermediaries called “education brokerages”. Students are potentially able to learn what they need when and where they want to and in the format most appropriate to their needs.

The main challenges posed to the proposed pioneer electronic educational brokerage system were: the need for specialised software tools to process electronics books online; carry out exams online; tools to facilitate collaborative interactions and negotiate conditions of payments possibly through brokers and format of course delivery. It also specifies development of appropriate data structures for repositories of course material and coping with the general problems faced by electronic commerce applications. This is critical as there is a need to harmonising the various course structures from different providers to 1) facilitate access by the brokers, 2) to enable effective comparison of courses; and 3) set a course structure standard necessary for the providers.

Matti et al, 1996 also discussed other issues of online electronic education brokerage that deals with copy right issues with combined resources, to meet the demands of learners; rights of documents from producers as well as brokers and tracking use of documents; brokers rights as producers of data structures that enable part or all of a producers’ document to be used; and licensing process allowing re-use of documents.
Other issues of the proposed education brokerage system, included accreditation, which required an international accreditation body, or large companies to provide accreditation for courses, and assessment of how course objectives are to be met; as well as dynamic reconfiguration of courses, to suite fast and slow learners.

The proposed system suggested coalition of course providers (or partners) in providing courses that meet requirements of corporate bodies / institutions / professionals as well as individuals requirements. It discussed education brokerage as a network based learning environment, making education / learning more accessible and cost effective for all parties; with course delivery accessible through digital libraries, electronic books, collaborative tools, study tools designed by brokers and assessment/feedback systems.

Electronic market and Education Brokerage system: To add value to existing repository of learning resources, the system suggests’ a linkage of learner specifications, as a defined criteria to contract-required-elements from various suppliers (Universities, Software and Hardware companies, Market Research firms, Publishers, Experts and Company Executives). To deal with copy-right issues the system specifies that suppliers are responsible for quality of the courses delivered to the brokers, but the delivery and presentation to learners, do not need to be tied to the original developers of the course. This is comparable to buying raw materials and re-processing or transforming them to generate a different product to re-sale. These pose new challenges to developers and providers. Course ontology was needed to enable suppliers submit courses to an electronic repository; with agreed terminologies, serving as basis for classification; a list of subject areas and a list of courses available through a prototype submission form for providers.

Matti et al, 1996 conclude that the combine power of electronic publishing, delivery and collaboration, are building blocks of “Electronic Market Education” – transforming education/training in specified disciplines to meet customised, personalised and on-demand learning. New models of course production, delivery and presentation are needed for flexibility and ease of dissemination of courses without sacrificing effectiveness of learning.

Sample implementation of electronic marker and education brokerage system included: Questionnaire form to collect customer needs; Profiler – tool that analyse the
questionnaire, Course element Collector, which collects relevant elements from a course repository and passes them to a course generator; Document management system that supports submission of course elements; Course Generation tool to generates and compile courses using learner profile; Course Templates and Course Material Repository; Discourse-Web which facilitates group discussion needed to integrate network based resources / collaborative learning and Web-Quiz – an online exam feedback system.

The system does not however address targeted learning, efficient management of learning resources, and learner participation in setting learning goals and thus the issue of clarifying learning objectives also remain unaddressed.

### 3.5 Other Learning Approaches

**E-Learning Framework (ELF) Model**

As reported in *Contemporary perspectives in e-learning research* (Conole, 2007), the E-Learning Framework (ELF) program aimed at bringing together communities which have previously tended to work separately, particularly technology developers, and those involved in teaching and learning, to look at the wide range of practical questions involved in making e-learning effective from the point of view of learners, teachers, and institutions; ensuring new learning technologies and resources are developed and exploited in the best possible way.

Modular courses design was part of the ELF system. For the courses to be accessed by different systems and made available to learners in various environment/platforms, the course structure needed standardisation. This pointed to the fact that there was (and still is) a need for e-learning providers to work with standard course formats to ensure compatibility and a common structure accessible by both learners and providers alike. This was an issue to be addressed, to facilitate shared accessibility of scarce resources; enabling a range of resources to be made available to learners of diverse background; and hence address specified needs/requirements.

SAKAI, another online learning system, is a collaborative learning environment, built using various programming tools such as Java and Tomcat. SAKAI allows various institutions to collaborate and work with similar tools within the same platform, using open source software such as Linux, Solaris and Apache, which are affordable and cost
effective; as well as for general interaction on ICT issues: exchange of information, sharing ideas and problems, resolving general ICT problems, interacting and communicating using similar tools.

SAKAI and ELF are similar collaborative environments in that they facilitate both formal and informal learning and certainly provide a forum for resolving learning/training problems and technical issues. SAKAI and A-TUTOR are e-learning platforms that make use of learner profiles, and attempts to provide appropriate learning resources to online learners. But the problem of resource management for a wide range of users, matching resources to targeted learning goals and learning objectives remains unaddressed.

**MOODLE-based Learning and Learn-Direct Approach**

Learn-Direct (LD), [www.learndirect.co.uk](http://www.learndirect.co.uk), is a UK government e-learning system for community learning. It is a pre-designed system that provides a range of e-learning courses. The system depends on the expertise of contractors or learning centres to manage and administer the online courses effectively. As other e-learning systems, it is proprietary and learners are restricted to the pre-designed courses offered by UFI (University of Industry), who is the sole editor of the system. The LD system is a typical “one size fits all” approach with no adaptive or customisable infrastructure. Given its rigid infrastructure the system is heavily dependent on human intervention for advice and guidance through the system. It also depends on intermediaries or human-brokers to effectively implement the over 800 courses online. Brokers who may be individuals, private organisations or learning institutions, may or may not have the necessary expertise to administer, run and support the wide range of courses online. This raises the issue of online expert and pedagogic resources support.

A MOODLE-based system ([www.moodle.org](http://www.moodle.org)), unlike LD, is an open source e-learning platform being adopted by a growing number of training and educational institutions. Course content on the system can be edited by the various community institutions or designated administrators concerned. It is more flexible than LD. However, it is a tutor-oriented system, which enables course providers (including instructors, tutors and teachers) to upload and configure course content, according to the perceived needs of the learners. Again it does not have learner tools (or options for the learner) to modifying learning paths, independently, nor does it implement any personalised,
adaptive learning strategy. Others Commercial, as well as academic online systems, such as WebCT and Blackboard, including MOODLE and Learn-Direct, could be improved with tools that co “Personalised / Customisable Learning Plan” to help guide and focus the learner on specified learning objectives.

The issues associated with commercial e-learning systems such as Blackboard and WebCT as well as “academic-oriented-type” e-learning systems such as MOODLE and Knowledge-Trees, are that in most cases resources are proprietary and restricted to a single provider; other issues include prefixed learning objectives, with limited options for learners; modularity and suitability of available Courses. Tools to facilitate provider coalition, could considerably ease limitation of existing systems and provided flexible access to a wider range of courses and course- objectives, to match a more diversified learner background.

### 3.6 Agent support E-learning Systems

Software agents are programs with reasoning and intelligent behaviour, acting on behalf of users; and can independently make decisions about what actions or activities to perform or execute, in various situations and circumstances. Software agents interact with its environment according to its own active properties, preferences and goals. This section reviews software agent applications in general and its application in learning support.

#### 3.6.1 Software Agents Applications and Systems

Alan Kay, a long time proponent of agent technology, provides a thumbnail sketch tracing the more recent roots of software agents: “The idea of an agent originating in the mid-1950’s, coined by Oliver G. Selfridge, in view a system, such that when given a goal, the system could carry out the details of the appropriate computer operations and could ask for and receive advice, offered in human terms, when it was stuck.. The agent would be living and doing its business within the computer’s world.” (Kay 1984).

Nwana (1996) splits agent research into two main strands: Strand 1 roots are mainly in distributed artificial intelligence (DAI) and “has concentrated mainly on deliberative type agents with symbolic internal models.” Such work has contributed to an understanding of “macro issues such as the interaction and communication between agents, the decomposition and distribution of tasks, coordination and cooperation, conflict resolution via negotiation, etc.” Strand 2, in contrast, is a recent, rapidly
growing movement to study a much broader range of agent types, from the simple to the moderately smart.

The very diversity of applications of software agents demonstrates that agents are becoming main-stream. “Agents” of many varieties have proliferated and there has been an explosion in the use of the term without a corresponding consensus. Some programs are called agents because they can be scheduled in advance to perform tasks on a remote machine (not unlike batch jobs on a mainframe); some because they accomplish low-level computing tasks while being instructed in a higher-level of programming language or script (Apple Computer 1993); some because they abstract out or encapsulate the details of differences between information sources or computing services (Knoblock and Ambite 1997); some because they implement a primitive or aggregate “cognitive function” (Minsky 1986, Minsky and Riecken 1994); some because they manifest characteristics of distributed intelligence (Moulin and Chaib-draa 1996); Others serve a mediating role among people and programs (Coutaz 1990; Wiederhold 1989; Wiederhold 1992); perform the role of an “intelligent assistant” (Boy 1991, Maes 1997), migrate in a self-directed way from computer to computer (White 1996); yet others called agents because they present themselves to users as believable characters (Ball et al. 1996, Bates 1994, Hayes-Roth, Brownston, and Gent 1995); some because they speak an agent communication language (Genesereth 1997, Finin et al. 1997) and some because they are viewed by users as manifesting intentionality and other aspects of “mental state” (Shoham 1997).

Agents viewed by users as manifesting intentionality and other aspects of “mental state” (Shoham 1997), serve a mediating role among people and programs (Coutaz 1990; Wiederhold 1989; Wiederhold 1992, and perform the role of an “intelligent assistant” (Boy 1991, Maes 1997), are more aligned with learning. This is later applied in a proposed approach (Chapters 4, 5 and 6) to address learning issues. Agents assume the role of a learning support companion as an assistant, providing professional / pedagogic advice from monitoring learning activities and performance scores of the learner.

3.6.2 Agent characteristics and Capabilities for Learning Support
The following agent properties, generally designed into Multi Agent System (MAS), are applied (Chapters 4, 5 and 6), to assist learning:
• **Autonomy:** the agents operate without the direct intervention of humans or others, and have some kind of control over their actions and internal state. This could be useful in making intelligent plans to support learning activities.

• **Social ability:** the agents interact with other agents (and possibly humans) via some kind of agent-communication language. In learning, designated agents could interact with learners and amongst themselves to assist learning activities.

• **Reactivity:** the agents perceive their environment (which may be the physical world, a user via a graphical user interface, a collection of other agents, the Internet, or perhaps all of these combined), and respond in a timely fashion to changes that occur in it. This could assist in evaluating and responding to learner activities.

• **Pro-activeness:** the agents do not simply act in response to their environment; they are able to exhibit goal-directed behaviour by taking the initiative. In learning support, this could assist learners with appropriate feedback.

Some or all of the above features are implemented with existing agent platforms. A Belief, Desire and Intentions’ (BDI) agent model that closely represent human mental states, is found to be suitable for agent based learning systems, and provides both qualitative and quantitative learning support. Other agent models (BGI) are more applicable on other subject domain.

**Agents Platforms and Capabilities applied to E-Learning**

Agent planning derived from AI techniques (Ajith Abraham, 2005.) have been applied to various extents, in existing e-learning approaches. Fuzzy Case Based Reasoning (CBR) and Collaborative Case Based Reasoning (CCBR) have been used in resolving issues that need intelligent multi-agent system support in Distributed Learning Environments (DLE), (Lin, 2005).

Hybrid CBR is also used to build learning systems dealing with different knowledge representation for problem descriptions, domain knowledge and learning objects with both numeric and qualitative features.

To provide advance intelligence support for DLE (Dillon and Young, 2002), Multi-Agent Systems (MAS) for Distributed Learning Environment use fuzzy set theory and Case Based Reasoning (CBR) to help match or describe problems in linguistic terms,
transform numeric features and qualitative features required for indexing, case retrieval and similarity measurements. The drawback of CBR is that as case base increases, inherently the transaction speed drops. However this could be overcome with a more efficient indexing system.

Agent platforms, such as Jade, Jadex and Zeus (see Table C.2, Appendix C), to name a few, with agent interaction facilities, are yet to be fully exploited and developed to support online learning in distributed environment and heterogeneous learning background. An example is established contract net protocols that have been implemented with intelligent agents, in various online applications within agent platforms, providing “bidding” and negotiation of suitable supplier offers to clients and customers’ request or purchase orders, in online business environments.

3.6.3 Justification of Intelligent Agents and online Learning
Agents, by nature, are autonomous, with intelligent and scalable capabilities; combined with Web services they have established standardised communication protocols and inter-operability capabilities, making complementary partners. The integration of agents and Web services simplifies the deployment complexity of DLE and e-learning. Agent capabilities enable them to utilise well established standard Web communication protocols such as TCP/IP and UDP/IP in a distributed network. This provides the option of using the Internet to deliver courses and to blend campus-based education and distance learning. Esmahi and Lin (2005) in their Multi-Agent Framework for Adaptive E-learning system (MAFE), demonstrate the need to use Intelligent Agents.

Given agent characteristics and capabilities, they can be configured to facilitate Flexible and adaptive e-learning, delivering user content that matches the learner’s profile and request; as well as facilitate learner interaction with learning resources. The autonomy, intelligent, reasoning and collaboration capabilities of agents fit expectations of e-learning provisions and management for flexible learning. Agent properties allows asynchronous and collaborative processing of tasks and support for dynamic topological services.

Mobile capabilities of agents are utilised to reduce network traffic, decrease pressure on centralised network management, reduce the influence of signalling network faults during service, and tolerance regarding failure, by migrating (when the need arises) and performing locally. These “mobile capabilities” of agents are not incorporated in this
research work, although future research may explore this and extend the utilities of agent based e-learning systems.

Examples of policy-based negotiation between agents in MAS have been applied in security management and privacy protection for collaborative learning systems (Yang et al., 2002). Utilities of agent platforms, such as the semantic web and XML are used to express ontology for learning provider metadata, and ontology controlled hierarchical vocabulary for representing the knowledge system in DLE. But this could be improved upon and further exploited for personalised and flexible e-learning.

3.6.4 Distributed Learning Environments with Intelligent Agents

Lin, in *Designing Distributed Learning Environments with Intelligent Agents (DLE)* (2005), utilises a facilitator agent in learning environment. In group learning, facilitator agents, unlike agents of other Intelligent Tutoring Systems (ITS), study tutor-student relationships, through messages and feedback, and carry out activities on their own. This is an improvement on earlier pedagogic agents in ITS (Wenger, 1987; Johnson and Rickel, 1997; Lester et al., 1999; Cassell, 2000). Agents work in the background, collect data, compute statistics and monitor collaboration in a distributed learning environment. In the DLE group learning scenario, agents carry out task and various activities for the group, while evaluating the participation of group members to attain group learning goals (Dounish and Bellotti, 1992). In order to carry out their task coherently, the agents need to be aware of each other’s activities.

**Software Agent Awareness capability application in DLE**

Through Agent collaboration, it applies “awareness capabilities” to support group learning in distributed learning environment. Gutwin and Greenburge (1995) identify four types of awareness: social, conceptual, task and workspace awareness. Social and workspace awareness is utilised in group learning in a distributed learning environment.

Various mechanisms are used to provide awareness that is explicit in a learner-agent feedback and recommendations process. Gutwin et al. (1995) observe that excess information may overload the user. Too much information presented to the learner, also presents problems in discerning which is useful. Hence, awareness to the learner’s needs is an important consideration of agent collaboration in learning support.
The choices and presentation awareness of information to learners is critical. Research in computer supported collaborative working environments (CSCW), has shown that agents reduce the complexity of co-coordinating collaborative work in resource-sharing and machine-to-machine interaction (Silver, 2002).

In Computer Supported Collaborative Learning (CSCL), an aspect of collaborative work environment (CSCW), the Learner and Course Schedule, Course Presentation to Learner, Course Relevance, Monitoring Learners and Learning Clarification, are essential characteristics identified for online learning. Facilitator agents (FA) present information to learners and schedule an evaluation questionnaire, discuss information through messages and feedback to help the learner; and the agents monitor learner activities to identify any misunderstandings by the learner.

In other agent learning approaches, Muukkonent et al. (1994), agent collaboration and awareness is implemented differently. Web-based groupware for CSCL for example implements “low-level Planning” where self-regulated meta-cognitive skills, (Boekaerts, 1999), reflective and critical thinking are carried out in an “agent-guided learning” infrastructure, as an active construction process in which learners set their own learning goals and monitor, regulate and control their behaviour, cognitive abilities and motivation; hence testing their opinions and different points of view.

In an alternative “high-level planning” approach, Cao and Greer (2003) developed a system that allows users to “Specify rules that agents will use to present awareness information” to learners. Also, Alarcon and Fuller (2002) mapped users’ actions to a semantic network in order to find out what awareness information was relevant. One approach deals with direct involvement, testing, developing skills, cognitive knowledge etc, and other with “relevant learning information”. Both contribute to adaptive learning paths, personalised courses, depending on available information, cognitive abilities and skills of the learner.

**Personalised learning in DLE**

Lin (2005), in DLE, regarded personalised e-learning as a shift in perception from “one size fits all” to personalised online services with adaptive learning utilities. Known implementations of adaptive e-learning in this domain include the shift of perception in e-learning in which Kay (2001) investigates the case of a shift from “studying to
graduate” to “studying to learn”. This leads to well defined personal goals of various careers for learners, change in strategy and control in learning with co-operative rather than competitive learning. Kay also investigates the shift from classroom and location base, to learning on the move, during spare time, anywhere; and being able to fit online learning and training courses into busy schedules at home or when travelling, which leads to cost effective, accessible and portable learning systems.

From the shortlist of items identified by Kay in answer to the question, “What, in the learning process, can be personalised”, are online learning issues regarding “Course Content Adaptation”, “Adaptive Presentation of Courses”, “Course Navigation and Learning Strategy” and “Collaborating Learning Provider”. Problem-based learning, lecture-based and other learning approaches provide satisfactory results in many cases, but fall short of supporting a wide range of learners with diversified backgrounds, due to the pre-designed fixed and inflexible learning models. Kay’s Shift of Perception in e-learning could also be extended from traditional stand-alone provider, with limited online learning options, to a “multi-provider environment”, taking advantage of the Internet, the Web and AI technology.

According to the work of Brusilovsky (2003), “… increased learning is achieved with personalised teaching material’. With AI techniques and agent technology, personalised learning is feasible and could be more effective and efficient; focusing on learning goals and objectives of the learner, current learner skills and learning performance data; rather than restricting learning to fixed models based on style and preferences.

Related Distributed Learning Environment Systems
INTERBOOK (Brusilovsky, 1998), supports adaptive sequencing of pages, adaptive navigation and adaptive presentation, offering supporting features for learning. It uses the same architecture as ELM-ART11 (Schoech et al., 1998) with features such as “teach me” and a glossary generator for teaching specific concepts. Again this approach is limited to “a single central resource”, without options for multiple resources.

Dynamic Course generation (DCG) authoring tools for adaptive courses (Vassileva, 1997; Vassileva and Deters, 1998; Brusilovsky and Vassileva, 2003), generates personalised learning according to student goals and models. It dynamically adapts course content according to required knowledge, and supports adaptive sequencing by
using domain concept structures, which help in generating plans for the course. Course sequencing is elaborated by graphs and sub-graphs using pedagogic models. The pedagogic models contain representations of instructional tasks, methods and sets of teaching rules. It uses probabilistic estimations of students’ levels of different concepts in the student model. But the problem with this system and model is that they are pre-designed, fixed and un-dynamic; and fall short of addressing real life learning scenarios such as target learning and efficient learning resource management.

It becomes essential that a dynamic approach is considered to cope with changes in real-time environment. This entails re-modelling and planning strategies to provide and support the ever increasing and demanding learning / training requirements.

Identifying and addressing the issues of fixed learning models, efficient use of recourses and hence targeted learning, could improve current online learning and contribute towards filling the gaps in existing approaches.

To illustrate some of the gaps in DLE and related systems such as DCG, for a student who fails to learn a concept with this approach, DCG provides a local re-planning option. In local re-planning, only parts of the plan related to the goals are changed. A global plan is required to find an alternative plan for the main teaching goal. DCG is designed mainly from a teaching perspective. It uses a planner to build course plans by searching for sub-graphs that connect concepts known by the learner to new concepts, which set the goal for the learner. Hence the planner may link (or connect) several known concepts of learners to several new concepts, which set the goals (or tasks) for the learner.

Finding an alternative plan may prove difficult or impossible if the system runs out of concepts known by the learner that can be connected to new ones on the system. Without the option for the learner to input and dynamically interact with the system, the learner may reach a deadlock and become disenchanted and drop out.

AHA (De Bra et al., 2000; De Bra and Ruiter, 2001; De Bra et al., 2002) is similar to DCG. It is a generic system for adaptive hypermedia, aimed at bringing adaptively to Web-based applications. AHAs “adaptive learning engine” is made up of a domain model, user model and adaptation model. The AHA model differs from the others,
mainly in the extension of the concept model, where concept values could be “non-existent or negative”. The new features are based on the AHAM reference model (De Bra et al., 1999), which is an extension of the well-known Dexter reference model for hypermedia (Halasz & Schwartz, 1994). A more flexible approach, reflecting real-time learning situations, unlike the probabilistic and fixed student model approach, to address dynamic learning requirements, would be desirable.

**Learning Activity Management System (LAMS):**

The LAMS is a tool for designing, managing and delivering online collaborative learning activities. It provides teachers with visual *authoring environment for creating sequences of learning activities*. These activities could include a range of individual tasks, small group work, class activities based on both content and collaboration. It utilise “learning design” tools, for re-use and adaptation of content, for collaborative e-learning. (Dalziel, 2003, “Implementing learning design: the learning activity management system - LAMS”)

The current LAMS features support the creation/development of learning sequences in formats that could be integrated with existing content management systems such as Blackboard 7 to 9, Moodle 1.6 to 1.9.x, dotLRN, WebCT, Sakai, MS SharePoint 2007. One of its features, the LAMS Activity Planner, provides a suite of ready-to-use templates based on "good e-Teaching practices"; and (in the course of this research), an “enterprise version”, provides features to make changes to “the Planner Template content”, by “authorised experts” and “a central support group”, to suit local context.

LAMS group’s learners in a “one-size fits all / Top-Down” design approach, and the system designed for teachers, is based on “group learning activity processes”. It falls short of addressing flexible, custom/personalised requirements, for learners, “personalised learner requirements”, or personalised learning-support processes,...

**3.6.5 Software Agents for Co-operative Learning (SACL)**

Guy A. Boy (1997) builds agents based on “knowledge blocks” and “metaphors”. He provides examples of agents for co-operative learning as follows:

1) Situation recognition agent: a case-based learning agent that recognises similar cases (situations) of the past and applies similar solutions; provides analogies of previous cases and motivates learners through a story telling agent.

2) Incidental learning agents: Agents that pick up and illustrate interesting...
situations on different subjects and situations.

3) Problem solving agents: Agents responsible for logical and cascaded problems, such that problem A must be solved before problem B, i.e. solving cascading problems with semantic connections between them.

4) Story-teller agents: Agents that pick-up and playback Video database to serve as story tellers. The main problem is indexing, for easy browsing and selection by learners in the right context (Bradshaw, 1997).

5) Learning-by-Doing Agents: agents that enable users to learn by doing, based on simulation. This is otherwise known as rapid prototyping.

6) Being “one’s own teacher”: Suggest questions (to) software agent, a knowledge-based system that helps in learning through interacting with students; listening to students and asking questions, which enable students to learn from their own ideas; asking questions students wouldn’t think about on the topic they presented; making efficient use of an online experts system.

7) Evaluation agent, in M-Software architecture (Bradshaw, 1997), to classify and assist students according to weaknesses and strengths; make better use of pedagogic resources to improve learning and training efficiency.

The above addresses specialised and pre-designed aspects of agent involvement in online learning. However issues of learner participation in specifying learning requirement and clarity of learning objectives, efficient management of learning resources and targeted learning, remain unaddressed.

3.6.6 Agent Framework for Learning Systems (AFLS)
(Hawryszkiewycz’s, 2004), in AFLS, (HIT), designed intelligent software agents that support users to accomplish “knowledge-intensive tasks” and training on defined projects. HIT provides a prototype of an intelligent programmed planning and scheduling system that sets up learning activities. It proposes a general framework for self-directed learning, different ways in which software agents can meet changes in training and learning environments, guiding learners through a learning plan. HIT looks at two classes of agents: agents that create learner plans and agents that manage the learner plan and dynamically amend it if and when the need arises. HIT concentrates on developing generic learning materials and combining them into study programmes with software agents to support the process. It defines elementary objects, combined in flexible ways to compose objects to achieve learning goals, and sets learning objectives together with learning plans and defined learning material.
The learning plan is usually a set of lectures and assignments. HIT proposes customisation to meet specific learner needs and guide the learner through the learning plan. According to HIT, guiding learners through learner plans could take the form of an expert instructor, providing elementary knowledge before proceeding with the actual plan.

But there are unaddressed issues with the learning environment of the HIT approach, such as where and how the learning tasks are accomplished and what support is needed in setting up learning goals; how to address specific needs of learners and educational institution; and prioritising learning goals. The prototype e-adviser examines limited learning resources in a restricted training environment of pre-determined set of tasks.

The learning methods of the e-adviser (a prototype of HIT), is currently restricted to lectures and assignments. Efficient management of learning resource is unaddressed; learner participation in specification of learning goals and clarity of learning objectives is still an issue and the lack of tools to manage targeted learning.

3.6.7 The E-adviser
The E-adviser, (Hawryszkiewycz’s, 2004), is a prototype of intelligent programmed planning and scheduling system that sets up learning activities. It focuses on “adaptive e-learning systems, using intelligent agent technology and Web Services (WS)”, designing intelligent software agents for supporting users to accomplish “knowledge-intensive tasks” and training on defined projects. This learning approach investigates and establishes aspects of adaptive Web-based educational systems in the context of achieving interoperability in the Semantic Web. The E-adviser architecture is an adaptive and collaborative e-learning system and consists of users’ personal agents, task agents running on distributed agent platforms and a set of discoverable web services. According to (Lin et al, 2006), one of the learner issues that E-adviser needs to address, is the ability to generate timely, personalised and adaptive learning plans and schedules, best suited for each learner in an MSc Information Systems (MSc IS) course. Substantial Work needs to be done to make the current E-adviser work well enough for practical use, even with the limited learner-centred features. For example, the schedule optimisation algorithm of the scheduling agent needs further improvement for a robust practical implementation.
In its current state, E-adviser is good for a specific project training environment. However, it is difficult to adopt it in other learning environments, given that it has fixed pre-designed and pre-planned tasks, with limited adaptability. Some elements of E-adviser, such as the “programmed planning and scheduling system” are critical in scheduling learner activities, especially where several tasks are to be accomplished within a given timeframe. However, this is limited to a confined project work environment. There is room to expand the agent framework of “programme planning” to operate in heterogeneous environments, to include intensive task management activities with different learning providers.

3.7 Summary of E-learning approaches and learning issues

To summarise the above E-Learning Systems:

- i) ADELE – Implements an eye tracking using hardware sensors; the system has limited intelligence and inability to evaluate performance and feedback to learner;
- ii) E-Adviser - Assists learning and training on defined project; Not adaptive but a highly intelligent system;
- iii) Knowledge Tree – uses adapting hypermedia with learning content based on a “learner model”; with limited pre-defined learner preferences.;
- Intelligent Tutoring Systems (ITS): Using AI to Improve Learning of Algebra; Training in Maintenance of Electronic Systems; Have fixed and predefined subject domains;
- V) Commercial Systems: LAMS, WEBCT, Blackboard, Learn-Direct are Non Intelligent systems, designed with pre-determined learning models and fixed learner preferences.

Classification of Existing E-learning systems

The above approaches could be classified (see Figure 3.1) into three main categories, Intelligent, Non-Intelligent and Brokerage systems. Type A: The Intelligent systems (ITS, E-adviser, ADELE and Knowledge-Tree are mostly proprietary, prefixed and inflexible); Type B: Non-Intelligent systems (BD/WCT, Learn-Direct, etc) - Systems with fixed and inflexible learning content, with limited personalised features; and Type
C. Non-Intelligent Educational Brokerage Systems (EBK), with coalition features for course supply on-demand learning.

These systems are compared with the ADALP, a proposed approach, discussed in Chapters 4 and 5, which applies BDI agent capabilities to provide personalised and flexible online learning, with provider options and learner participation features, in determining learning objectives.

Figure: 3.1 Classification of Learning Systems - illustrating gaps addressed by proposed agent-based system – ADALP (an intelligent Brokerage System for online learning support)

E-learning issues unaddressed by the systems reviewed include: i) Restrictive Access to learning providers (resources) - the systems depend on a single provider; ii) Narrow Coverage of Learning Objectives – the systems have limited predefined learning objectives and iii) Ineffective use of Open Educational Resources (OER) – existing and available learning resource are not sufficiently exploited. Hence, it is seen that the three main identified issues in Chapter 2 (Table 2.6): 1) Targeted and Customised Learning, 2) Ineffective use of available resources and 3) Defining and Clarifying learning goals, are only partially addressed or completely unaddressed by the above systems.

The “Targeted and Customised Learning” issue could be sub-divided into three parts as follow: 1) Personalised learning (Planning of learning activity and online learning tasks support); 2) Evaluation of Learning Progress; and 3) Modelling Learner’s need. Other identified issues of: 4) Ineffective use of available resources; and 5) Defining/Clarifying learning goals; makes a total of five main issues addressed in this research work. Table 3.1 summarises the above issues of existing e-learning approaches.
and Table 3.2 summarises partially addressed and unaddressed issues of each approached.

**Table: 3.1 Summary of adaptive e-learning and personalised issues**

*Abbreviations:* BD/WCT – Blackboard/Web-CT, Adv - E-Adviser, AD-ADELE, KLG-Knowledge-Tree, EBK – Education Brokerage System

<table>
<thead>
<tr>
<th>S/N</th>
<th>E-Learning issues</th>
<th>SACL</th>
<th>ITS</th>
<th>BD/WCT</th>
<th>Adv</th>
<th>AD</th>
<th>KLG</th>
<th>EBK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Approach Types</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>C</td>
</tr>
<tr>
<td>1</td>
<td>Personalised learning: Meeting Learners, expectations, Planning of learning activity and Online Task support</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Evaluation of Learning Progress (IEL)</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Modelling Learner’s need</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Effective distribution and re-usable learning resources</td>
<td>√</td>
<td></td>
<td></td>
<td>√</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Improving Clarity of learning goals &amp; learning objectives for targeted and customisable learning) (IEL) – Unaddressed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The ticks in the boxes of Table 3.1 indicate the issues addressed or partially addressed by the existing approaches and systems.

**Table: 3.2 Learning approaches and identified issues**

<table>
<thead>
<tr>
<th>S/N</th>
<th>Issues</th>
<th>Existing Approaches</th>
<th>Addressed issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Need for personalised learning content according to learner objectives, skills and available provider capabilities</td>
<td>Knowledge Tree, Educational Brokerage System (EBK), E-Adviser, ADELE</td>
<td>Partially addressed</td>
</tr>
<tr>
<td>2</td>
<td>Lack of clarity in designing learning goals and objectives of courses on existing e-learning platforms; improving perception of learning goals and objectives for online courses (online mentoring)</td>
<td>None</td>
<td>Currently Unaddressed</td>
</tr>
<tr>
<td>3</td>
<td>The need for effective distribution and re-usable learning resources</td>
<td>None</td>
<td>Currently Unaddressed</td>
</tr>
<tr>
<td>4</td>
<td>Evaluation of learning progress, feedback and support for online learners (ELP)</td>
<td>Blackboard, WebCT, LearnDirect</td>
<td>Partially addressed,</td>
</tr>
<tr>
<td>5</td>
<td>Improve modelling learners’ needs (learning requirements and learning styles (MLN))</td>
<td>Knowledge Tree</td>
<td>Partially addressed</td>
</tr>
</tbody>
</table>

As shown a) Personalised Learning is partially addressed by Knowledge Tree, DLE (Lin, 2005) and EBK system; b) Effective distribution and re-usable learning resources is partially addressed by EBK system; c) Improving Clarity of learning goals & learning...
objectives for targeted and customisable learning is unaddressed; d) Evaluation of Learning Progress (ELP) is partially Addressed by existing commercial e-learning systems (such as LAMS, Blackboard, Web-CT, Learn-Direct) and EBK system; e) Modelling Learner’s need (MLN) is also partially Addressed by Knowledge-Tree and EBK system.

Also, Knowledge-Tree partially addresses targeted and customised learning (i.e. narrow coverage of learning objectives), applying client-server technology; Knowledge Tree and Educational Brokerage Systems (EBK) also partially address the issue of inefficient learning resource management.

The next chapter presents an agent-based approach, ADALP, which focus on addressing the above issues, applying a dynamic agent-support model with specified learning requirements and objectives), to re-dress existing inflexible student modelling (currently based on learner preferences and anticipated behaviour from fixed learning models).
Chapter 4: The ADALP Approach for Flexible and Personalised E-Learning

This chapter presents an overview of ADALP, an innovative approach to flexible learning, which addresses e-learning issues reviewed in Chapter 3. The approach supports personalised and flexible learning applying intelligent agent capabilities. The issues outlined in Table 3.2 are addressed with the ADALP features discussed in the following sections.

4.1 ADALP Overview

The approach, Figure 4.1, focuses on negotiating courses, based on learner specifications (or requirements), with multiple providers; generating a dynamic learner plan (DPLAN), and support for flexible learner requirement specifications, which help clarify learning goals and objectives. The approach constitutes suitable courses for learners, from the learner specifications. It also focuses on feedback and evaluation of learning progress.

The overall learning approach models personalised learning needs, composing learner requirements interactively with the learner, providing “expert feedback”, (subject domain advise), resulting in the generation of a list of course options for the learner to chose from. The approach develops learner requirements from flexible and updatable templates that capture basic information describing learner’s intention and learning objectives. This “ground-up” approach constitutes a “Basic Requirement Model” (B-Mode), which is made up of processes that involves capturing “current learner needs”, “current learning performance”, and matching them with suitable courses from multiple providers, mediated by software agent. This deviates from the existing Top-Down approaches, where instructors and designers create fixed models of different categories of learners and their needs.

A flexible updatable template is developed and utilised to generate online contracts (i.e. an E-Contract) between the learner and the provider(s), given that multiple providers are involved in the learning model. The E-Contract, binds the learner with flexible learning (and training) terms and conditions based on the number of course modules to be taken, course duration, cost and any supplementary courses that may be needed. A provider may also sub-contract with other providers to supply the learning requirements of the learner.
Thus, with the learner’s requirements, which are generated interactively with learning-support agents, applying flexible requirements capture templates, the DPLAN, as well as a binding flexible E-Contract; the ADALP approach, based on flexible agent architecture, provides flexible and personalised learning. The captured learner requirements are negotiated with multiple providers, generating updatable learner plan, hence empowering learners and accommodating a wide spectrum of learning needs.

**Figure: 4. 1 ADALP Approach Block Diagram**

During course negotiation, providers offer various courses, through a broker agent, which meet learner’s specific objectives. As shown on the Figure 4.1, the personalised *learner resource* (i.e. personalised courses), are generated from agreed offers and updated according to learning performance. A Dynamic Learning Plan (DPLAN), for each learner, serves as an index to personalised resources as well as maintaining a record of learning goals and objectives; while an online learning contract (E-Contract) specifies agreed terms and conditions of learning, between the learner and the providers.

*Evaluating learning performance* is based on learning evaluation indicators and target scores (which reflect learning objectives), set-up at the start of a course. These are
updatable in the course of learning. The approach provides learning feedback to learners in feedback process which helps personalise learning.

4.2 The ADALP Structure
Agent interaction with learners and negotiation with providers (cluster A1), Figure 4.2, is carried out at three levels: Agent-to-Learner (LA), Learner-to–Provider (LP) interactions and Provider-to -Provider (PP). Interaction between modules of the ADALP system is driven by intelligent agents (not shown in Figure 4.2). Agents assist learners to specify personalised learning requirements and generate dynamic learning plans with course options, as well as provider options. Designated learning support agents negotiate with provider agents to generate specific learning resources that match learner requirements.

4.2.1 Learner Requirements
The learner’s requirements consist of learning goals and objectives, generated from a template which specifying subject domain and required subject specialisation. Learning requirement specifications could include the skills level requirements, Course Internship requirements, Mode of delivery, Course duration and Summary description of learning interest. These requirements are assessed by designated agents that apply intelligent techniques (Engelmore et al, 1993) to ensure specified subject titles and learning objectives are valid.

A learner interface agent captures the learning requirements that are formulated as a learning request. The learning requirements are analysed into specific learning courses (tasks and sub task), before the negotiation phase between a broker and provider agents.

4.2.2 Negotiation with Providers
ADALP employs learning support agents which engage in collaboration and negotiation with provider agents (PIA), to match the captured learning requirements, with courses offered by PIA. The providers assess the learners’ requirements, (in a negotiation process), to propose matching resources.

By the end of the bidding process learners are provided with a definitive course offers from providers, enabling them make informed decisions about the courses and resources that they would need. The course title, cost of the courses, course duration, supplementary courses (if any) are issues considered in the negotiation process.
Contracted and personalised learning resource as well as initial DPLAN and E-Contract, are generated at the end of the negotiation phase.

4.2.3 Learner Evaluation
Continuous evaluation of learning performance is carried on the selected courses, based on target scores and learning evaluation indicator (LVI) components of DPLAN for each learner. On-going results of learning performance are fed back to the learner with recommendations for action.

The ADALP approach engages a two-way evaluation of learner requirements and provider capabilities. The providers evaluate learner’s requirements, applying a decision table based on the specified learning objectives, to propose course offers, and the learners evaluate the offers (and hence provider capabilities), to accept the offers and/or update their learning requirements. In a feedback process, designated support agents, evaluate learning performance score against target scores set in the DPLAN. The evaluation results in: (1) update of personalised learning resource based on the learner requirements and provider course offers; (2) setting up new target scores or updating existing ones and learning evaluation indicators of DPLAN; (3) review of the learning objectives and recommendation of new or supplementary courses based on learning performance; (4) switching or replacing providers and supplementary courses with alternative or more suitable ones (while considering contract terms and conditions. The dynamic learning plans set-up in the approach and the e-contracts are updated, as a result of learners underperforming, (Not matching set target scores for a specified learning objective) or new requests that are made.

Figure 4.2 also illustrates typical activities involved in ADALP. Activity cluster A1 involve agents who collaborate to generate DPLAN and e-contract; Activity cluster A2 consist of agents that support learning/training process as specified in the DPLAN and e-contract, focusing on the process of evaluation; and Activity cluster A3 consists of agents responsible for analysing target and learning performance scores, formulating specific learning request and feedback to learners, based on their requirements and learning/training results.
4.3 ADALP Process

The flexible online learning approach applies agent deliberation capabilities in the following process:

1) Capture of learning requirements and generate learning request, cf Section 4.2.1;  
2) Negotiate of learning requirements with providers (cf Section 4.2.2);  
3) Devise dynamic learning plan (cf Section 4.2.2);  
4) Devise learner-provider contract (e-contract, cf Section 4.2.2);  
5) Evaluate and update learning plan and e-contract (cf Section 4.2.3);  
6) Revise (1) to (5) as appropriate (cf Section 4.2.3).

Steps (1) to (4) is carried out by agent cluster A1, step 5 by agent cluster A2 and step 6 by agent cluster A3. These process steps is summarised in Table 4.1.

Table: 4.1 ADALP Features and Process Steps

<table>
<thead>
<tr>
<th>Process Steps</th>
<th>Step Title</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Learner Requirements (LR)</td>
<td>Section 4.2.1</td>
</tr>
<tr>
<td>2</td>
<td>Negotiation with Providers (NP)</td>
<td>Section 4.2.2</td>
</tr>
<tr>
<td>3</td>
<td>Devising Dynamic Learner Plan (DP)</td>
<td>Section 4.2.2</td>
</tr>
<tr>
<td>4</td>
<td>Devising E-Contract (DC)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Learner Evaluation (LE)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Revise (1) to (5) as appropriate (Rev)</td>
<td></td>
</tr>
</tbody>
</table>
As shown, evaluation of learning performance could result in re-formulating a learning request, hence the process iterates from (1) to (5). The algorithm exits when learning targets scores set-up in the learning plan (and specified learning goals), are accomplished.

4.4 ADALP

Based on the hypothesis that agents could support flexible and personalised learning (Section 1.4), this thesis makes the following contribution to knowledge:

C1 A learning support process based on Multi-issue-Negotiation and Contracting Courses with Multiple Providers; C2a) Renegotiation of learner requirements base on learning performance (devising and updating Dynamic Personalised Learning Plans and E-Contracts with multiple providers); and C2b) Two-way evaluation of learner performance and provider capabilities as a supplementary contributions.

C1 The negotiation process is underpinned by calls for proposals from multiple providers by broker agent, on behalf of the learner; with options for coalition and subcontracting between providers on courses that match learner specifications. The six-step iteration process ensures that specified learning objectives are met.

C2a Re-negotiation of courses based on learning performance scores and specified learner requirements; Dynamic learning plans are generated based on specified learner requirements and are updatable on re-negotiating courses, based on changes in learner requirements and learning outcomes; online learning contracts (e-contracts) with multiple provider are aligned with dynamic plans.

C2b The Evaluation of Learning Performance and Provider Capabilities is based on tracked record of performance scores and learning evaluation indicators (LVI).

Figure 4.3 illustrates the ADALP approach contributions classified as innovative process and agent support algorithms, mapping them to the process steps. The mapping is later used to motivate an appropriate evaluation approach for each contribution.
4.5 E-learning issues Addressed by ADALP

Agents of ADALP approach, carry out activities that address current e-learning issues. The learning issues and research contributions are related as follows:

1) C1: This contribution (An interactive learner support process based on Multi-issue negotiation of courses with multiple provide), takes care of the need for personalised learning, and provides a Contract-based flexible and personalised learning support (with negotiated courses from providers);

2) C2a: This contribution (Dynamic updatable learning plans) enables Re-negotiation of courses based on learning performance scores; aligning DPLAN and E-Contract; Devising and updating personalised dynamic learning plan (DPLAN) and e-contracts address issues of fixed and inflexible learning models (Table 3.1); this also address the issues of evaluation and learning progress issue;

3) C2b: The Two-way evaluation of learning performance and provider capabilities addresses issues 1 and 4 on personalised learning and efficient resource management.

Detail mapping of ADALP contributions and the identified learning issues are outlined in Table 4.2.
Table: 4.2 ADALP contributions and addressed learning issues

<table>
<thead>
<tr>
<th>E-Learning Issues</th>
<th>Contributions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C1</td>
</tr>
<tr>
<td>1) The Need for personalised learning</td>
<td>Interactive process supporting learners’ needs)</td>
</tr>
<tr>
<td></td>
<td>Agent interaction and collaboration support for</td>
</tr>
<tr>
<td></td>
<td>personalised and targeted learning</td>
</tr>
<tr>
<td>2) Evaluation of learning Progress</td>
<td>Updating target scores etc of DPLAN, as well as e-</td>
</tr>
<tr>
<td></td>
<td>contract terms &amp; conditions</td>
</tr>
<tr>
<td>3) Fixed /inflexible learning model</td>
<td>Matching relevant resources to learners’ goals and</td>
</tr>
<tr>
<td></td>
<td>objectives</td>
</tr>
<tr>
<td>4) The need for effective distribution, sharing and</td>
<td>Aligning OER, pedagogic and professional resources</td>
</tr>
<tr>
<td>re-use of learning resources</td>
<td>to specified needs</td>
</tr>
<tr>
<td>5) – Lack of clarity on learning goals and objectives</td>
<td>Defining and Specifying learning goals and</td>
</tr>
<tr>
<td>(improving learning perceptions)</td>
<td>objectives</td>
</tr>
<tr>
<td></td>
<td>Agent support in negotiation and course</td>
</tr>
<tr>
<td></td>
<td>recommendation</td>
</tr>
<tr>
<td></td>
<td>Support in sourcing learning resources</td>
</tr>
</tbody>
</table>

4.6 The Role of Agents

The role of agents in the ADALP approach is to support learners with the following intelligent capabilities in specifying learning requirements, learning objectives, feedback on performance scores and efficient management of learning resources: Reactive and Pro-active agent behaviours are applied to support negotiation of flexible and personalised learning requirements with multiple learning providers. Agent activities include updating learning plans and e-contracts, analysis and evaluation of learning progress of the learner and recommending courses based on learner’s background and performance.

Figure 4.3 illustrates designated ADALP learning support agents made up of agent activity clusters A1, A2 and A3, Figure 4.2. Cluster A1 deals with interaction and capturing learner requirements, negotiation of courses with providers, generating dynamic learning plans (DPLAN) and formalising contracts (e-contract).

Cluster A2 deals with evaluation of learning processes, responsible for updating DPLAN and E-Contract. Cluster A3 carries out analysis of evaluation results and makes recommendations of replacement courses based on learner requirements and performance scores.
Figure: 4.4 Expanded ADALP Agent Activities

Figure 4.4 shows agent clusters A1, A2 and A3 interacting to provide learning support to learners - from the capture of learning requirements, management of learning resources, to analysis/evaluation of learner performance and feedback; updating learning plan to suit learners’ background and target skills.

A Results analysis agent (RAA) collaborates with the Expert Interface Agent (EIA) (Cluster A2) to generate appropriate feedback on learner requirements or performance results (Figure 4.5). While generating learner requirements, the expert interface agent is supported by a Task analysis agent (TAA) in recommending courses; and assist in the “break down” of learner’s requirements into learning tasks, matched with courses from “competing” learning providers.

A Supervisor and Co-Supervisor agents (SA/Co-SA), of cluster A1, co-ordinate learning activities, facilitating the delivery of courses to learners and update personalised learning plans and e-contract.
The ADALP approach agent system also provides specialised adviser and pedagogic support (Figure 4.4) to learners, helping in formulating learning requirements.

Cluster A1 agents are responsible for the negotiating learning courses with providers, generating and aligning DPLAN with corresponding e-contract (C1 and C2a). Cluster A3 agents (Figure 4.5) are responsible for diagnosis, evaluation and feedback on learners performance in a two way evaluation process (C2b). The evaluation process may also result in the update of DPLAN and e-contract, hence re-enforcing contribution (C2a).

In summary, ADALP agents adopt learning goals and objectives from learners and translate them into tasks and sub-tasks, evaluating them by target scores and learning evaluation indicators.

4.7 *Summary of the ADALP Approach*

ADALP’s unique features include interactive learning activities and collaboration between designated agents, to aid learning requirement specification, evaluation and feedback options for flexible learning plans. It generate e-contracts between learners and providers; hence empowering learners and ensuring flexible personalised learning. It’s a six-step learner-support process applying designated agent clusters. The next chapter discusses further details of ADALP approach and its contributions to e-learning.
Chapter 5: The ADALP Approach Structure and Features

This chapter elaborates the design and main contribution of the Adaptive Agent Learner Plan (ADALP) approach introduced in Chapter 4. It discusses the six-step process of the approach and presents in detail, the ADALP structure and features. The chapter also outlines the principles underpinning the design and concludes with a summary of the ADALP artefacts.

5.1 Design Principles

The ADALP Approach is based on a “Basic Learning Requirements Model” functional specifications and design of ADALP agents applied to flexible learning.

Basic Learning Requirements Model (B-Model)

The limitations of prefixed and inflexible learning models of current learning system discussed in Section 3.6.4 are addressed by ADALP agent-support learning approach with a dynamic six-step learning process. The ADALP Basic Six-Step learning Model (B-Model) approach complements Kolb's learning styles model based on experiential learning theory (ELT), 1884. Kolb's experiential learning theory (learning styles) model sets out four distinct learning styles (or preferences), based on a four-stage learning cycle, which might also be interpreted as a 'training cycle'. Kolb offers an approach to understand individual different learning styles which includes 'cycle of learning' as a central principle of experiential learning theory. In the Kolb model 'immediate or concrete experiences' provide a basis for 'observations and reflections'. Many learning providers have adopted this model. However, irrespective of the learning model adopted by course providers, the ADALP (B-Model) approach ensures effective learning through clarifying learning objectives, empowering learners to achieve learning goals with course options from multiple providers, applying agent negotiation principles.

The six-step process of ADALP approach caters for heterogeneous learning background and hence various learning styles; also enabling "competition services” between providers and “quality course provisions”; empowering learners to determine relevant courses matching their learning objectives from multiple providers. The B-Model supplements the constructivist theory (See appendix A), as learners are empowered to 'construct their learning' and 'build up knowledge and skills' in collaboration with facilitator agents and learning providers.
The reasoning capabilities of agents provide learning support thus: the agents “learn” from their environment – sensing and capturing learning needs, generating new learning plans or strategies for a given problem and update existing ones (Sadri F, 2006). ADALP agents apply matchmaking and negotiation techniques to generate and update dynamic learning plans and learning contracts. Agent capabilities of mobility and information sharing, (Sadri F, 2007), helps decentralise learning resources, decongest access to resources and speed up the system. However, agent mobility aspects are left for future application.

The “Basic Six-Step Learning Requirement Model” of the ADALP approach, involves the capture and analysis of basic learning requirements to generate a dynamic learning plan (DPLAN) and formalize learning contracts (E-Contract) between the providers and the learner. The DPLAN and E-Contracts are updated as the learning needs and requirements change. The approach provides learners the option to choose courses from multiple providers.

Apart from capturing learner requirements, learning activities are monitored, and feedback generated to learners. The approach ensures learner participation in specifying learning objectives in contrast to fixed model approaches (e.g. Knowledge Tree) with no learner participation in deciding learning goals and objectives; hence ADALP accommodates learners of heterogeneous background.

The agent-enabled feedback feature prompts learners with proposed actions for flexible learning, as well as update learners on learning progress; empowers them to make informed decisions with personalised advice; making provision to update learning needs and expectations, hence providing personalised and flexible learning matching specified learner requirements.

ADALP approach supports learners and learning activities with distributed and reusable learning objects (courses and lessons) from multiple-providers. However, this is unlike Distributed Object Resources that are shared but restricted to a single provider. It provides options for courses (and/or course modules) from various providers that may “compete” or collaborate to provide learning requests from various learners (ref Section 3.7.3).
5.2 ADALP Approach Functional Specification

To provide flexible and personalized learning with specified learning requirements, considering learning activities described in Section 4.3 and agent cluster activities (Section 4.5) applied by the ADALP approach to address learning issues established in Table 3.2, the six-step learning process is driven by the following functional specifications:

1) The capture of learning requirements and determining learning goals and objectives (FRM1)
2) Negotiation of derived learning task (courses established from learning requirement specifications), with providers. (FRM2)
3) Devising personalised learning plan and e-contract, based on learning requirements and negotiated courses (FRM3)
4) Aligning and Re-negotiating requirements of learning plan based on learning outcomes (FRM4)
5) Evaluating learning performance to monitor and meet learning targets (FRM5).

The above functional specifications address personalised learning issues, providing a flexible learning model, as well as optimise the use of learning resources, unavailable in existing systems (Section 3.6).

Table: 5.1: ADALP Functional Specifications, Demonstrations and Contributions

<table>
<thead>
<tr>
<th>ADALP Contribution</th>
<th>ADALP Approach Functional Specifications</th>
<th>Proof of Concept (Demonstration)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1) Learning support process based on Multi-issue-Negotiation with multiple providers (for personalized and flexible learning on learner-specified course objectives).</td>
<td>1) Capture of learner requirements using flexible customisable Templates (Learner-agent interface): (FRM1) 2) Analysis of proposed learning goals and translating them into corresponding learning task (Courses); applying expert knowledge base/resources and generating feedback messages with learner participation (FRM2) 3) Bidding for courses; Negotiating Course requirements (FRM3) 4) Devising and Updating personalised learning plan, based on learning objectives; Aligning learning plan with e-contract (FRM4)</td>
<td>1) LIA - learner interface Agent (Applying User-Interaction Template to capture learner requirements) Future Implementation 3) SA – Supervisor Agent Bidding with providers for relevant courses, based on learner requirements 4) SA Generate and update DP LAN and E-contract database structure, based on messages - confirmed courses trigger by learner (LIA) or performance results).</td>
</tr>
<tr>
<td>C2) a) Re-negotiation of courses based on learning performance scores; aligning DPLAN and E-Contract</td>
<td>(FRM4)</td>
<td>LIA notifying SA with Learner Requirements (LO1, LO2); SA updates DPLAN and E-Contract based on bids and negotiation with provider</td>
</tr>
<tr>
<td>C2) b) Two-way evaluation of learner performance and provider capabilities</td>
<td></td>
<td>5) SA evaluate learner (Simulated range of learning scores processed with applicable agent plans)</td>
</tr>
</tbody>
</table>
Functional Requirements Justifications

FRM1 (FRM1a, FRM1b), FRM2 and FRM3, are responsible for the ADALP contribution (C1) – learning support process based on multi-issue negotiating and contracting courses with multiple providers. This helps improve education and learning in particular as follows: negotiation issues of learner requirements such as course cost, course duration and course pre-requisites, amongst others. Negotiation criteria are designed and developed (Section 5.7 and 6.2) to ensure provider flexibility and flexible learning, considering learners of diverse background. Multi-issue negotiation criteria empowers the learner with options that enhances the opportunity for learners to achieve their learning goals/objectives. This is elaborated in Chapter 6, Section 6.2.

FRM4 implements contribution C2a – Aligning and re-negotiating learning requirements of DPLAN and E-Contract based on learning outcomes; while FRM5 implements C2b – Two way evaluations of learner performance and provider capabilities.

The functional specifications, FRM1 – FRM3 underpin the B-Model in the following key activities:

- Personalising learning plan developed with learner participation;
- Devising personalised dynamic learning plans and e-contracts based on specified learning requirements;

FRM4 and FRM5 maintain and manage the learning plan and e-contract, updating them depending on the achievements (learning outcomes) of the learner by:

- Evaluating provider capabilities (ensuring providers courses match defined learning goals);
- Aligning and re-negotiating changing learning targets of learner plan and the e-contract.

The above functional requirements and corresponding ADALP contributions, are elaborated in Table 5.1. The agents (LIA, SA, and PIA), (discussed in Section 5.4.2) and shown in the “proof of concept column”, implement the functional requirements.
The ADALP Six-Step Process

The six step process (Sections 4.3) and the functional specifications discussed above, are elaborated as follows: Figure 5.1 outlines the sequence of learning activities and illustrates the flow of information between the ADALP process steps.

In Step1, the capture of learning requirements is subdivided into: 1) identification of Learning objectives (LO); 2) Analysis of LO and proposal of Task; Step 2 is the negotiation of learning requirements with provider. This is broken down into: 1) Selection of learning Task and 2) Provider allocation; Steps 3 and 4 devises learning plan and sets up learning targets as well as devise learner-provider contract (e-contract), shown as the 4th set of activities in the schematic representation. Step 5 of the ADALP process evaluates and updates the learning plan and e-contract, represented as 5.1, 5.2 and 5.3 set of activities, which are labelled “Select learning Options”, “Evaluate Learning” and “Determine Learning Solutions” respectively. Step 6 of the ADALP approach “Revise steps (1) to (5) as appropriate”, implicitly represented by the information exchange, shown by the double-head arrows.

Figure: 5.1: Schematic representation of the ADALP approach process
The boxes of Figure 5.1 indicate the main activities in each step of the process. The two way arrow indicates the activity in question, exchange information (outcome or result) with the next or previous one; a one way arrow indicates the activity is dependent of the other. Hence the “learning objectives identification” activities exchange information with the “Analysis and proposal learning task” phase, until a definitive set of tasks are composed and passed on to the next phase of activities in the process.

A similar exchange of information process occurs between the step (and phase) responsible for evaluating the learner, which determines the specific learning and training solution for the learner. Through the evaluation process, learning objectives and learning paths are generated and updated to achieve learning (or training) solution(s) which match specific learning goals. Hence personalised learning plans and e-contracts are devised and/or updated.

Each step (and Phase) of the system process learning aspects ranging from learner requirements and confirming learning objectives; to selecting suitable courses (tasks), allocating available learning providers, and evaluating learner performance and provider capabilities.

The following sections describe the detail agent design process, applying the Prometheus design methodologies (Lin Padgham, 'Tool Support for Agent Development Tools, 2005), implementing the above functional specifications of the ADALP approach.

5.3 Agent System Design for ADALP Approach

Agent-to-agent interactions are designed to emulate “human efficiency” in managing tasks on behalf of the learner to support flexible and personalised learning. The agent roles in the ADALP approach include: Analysis of learning task and managing learning tasks that are generated from the captured learner requirements; Advisory support to learners on specified subjects, Analysis of learner performance results and provider options on a range of courses, to achieve personalised and flexible learning.

The Prometheus methodology (Section 5.3.1), is applied to design the agents of the ADALP approach and results of the design steps are discussed in Section 5.3.3.
5.3.1 Prometheus Methodology
The growing interest in Agent system development is attributed to the added-value of the agent technology in many application fields. Several development environments exist to build agent systems (for example Zeus, AgentBuilder, AgentTool, RETSINA, FIPA-OS, JADE and Jadex) in compliance with the FIPA specifications. Other promising agent-oriented software development methodologies are Gaia, AUML, Tropos, and MASE. The Prometheus agent design methodology, also an intelligent agent development methodology, covers all phases of development specification, design and implementation.

Prometheus methodology is chosen for the ADALP approach, given its suitability based on the design specifications for the learning support approach. The choice is also due to relative ease in converting the design of the methodology to Jadex platform agent applied in developing the prototype (see Chapter 6). The Prometheus methodology contains three main phase: System Specification, Architectural Design and Detailed Design. The following sections elaborate the design process.

5.3.2 Prometheus Methodology Steps and Results
The system specification phase of Prometheus methodology identifies agents that carry out the functional specifications (Section 5.2) of the ADALP approach. The agent system specification process consists of the following steps:

1) Identification of agent actors and their interactions;
2) Developing scenarios illustrating the system’s operation;
3) Identification of the system goals and sub-goals,
4) Identifying any external data and grouping goals and other items into basic roles (functionalities) of the system.

The Architectural Design and the Detailed Design phases determine the agent types included in the system and the interaction between them. These two phases provide crucial information for implementation of the system and is considered as an initial point for mapping the design into concrete programming constructs leading to the implementation in an agent environment. The results the Prometheus Methodology phases, Agent System Specification, Architectural Design and Detail Agent Structure and Behaviours) are elaborated in Sections 5.4, 5.5 and 5.6 respectively.
5.4 Agent System Specification (with Prometheus Methodology)
The agent system specifications (in line with the functional specifications of the ADALP Approach) are determined as follows:

5.4.1 Key actors of agent System
The key actors of the agent system for ADALP approach are the Learner, Course broker and the Course Provider.

The learner is supported by the Learner Interface Agent (LIA), which helps capture and analyse learner requirements; Course providers are represented by Provider Interface Agents (PIA), who supply courses that match learner requirements. The course broker is represented by a Supervisor Agent (SA) that helps generate call for bids from providers to match learner requirements, helping the learner identify and make informed decisions on the offers from the providers, as well as co-ordinate learning activities and feedback to learners.

The supervisor agent activities are supported by a co-supervisor agent and designated learning support agents such as a results analysis (RAA) and evaluation agents (EVA).

5.4.2 The Agent System Goals
The goals of the key agents of the Agent support System of the ADALP approach are as follows:

General Goals
a) Clarify learning Objectives: Translate learner requirements to matching courses;
b) Provide flexible Course provider options through bidding and negotiating courses with providers on behalf of the learner;
c) Evaluate targeted learning objectives and supply supplementary courses; re-negotiate courses when targets are not met;
d) Issue certification and credit for achieved learning targets;

Specific Goals
a) In clarifying learning objectives, the specific goals of the agent system include:
   - Capture learner requirements (Goal-CLR)
   - Identifying courses from Learner requirements (Goal-ICR);
   - Generate learner request for courses with specified conditions (e.g. duration, internship, cost etc) – (Goal-RQT);
   - Determining suitable courses for learner with learner participation (Goal-DSC);

b) On providing flexible course options to learners, designated agents:
- Request Bids from course from providers (Goal-RBP);
- Update requirements (Goal-UPR)
- Negotiate specified conditions for courses in the negotiation process with multiple providers (Goal-NSC)
- Evaluate bids from providers (Goal-EBP)
- Present available course options to learner (Goal-PCO)

c) The agent-support learning approach evaluates targeted learning objectives by:
- Generating (and updating when appropriate) a Dynamic Leaner Plan (DPLAN) as well as an E-Contract (between learner and provider), with learner-specified course details (Goal-UDE);

d) And on issuing certification and credit for achieved learning targets, for course to learners:
- Evaluate learner Performance Scores, Target Scores and Learning Evaluation Indicator (LVI), and generate recommendations (Goal-PTL).

From the above specified goals of the system, updating the learner plan and e-contract is based on learning performance and specific request of Learner. Other designated agents (Table 5.2) support the role of key actors of the system, to accomplish the goals and hence carry out functional specifications of the approach.

<table>
<thead>
<tr>
<th>Key Agent Actors</th>
<th>Support-Agent Actors</th>
<th>Description of Key Agents Actors</th>
<th>ADALP Approach Functional Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learner Interface Agent (LIA)</td>
<td>PA, EAI</td>
<td>1) LIA (Supported by EAI and PA where required) - learner interface (user-friendly interaction with learner)</td>
<td>1) Capture of learner requirements using flexible customisable Templates (Learner-agent interface); (FRM1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) EAI - expert Interface Agent for feedback and inference from expert knowledge base; PA – Pedagogic agent, that advises on learning requirements.</td>
<td>2) Analysis of proposed learning goals and translating them into corresponding learning task (Courses) ; applying expert knowledge base/resources and generating feedback messages with learner participation (FRM2)</td>
</tr>
<tr>
<td>Supervisor Agent (SA) and Provider Agent (PIA)</td>
<td></td>
<td>3) SA (Supervisor Agent) – Bidding with providers (PIA) for relevant courses; Multi-issue Negotiation.</td>
<td>3) Bidding for courses; Negotiating Course requirements (FRM3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4) SA – Generate and update DPLAN / E-contract based on courses confirmed by learner.</td>
<td>4) Devising and Updating personalised learning plan, based on learning objectives; Aligning learning plan with e-contract (FRM4)</td>
</tr>
<tr>
<td></td>
<td>Co-SA: (Evaluation Agent – EVA and Results Analysis Agent - RAA)</td>
<td>5) EVA and RAA – evaluation of Learner performance; feedback of learning results; and update of DPLAN / E-contract</td>
<td>5) Evaluate learning performance; taking pro-active measures to meet learning targets (FRM5)</td>
</tr>
</tbody>
</table>
The Supporting Agents are: Pedagogic agent (PA) and Expert Interface Agent (EAI) that help the capture of learning requirements by providing advisory support on various subject domains, enabling learners specify their requirements. The Evaluation Agent (EVA) and Results Analysis Agent (RAA) support the supervisor agent in the assessment and performance analysis of learners.

5.4.3 Functions and Capabilities of ADALP Agent system

To design (and implement) the functional specifications of the ADALP approach (summarised in Table 5.2) and address the identified learning issues (Table 3.2), related goals and sub goals, are grouped by designated agents as follows:

The Learner Interface Agent (LIA):
- Capture Learner Requirements (Goal-CLR);
- Identify Courses that match learner requirements (Goal-ICR);
- Generate Learner Request for required courses (Goal-RQT);
- Update (and negotiate) Requirements (Goal-UPR);

The Supervisor Agent (SA):
- Request Bids for required course from providers based on course requirement details, designated as course issues; for example Issue1 -Course Name, Issue2-Intnshp, Issue3 - Cost, Issue4-Duration etc) - (Goal-RBP)
- Negotiate courses; Respond to provider queries and update calls for proposals (CFP) from providers when required, during negotiation of learner courses (Goal-NSC);
- Present available courses (Proposals) from providers to learners for evaluation, response and confirm Bids matching required learner courses (Goal-PCO);
- Generate Learner Plan (with Courses, targets, providers) - based on Courses confirmed by learner, as well as E-contract (with Course, duration cost, provider) - based on confirmed courses and provider terms and condition) - (Goal-UDE);
- Evaluate learning performance - (Goal-PTL)

The Provider Interface Agent (PIA):
- Evaluate Bid Request (CFP) and Respond to call for bids, addressing the various course issues presented; Make and Update Course Proposals - (Goal-EBP)
5.4.4 Scenarios Illustrating System Operations

To illustrate operations of ADALP agent system, a data capture template of learner requirements is used. Based on the template, Key fields are selected and matched with available course resources and hence learners are advised and recommended specific courses based on their background and requirements.

On completion of the Course Identification and Selection Process, a Course Request with course specifications, is generated e.g. - Course Name, Duration, Internship and Cost. The Learner Request is prioritised according to learner's choice of courses, with the help of a Learner Interface Agent (LIA).

The agent system keeps track of learner requests, updates from learner and queries from providers in the cause of negotiating suitable course. Calls for proposals from providers to Bid on the specified courses, are made by a supervisor (or broker) agent who also collects and evaluate the bids from providers and advise the learner of available course options.

On confirming the courses (through learner interface agent), the broker agent generates an e-contract between provider and learner, based on negotiated and accepted courses, as well as a learner plan for the learner, based on the offered and accepted courses.

Learner performances on the contracted courses are evaluated, based on achievements of targeted scores, by the broker and support agents such as CO-SA, RAA and EVA. Accreditations and credits are issued for successful completed of courses; and options provided for those courses whose performance scores were lower than the target scores threshold.

Real life learning and training environments (such as Schools, Colleges, enterprises and independent learning at home), applying the ADALP approach, are illustrated as follows:

The Learner - Provider Environment

The ADALP approach engages providers to independently or collectively advertise their courses to learners, using agent capabilities. Existing generic open source tools such as Jade agent platforms and MOODLE Course Content Management System (CMS) could be adapted and configured to implement the ADALP approach (Figure 5.2).
Intelligent agent system (such as Jadex) could support flexible learning through applying intelligent agent capabilities of deliberations and “reasoning” that is based on the Belief, Desire, Intention (BDI) model (Braubach L. et al, 2005) to empower learners and providers for mutual benefit (see details in Appendix C2).

Scenarios of ADALP implementation include: 1) supporting learners based within a provider institution (e.g. College or University environment) in accessing learning resources as well as supporting access of resources from external providers, hence enabling collaboration between institutions; and 2) supporting learners within non-learning environment e.g. home and enterprise environment, to access provider resources for independent or enterprise purposes.

![Figure: 5.2: Learners-Providers and Learning Centre Scenarios](image)

**Figure: 5.2: Learners-Providers and Learning Centre Scenarios**

**5.4.5 External Data to ADALP Agent System**

To manage learning access of courses delivered by providers using Course Management Systems, such as MOODLE (and similar modifiable systems), the provider courses (or learning resources) are agent enable with courses templates (Figure 5.6), which specify course attributes (such as name, delivery mode, cost, duration etc) of the course. Next, the system is modified to generate external data which include learning evaluation indicators (LVI) e.g. access frequency of the course / modules and Performance scores per course, per module. These are matched against internal data, (generated target scores and Target LVI) within Jadex agent environment.
External Data (Recording of Learner Activities for Access by Agent System)
Captured learner requirements and provider CMS (or learning environment) data for each learner (see learner requirements template, Figure 5.3) constitute the sources of external data for the ADALP agent system.

With course management learning environment such as MOODLE (www.moodle.org) (or similar content management system), all learner activities are logged in a MOODLE log (or equivalent) table. The table is an external data source (outside the Jadex agent environment), representing learner activity data (performance scores and learning evaluation indicator -LVI) that are accessed by SA. The devised data structure of main external data items are: Learner ID, Access Time, Learning Resource ID, Course ID, Provider ID, Recent Activity codes / information, Course modules, Course duration, Course Access frequency, Duration and Course Fee. The following is typical of an external data profile structure required for the ADALP agent systems:

1) **Course Title**: Electronics / Communications Eng; 2) **Course ID**: ECE; 3) **Provider ID**: P1; 4) **Target/Learning Objective**: HND / B. Sc / M.Sc.; 5) **Duration**: 10 months to 24 months (depending on experience and performance); 6) **Course fees**: £500 - £3,145 per annum negotiable subject to course modules; 7) **Course module**: CSC201, CCS202, CSC204;

With seven key fields in this case, and

2) **Learner Performance data** for a course could include: Quiz, test, Assignment, Exam, Practical-work placement), with five key fields;

As well as

3) **Learner Evaluation indicator data** (Course duration, Access Frequency, Average Access Intervals and Learning Breaks), with four fields;

Table 5.3 and 5.4 illustrates sample external data of provider courses (e.g. Advanced Database Systems CSC204) and course codes.

Table: 5.3: Sample Learner Performance Table - External data

<table>
<thead>
<tr>
<th>S/N</th>
<th>Learner ID</th>
<th>Course ID</th>
<th>Quiz &amp; Test /20</th>
<th>Assignments /20</th>
<th>Exam /20</th>
<th>Practical-Wk-Plc /</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UM100001</td>
<td>CSC201</td>
<td>14</td>
<td>16</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>UM100001</td>
<td>CSC204</td>
<td>16</td>
<td>14</td>
<td>12</td>
<td>15</td>
</tr>
</tbody>
</table>
Table: 5.4: Sample Learner Evaluation Indicators Table - External data

<table>
<thead>
<tr>
<th>S/N</th>
<th>Learner ID</th>
<th>Course ID</th>
<th>Duration (Months)</th>
<th>Access Frequency</th>
<th>Intervals (hrs)</th>
<th>Breaks (Min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UM100001</td>
<td>CSC202</td>
<td>24</td>
<td>6</td>
<td>60</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>UM100001</td>
<td>CSC203</td>
<td>24</td>
<td>5</td>
<td>60</td>
<td>5</td>
</tr>
</tbody>
</table>

Internal data generated by the ADALP agents system for personalised and flexible learning, Tables 5.5, help determine achievement levels for each learner.

Table: 5.5: Target Scores Table - Internal Data

<table>
<thead>
<tr>
<th>S/N</th>
<th>Learner ID</th>
<th>Course ID</th>
<th>Quiz &amp; Test /20</th>
<th>Assignments /20</th>
<th>Exam / 20</th>
<th>Practical-Wk-Plc /</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UM100001</td>
<td>CSC201</td>
<td>12</td>
<td>14</td>
<td>14</td>
<td>15</td>
</tr>
</tbody>
</table>

5.4.6 Systems’ Interface to Learner and Provider environment

The interface of the ADALP agent system is made up of learner and provider interaction templates that capture various data input from the learners and providers. Corresponding agent actions (activities) are determined from the captured percept (the learner requirements and course attributes) based on the sample templates (Figures 5.3 through 5.6).

**Learner Request Template**

1). Learning / Training of interest (LO1): *Information Technology*

2) specialisation / Specific interest (LO2): ……N/A

3) Course Title (if know) …………

4) Course Duration (if known)…..

5). Brief description of Subject / Field of Interest – LO3 (20 to 30 words)…

*Computers and Communications*

6) Internship / Work placement / Practical or Laboratory training– LO4 (Yes / No)

7) Current or expected employment / Job title (if applicable – LO5)…N/A

*Learning Goals and objectives (LO = LO1 + LO3+LO4 = Information Technology; Communications Engineering; Computer Engineering; or Information Systems, with practical*

Figure: 5.3: Sample Learner Requirement Template
### Learning plan (DPLAN) Template

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1)</strong> Learner ID (Gen):</td>
<td><strong>07875109</strong>; Course ID: <strong>G511</strong>; Subject Domain: <strong>Engineering</strong></td>
</tr>
<tr>
<td><strong>2)</strong> Provider1:</td>
<td><strong>M20</strong>; Backup Provider2: <strong>M22</strong>; Others: <strong>NONE</strong></td>
</tr>
<tr>
<td><strong>3)</strong> Content Summary:</td>
<td>-----</td>
</tr>
<tr>
<td><strong>4)</strong> Course Assessment method:</td>
<td>a) <strong>Assignments</strong> b) <strong>Test</strong> c) <strong>Practical work</strong></td>
</tr>
<tr>
<td><strong>5)</strong> Expected Course unit scores:</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>6)</strong> Course Assignments:</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>7)</strong> Course Practical / Industrial placements:</td>
<td><strong>YES</strong></td>
</tr>
<tr>
<td><strong>8)</strong> Course Delivery format:</td>
<td><strong>Audio / Video / Text</strong></td>
</tr>
</tbody>
</table>

**Figure: 5. 4: Sample DPLAN Template**

### E-Contract Template

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1)</strong> Learner ID:</td>
<td><strong>07875109</strong>; Learning Providers: <strong>M20, M22</strong></td>
</tr>
<tr>
<td><strong>2)</strong> Negotiable course durations:</td>
<td><strong>24 months</strong></td>
</tr>
<tr>
<td><strong>3)</strong> Enrolment/payment:</td>
<td>£<strong>500</strong></td>
</tr>
<tr>
<td><strong>4)</strong> Balance due (Pending payments):</td>
<td>£<strong>400</strong></td>
</tr>
<tr>
<td><strong>5)</strong> Total Course payments due:</td>
<td>£<strong>900</strong></td>
</tr>
<tr>
<td><strong>6)</strong> Course start-date:</td>
<td><strong>Jan 2007</strong></td>
</tr>
<tr>
<td><strong>7)</strong> Official Course End date:</td>
<td><strong>Jan 2009</strong></td>
</tr>
</tbody>
</table>

**Figure: 5. 5: Sample E-Contract Template**
**Agent Actions**: Corresponding agent actions in response to learner and provider percept are based on the goals and functions of the agent system (discussed in Sections 5.4.3 and Section 5.4.4), which include: negotiating suitable courses with multiple providers, matching learner requirements to course provider offers, evaluating targeted learner performance and issuing accreditation for accomplished courses.

### 5.5 ADALP Agent System Architecture

The ADALP agent system architecture introduced in Chapter 4 (Figures 4.4, to 4.6), consists of agent cluster for capturing learner requirements, accessing expert information resources for advisory purposes (A1), evaluation and feedback to learners (A2); and carrying out results analysis of learner performance (A3).

#### 5.5.1 Interactions of Agents and Agent Clusters

From the roles of specified agents in Section 5.2, the learner interface agent is the Key agent for cluster A1, the supervisor agent (SA) and Provider agents (PIA) provide learner feedback for cluster A2 and the results analysis agents (EAI, ESA, RAA and EVA with specialised support functions) make up cluster A3. The key agent functions are designated to support the six step process of ADALP approach specifications. Figure 5.7 illustrates the agent interactions and data components that make up the approach.

---

**Provider Course Attributes Template**

| Provider ID (PID) | Course ID (CID): **Eng1** | Suppl. Course ID: /.
|-------------------|---------------------------|
| 1) Provider ID (PID) | 2) Course ID (CID): **Eng1** Suppl. Course ID: /.
| 3) Course Title... **Electronic** | 4) Subject Domain ... **Engineering**. |
| 5) Course Duration ... **12 months** | 6) Negotiable course durations: .... |
| 7) Course start-date: .......... | 8) Course End date: ...........
| 9) Course delivery mode... **LCT / PRC** | 10) Cost of course / modules...£800
| 11) Course Placement Option (CPLM) ...... | 12) Course Content Summary (CCNT)
| 13) Course Accreditation level .... | 14) Course Assessments mode... **Test / ASGNT**
| 15) Certification Options / Progression route....../... | 16) Course Objectives... **L01** ...
| 17) Course Requirements (prerequisites) /..... | 18) Course benefits ......

---

**Figure: 5. 6: Provider Course Attributes (Features of Provider Capabilities)**
Figure: 5. 7: Agent System Architecture: (Demonstrating agent collaboration, Generating Learning Task, learner plan and e-contract)

Given the feedback structure of the six step process, the **Iterative** and exit **conditions** of the system are based on learners’ choice of courses, achievement of target performance scores of the DPLAN and E-Contract (Section 4.2.3)

The learning task (Course1, Course2), learning plans and e-contracts between providers and learners, generated from learner requirements, are key components of the approach. Provider-to-provider e-contracts (or sub-contracts), not shown, are negotiated between providers, enabling access to resources from multiple providers.

Data conversion between the provider environment and the agent platform environment, to support learning evaluation, is managed by specialised Environment Support Agent, ESA (e.g. processing details of a Content Management System such as the MOODLE activity Log Table).

The Expert-Interface Agent (EAI) supports the learning approach, by facilitating access to expert knowledge resources (Not Shown), based on the learner’s requirements (as well as learning performance results in carrying out learning activities, to make
necessary recommendations to learners. The activities ensure learners are supported with professional and pedagogic feedback.

Independent providers could set-up collaboration policies to carry out designated learning tasks efficiently in the interest of the learner; and to ensure efficient co-ordination and execution of agent tasks to support assigned learning activities. The concept of “Team work” and agent collaboration is applied by the approach in carrying out complex tasks analysis and learning support activities.

### 5.5.2 Interactions of Key Agent Actor

Interactions between the key actors of the agent system include: 1) Learner-to-Agent interaction (LA); 2) Agent-to-Agent interaction, e.g. the supervisor agent (Course Broker on behalf of the learner) and Provider agents, on behalf of course providers (LPI); and 3) Provider-to-Provider Interaction (PPI) to sub-contract courses on behalf of a learner.

The options available for the designated ADALP agents - Supervisor (Broker) and Provider Agents, to negotiate courses, include using with FIPA compliant Iterate Contract net protocol, the “Blackboard read / write principle” , (Teruaki Ito and Mohd Rizal Salleh, 2000), as well as direct message exchange between the agents. With Contract nets, as a negotiation package, multiple issues (or required courses in the form of Calls for Proposal - CFP) are generated, applying request / propose protocols in the negotiation process.

Direct message exchange between agents would equally apply Request, Proposal and Inform protocols (FIPA0029, FIPA Contract Net Interaction Protocol Specification, Foundation for Intelligent Physical Agents (FIPA), 2002), to carry out negotiation of learner requirements. However, detailed processing of associated activities such as priority options for the learner are handled separately in the negotiation process, for this option.

On the other hand applying the blackboard principle requires the requesting agents to post request to a "Blackboard", while the provider agents post proposals, from which offers could be exchanged and acceptable contracts generated. The Blackboard-based negotiation is an open tender concept which provides opportunity to all participants to compete objectively, for suitable tenders to be obtained. The Blackboard-based
negotiation, derived from the mechanism of negotiation among intelligent agents, use a blackboard as a media where agents exchange information. Candidate providers to the tender are invited to issue their quotations, which compete one another under an open environment and the most appropriate candidate (s) are selected as a result of open competition.

The Iterative Contract Net Protocol (ICNP) is also suitable for negotiation of learner requirement with providers, for the ADALP approach; to negotiate courses with multiple characteristics. Hence a multi-issue negotiation could be established with the ‘Iterative’ feature of ICNP, between the broker agent and each provider.

The direct message exchange between agents is used for negotiation in this design, as this enables more control and integration of FIPA compliant protocols, with designated agent algorithms developed in this research work.

The three interaction categories are detailed as follows:

a) Learner-To-Agent-Interactions (LA)
The Learner-to-Agent interactions establish “pedagogically acceptable” learning requirements. The LIA and supporting agents (PA, EAI and TAA) interact with learners and specialised resources to compose learner requirements.

b) Course Broker and Provider Interaction (LP)
The Learner-to-Provider (LP) interaction enables the learner to specify learning requirements and request relevant courses from the providers through the Supervisor Agent (Broker). The broker establishes a multi-issue negotiation on the cost, duration, internship and other course requirements with providers, on behalf of the learner.

c) Provider-to-Provider Interaction (PPI)
The Provider-to-Provider-agent interaction (PPI), not covered in this research but specified for future work, ensures relevant courses matching learner requirements. Sub-contracts are negotiated (including course accreditation details), based on the number of course modules and durations involved.
Figure 5.8 demonstrates an instance of ADALP agent system, highlighting activities of LIA, SA and PIA in a typical learning and training session. It demonstrates interaction of the key agents of the system, resources and data structures of the agent belief-base.

Negotiations with provider maximise the options of the learner with available learning resources. The learning resources from the providers are characterised by key fields which represent Course ID (CID), Summary of Course Content (CCNT); Internship (which include field work, laboratory and Industrial placement - CPLM) as well as the Course fee or cost of enrolling to the course. These key fields are utilized by the provider agent to match available resources with the learner requirements.

The broker agent adopts learning targets, reflecting the desires and intentions of the learner and confirmed choices of courses negotiated with providers. The choices of the learner trigger learning targets to be generated that helps evaluate learning performance. Other activities such as updating learning requirements are triggered by below average performance results or the express request of the learner.

Figure: 5. 8: Highlight of an Instance ADALP Approach Agent System

5.6 Detail Agent System Design of the ADALP Approach

The agent system emulates a tripartite collaboration of learners, providers and agents, with the brokering agents (SA) mediating for the mutual benefit of learners and
provider. The flowchart of the agent system (Figure 5.9) illustrates the key processes, associated agents and data flow between key agents.

### 5.6.1 ADALP Agent System Flowchart

The first part of the flowchart Figure 5.9), details the composition of learner requirements. This include processing of learning request template (LRQ) by the LIA/PA agent, and setup of initial request for courses by EAI/TAAS.

The second part of the flowchart concerns the negotiation of courses by the supervisor and co-supervisor agents (SA and Co-SA), triggered by notification of a request (LRQ), from the learner interface agent (LIA); the negotiation is based specified course attributes (or multi issues i.e. course title/course code, course description summary, course delivery mode etc); see provider template, Section 5.4.6). SA initiates bidding for courses from provider agents (PIA). The provider agents (PIA) consult their various resources to evaluate and respond to the request. The Bids and Request are store for future analysis and reports. Courses proposed by various providers are presented to the learner for selection and confirmation. On confirming the required courses, DPLAN/E-contract is generated with the relevant details of the courses for the learner.

The third part of the flow chart shows evaluation, analysis and feedback messages to learner, on learning performance. The learner may decide to "abort" learning and end a course session or engage on another course, based on the learning requirements set up in the DPLAN. The learner may also come to the end of their course after obtaining provisional feedback results in the cause of learning.
5.6.2 Structures of Key ADALP Agents and Agent Behaviours

The structure of key agents SA, LIA and PIA are shown in Table 5.6. The agent plans (constituting key agent behaviours), which support flexible and personalised learning include handling enquiries from learner and negotiation with providers, request for courses from providers, amongst others, as listed on the Sample Plan column of Table 5.6.; while agent interaction types include negotiation of course requirements and collaboration between agents to achieve target scores and learning objectives.
Non- key agents such as Co-SA, Evaluation Agent (EVA) and Results Analysis Agent (RAA) – not completely implemented in this work, are simulated with an evaluation and analysis plan of the supervisor agent (SA) – See Chapter 6. Detail plan events and triggers for the sample plan (Table 5.6), e.g. matching courses with learner requirement and negotiating with providers, are further discussed in Section 6.5, Chapter 6.

### Table 5.6: Key Agent Structures

<table>
<thead>
<tr>
<th>Agents</th>
<th>Set of Beliefs</th>
<th>Sample Plans</th>
<th>Types of Interactions</th>
<th>Interaction Partners</th>
</tr>
</thead>
</table>
| SA     | Learner profile, Provider profiles, best bids, DPLAN, E-Contract, Learner Requirements | - Handle enquiries from learner  
- Handle enquiries from Providers  
- Generate DPLAN  
- Formalising E-Contract  
- Matching learner requirements with providers  
- negotiating with learners and providers ; determining courses from providers for Learner | - Call for proposals  
- Negotiation  
- Collaboration (Delegating duties: SA and Co-SA) | LAI and PIA1, PIA2, PIA3 etc |
| LIA    | Learner Requirements, learner profile | - Compose Learner requirements;  
- verify learning requirements / objectives from expert resources; | - Interaction with Supervisor Agent  
- Interaction with expert resources (formalising learner requirements) | - Supervisor Agent, specialised / expert learning resource |
| PIA    | – Courses on offer (see sample provider course template), History of requested courses | – Inform Supervisor Agent (SA) of matching courses to Learner requirements;  
- Request course requirements from other providers; | – Interact with SA  
- providers (PIA1, PIA2 etc) to generate courses that match learner requirements; | – SA, PIA2, PIA3 etc |

A set of Beliefs and Plans constitute the structure of each agent. The beliefs or belief set is the knowledge base, which enables the agent to carry out activities representing “strategies” (Plans) employed by the agents to achieve its goals. The supervisor agent for example, keeps track of learner and provider details (requirements / request, proposals) in the course of negotiation; builds up learner and provider profiles (bids for each learner request). Message events for various learning activities (request, proposals etc) trigger a set of plans that handle learner and provider queries.

Table 5.7 identifies agent plans, such as, a plan to “Verify learning requirements and objectives from expert resources” and corresponding agent goals, e.g. a goal to “Identifying courses from Learner requirements (Goal-ICR), Update requirements
Determining suitable courses for learner with learner participation (Goal-DSC); (Section 5.4.2).

Table: 5.7: Corresponding agent goals and plans

<table>
<thead>
<tr>
<th>Agents</th>
<th>Agent Plans</th>
<th>Agent Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIA (and supporting agents</td>
<td>Sample Plans</td>
<td>Specific Goals</td>
</tr>
<tr>
<td>EAI)</td>
<td>- Handle enquiries from learner</td>
<td>- Capture learner requirements (Goal-CLR)</td>
</tr>
<tr>
<td></td>
<td>- Compose Learner requirements;</td>
<td>- Identifying courses from Learner requirements (Goal-ICR)</td>
</tr>
<tr>
<td></td>
<td>- Verify learning requirements / objectives from expert resources;</td>
<td>- Update requirements (Goal-UPR)</td>
</tr>
<tr>
<td></td>
<td>- Inform Supervisor Agent (SA) of matching courses to Learner requirements;</td>
<td>- Determining suitable courses for learner with learner participation (Goal-DSC);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Generate learner request for courses with specified conditions (e.g. duration, internship, cost etc) – (Goal-RQT);</td>
</tr>
<tr>
<td>SA (and supporting agents</td>
<td>- Negotiating with learners and providers; determining courses from providers for Learner</td>
<td>- Negotiate specified conditions for courses in the negotiation process with multiple providers (Goal-NSC)</td>
</tr>
<tr>
<td>(e.g. Co-SA, EVA)</td>
<td>- Handle enquiries from Providers and update learner requirements in collaboration with LIA.</td>
<td>- Evaluate bids from providers (Goal-EBP)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Request Bids from course from providers (Goal-RBP);</td>
</tr>
<tr>
<td></td>
<td>- Generate DPLAN</td>
<td>- Present available course options to learner (Goal-PCO)</td>
</tr>
<tr>
<td></td>
<td>- Formalising E-Contract</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Matching learner requirements and learning objectives with provider courses</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Generating (and updating when appropriate) a Dynamic Learner Plan (DPLAN) as well as an E-Contract (between learner and provider), with learner-specified course details (Goal-UDE);</td>
</tr>
<tr>
<td>PIA</td>
<td>- Propose courses to learners and Request course (based on specified requirements) from other providers;</td>
<td>- Evaluate learner Performance Scores, Target Scores and Learning Evaluation Indicator (LVI), and generate recommendations (Goal-PTL);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Evaluate Bid Request (CFP) and Respond to call for bids, addressing the various course issues presented; Make and Update Course Proposals - (Goal-EBP)</td>
</tr>
</tbody>
</table>
5.6.3 Agent Behaviours Supporting Flexible and Personalised Learning

Agent behaviours that support the ADALP process steps range from reactive behaviours which respond to learning events that include the capture of new requirements (course title, course content, course description, target scores) and response to performance scores (target scores and learning evaluation indicators), to proactive behaviour that involves switching providers, adding supplementary courses; applying suitable plans based on specified triggering conditions to support learning and training.

From Table 5.3, agent plans such as “negotiations with learners and providers”, “determining courses from providers for Learner” support proactive behaviour of the agents, while “handling enquiries from learner and/or Composing Learner requirements”, (based on learning objectives or performance scores), underpin reactive agent behaviours.

Proactive behaviour of the supervisor agent executing plans such as matching performance scores with target scores, could reconstitute a new learning plan, triggered by request from learner or in respond to a below average score, hence updating the learners’ DPLAN. The intensity of learning events, such as persistent low average scores with a history of replacement supplementary courses, could also trigger proactive behaviour; but the difference with reactive behaviour (e.g. capturing learner requirement), is the complexity of the response.

Typical learning activities that attract response from the learning support agents, and enable update of courses with new option, (which include change of providers, add/drop supplementary courses, constituting new learning plans), are as follows:

a) Blow average performance scores, which indicate a problem with learners’ capabilities. On capturing learner performance scores that are below specified learning targets, the supervisor agent could apply an aptitude test to further evaluate areas of strength and weakness of the learner; generate options that enables the learner review their courses/course objectives, take supplementary courses or change providers. In the case of reviewing learner course options, it re-negotiates with providers for more appropriate course based on the learner request, results of learner performance and e-contract terms and conditions. The final decision on the choice of courses rests with the
learner and the DPLAN and E-Contract are updated accordingly. This encourages interactive learning with learner, agent and provider participation.

b) Specifying course requirements: LIA with support from expert resources agent examines the request template fields, reviewing learners’ request to determine suitable courses that match: 1) the target skill set (e.g. B.Sc., Post grad. / M.SC in Computer Science); 2) Course modules and Course titles. 3) Summary of course content; taking into consideration the current skill set of the learner, existing qualification or work experience (e.g. three years experience in Software development, diploma certificate in computer network systems). Results of the review are feedback to the learner for observation and confirmation of available course options.

c) Navigating through courses specified in learners DPLAN: In analysing learning activities e.g. quiz, test or exams on a course, the learning-supporting agents proactively execute appropriate agent plans, evaluating course target and performance scores. To carry out quantitative analysis of learning activities, the supervisor agents makes use of learner evaluation indicators (LVI) in addition to the target scores for each course. These are used to process performance score. The LVI is based on the actual time spent by each learner on the various allocated learning resources (e.g. 2 day or an Equiv. of 6 hours) for a course. It also involves evaluating specified schedule of resource data parameters for learners, on specified resources and the access (or use) of allocated learner slots, e.g. by-weekly, 3 hours equivalence useful learning time, per access slot).

5.6.4 Agent Plans and Triggering Conditions

Learning requirements and performance scores, adopted by LIA and SA influence deliberation and execution of the agent plans. The agent plans could change or modify agent beliefs based on the triggering conditions set for flexible learning in the BDI based agent configuration (beliefs, goals and plans). The later determines the behaviour of the agent.

A typical triggering condition of ADALP agent system occurs when the current learner plan (DPLAN) and E-Contract are updated, triggered by a “below-Average” event, generated from the learner performance results. The results of learning-performance (Performance-Score-Below-Average) trigger the Supervisor agent to run suitable plans that enables the learner to improve on their results.
Updating beliefs (i.e. learner requirements), also brings about changes of internal events, leading to the adoption of new goals and the execution of further plans (e.g. re-evaluation of learner requirements through an aptitude test assessment of the learner and making proposals for new courses based on new skill sets.

**Agent Plans and Goals**

The agent goals, designated to achieve specified LVI along with target scores, influence the agent's behaviour. To achieve its goals (the motivating force of the agent), it selects and executes suitable plans. Target scores and LVI for specified courses, are quantitative aspects of the learning goals, which learning support agents adopt and aim to achieve; the agent plan determines “how” the agent achieves the adopted goals.

The updatable plans (Table 5.6), determines how the “learning target” operations are evaluated. The BDI model of Jadex agent platform (for example) provides “meta reasoning capabilities” that enables various goal conditions to be set (ranging from change in beliefs to specific expressions matching defined conditions). The agent plans or set of plans are triggered by specified goal conditions.

**5.6.5 Major Agent Information Components, Goals and Messages**

Figure 5.10 shows the core information components (LRQ, DPLAN, E-Contract, P-Resources, Results and Tasks) of the ADALP approach and the relationship between them as a result of agent Services (Proactive and Reactive agent capabilities) provided by the agent system to the learner.

![Figure 5.10: ADALP information components](image-url)
The later information structure details (further elaborated in Figure 5.11), are utilised by the LIA, SA and PIA agents, to carry out negotiation of courses for personalised and flexible learning.

The *Learning Request (LRQ)* component (goal) is composed of a summary of learning requirements, while required courses or learning *Tasks (goals)* and *Sub-Task (Sub-goals)* are generated based on the analysis of learning requirements. Each course (or learning task) and supplementary course (sub-task) has a target score (goal) to achieve. Personalised Resources (*P-Resources*) are listed specified courses matching learner requirements; whereas the *E-Contract* component, consisting of Learner ID, Learning Providers, course durations, payment details, Course start/end date, keeps record of terms and conditions of courses contracted from learning provider(s). The *DPLAN* has the required details of the current course modules and target scores.

Further details illustrating relationships of the core information components and key agents of the ADALP approach are as shown in Figure 5.11. It outlines the information data structure that facilitates the provision of a range of learning *Services* by the designated agents (LIA, SA, Co-SA, PIA). This is also required for the agents to effectively collaborate between themselves and capture data from external information components (e.g. learning resource), interfaced to the agents.

The *DPLAN* structure has the Learner ID, Course ID, Subject Domain, Course Assessment method, Course Assignments, Course Internship, Delivery format and Target Scores / LVI; The *Results* component, with on-going Learning Evaluation Indicators (LVI) and performance scores for each module, keeps track of the achievements for each learner with a structure of Learner ID, Course, Performance scores and LVI scores), while the *E-Contract* specifies the various Task (course), Sub-Task (supplementary course), Duration and Cost of the subscribed courses. The Key players of the agent system (LIA, SA, Co-SA and PIA) take into consideration the information structure of these components to provide the *Services* supporting flexible and personalized learning.
Figure: 5. 11: Relationship of key Agents (LIA, SA and PIA) and Core information components of the ADALP approach, with associated Data Structure

The learner information component (with learning goals), which is dependent on the support agents SA and Co-SA, has DPLAN, E-Contract, Tasks (courses), Sub-Tasks (supplementary courses) and the Results components that constitute performance score of the subscribed courses. The Personalised Resources and Provider Resources are also dependent on the Supervisor and Co-Supervisor agents (SA and Co-SA), as far as information flow (request, negotiation, notification or inform messages) between the key agents is concerned.

The provider course attributes are represented in Figure 5.11 by Provider (Courses-Objectives – Target score, Course Title, Course Content - CCNT); the learner information components represented by: Learner (LO, Course Title, Supplementary. Course), DPLAN (LO, Task, Target), E-Contract (Task, Duration, Cost), Personalised-
resource (Courses, Supplementary-Courses, Course Targets) and Results (Task, Score). The arrows of Figure 5.11 represent direction of information flow, dependencies between the various information components and the associated ADALP agents.

The provider course attributes that match the Learning Objectives (LO1, LO2) - generated from learner requirements template, are short-listed by the supervisor agent as potential Personal Resource (P-Resource). Learner performance scores, from Results of learning activities, are evaluated against Course Targets (goals) set up in the DPLAN.

LRQ, DPLAN, P-Resource, and E-Contract have 1.1 relationships as they are generated from only one learning request. A course (Task) goal could have many sub-modules (Sub-Task) or sub-goals, hence a [1: N] relationship. Many courses could be selected from different providers, hence a many-to-many [M: N] relationship. The course targets scores goals are achieved when performance scores are evaluated to match or surpass the set targets.

**Agent Communication and Ontology**

The block diagram overview of relationship between major information components and key ADALP approach agents, (Figure 5.11) is also useful for future development of “education, training and learning” ontology for the agents, to facilitate common understanding of the information components of ADALP approach. For ADALP agent interactions and effective communication between existing legacy system, a suitable ontology (or controlled vocabulary system - not covered in this research) is required. However, ontology associated with existing agent platforms (e.g. Jadex) could be configurable to accommodate the terminology and vocabulary of ADALP key data structure as described above.

From the ontology perspective, to achieve the goals of supporting learners in personalized and flexible learning, the key terminologies that reference DPLAN, E-Contract, P-Resources and Learning Performance Results (such as Target score, Learning score, Target LVI, Learning-objectives, Course-Certification, Course-benefit, Course-Summary, Min-Max-course-duration, Course-modules, Course-module-flexibility and Course-cost) could be adapted from existing ontology.
A message processing algorithm, which processes variable length text data, delimited by space or return character, (demonstrated in Chapter 6), is designed and applied to communicate learner requirements, as well as learner performance scores between the designated learning-support agents.

### 5.6.6 Matching ADALP Agent System Design with JADEX Agent

Agents designed to carry out functions discussed in Section 5.4.5, are mapped to Jadex agent capabilities (goals, plans and belief structures), which are underpinned by artificial intelligence (AI) concepts.

Jade agent platform provides the necessary environment and tools for this requirement, despite specific standards that are yet to be put in place for the construction of intelligent agents in all facets. Applying the Prometheus methodology, the design phase (with designated agent structures, Sections 5.3 and 5.4) could be mapped to Jadex agent environment as follows:

The agent types provided in the Architectural Design Phase (Section 5.4) are represented as agents in the Jadex agent programming environment, defined as Agent Definition File (ADF) in XML. The behaviour (Plans) of the agents, are described in pure Java programming language. As required by Prometheus methodology, agent capabilities are defined in terms of plans, events and data that are use and produce. The plans and events have corresponding mapping in Jadex, while data is mapped as beliefs and goals in Jadex environment. Data captured from learners and providers (including learner requirements, performance results and provider course details) are beliefs, while Events include taking a test, quiz, exam and navigating courses) by the learner and the agent plans are as detailed in Table 5.6. Triggering conditions (request message from learner or learner performance score results) and goals, as described in Section 5.6.4 are configured with the Jadex platform programming features. This is elaborated in Chapter 6.

### 5.7 Agent Interactions Specifications for ADALP Approach

#### 5.7.1 Learner Interaction with Interfaced agent, LIA

Prior to negotiation of required courses, an Expert Interface Agent (EAI), Figure 5.12, helps clarify the learner requirements in collaboration with LIA, in an iterative feedback process).
The EAI intervenes in the case where the learner requirements are not clearly stated and hence there is a need for extensive assistance to clarify the learner needs by the system. The learner is prompted for further requirement details, in an interactive process which identifies and clarifies learning objectives with support from expert resources. Otherwise the capture and composition of learner requirements are processed directly by the learner interface agent.

![Diagram](http://www.fipa.org)

**Figure: 5.12: EAI support in Learner Requirement Specification (Adopted from [http://www.fipa.org](http://www.fipa.org))**

On clarifying the desired learning requirements (with or without EAI support, as the case may be) the LIA generates a *Request* message with the specified learner requirements, LO1 and LO2 (as specified in the learner requirement template). This is communicated to the supervisor agent, who calls for proposals (*CFP*), Figure 5.13, from providers (PIA). The providers could respond with proposals of available courses that match the requirements; or *Reject* the CFP if they are no matching offers or initiate another call for proposals from other coalition co-provider.

The supervisor agent *informs* the learner through the learner interface agent on available course offers, with options to modify and update their learning requirements; and could also carry out further negotiations with the providers on one or more of the issues (*course duration, course fee, internship* and other parameters) - see requirements...
template, Section 5.4.6). It could also optionally inform the learner to confirm, update and re-submit any new parameters of learning requirements. In either case, the learner effectively takes responsibility of negotiation with providers through the brokering support of supervisor agent. This ensures the agent support approach is adaptive and interactive, empowers the learner and addresses the issue of clarifying learning objectives (see Table 3.2).

Figure: 5.13: Multi-Issue (LO1, LO2) Negotiation and Contracting Courses with Providers (PIA) based on learner Requirements, LO1 and LO2 (Adopted from http://www.fipa.org).

5.7.2 Multi-issue Negotiation of Learning Requirements

Figure 5.13 illustrates multi-issue negotiation of learning requirements. Learning issues (LO1, LO2 in this case), representing learner requirements, are negotiated with multiple providers. As shown, a course request made by the learner interface agent, LIA, on behalf of the learner, could be accepted or rejected by a provider (PIA) and broker informs the learner accordingly. In the case of a rejected request, a new updated course requirement, LO4, for example, could be made. The providers could also propose alternative course (s) e.g. LO3), for the learners’ consideration and action. On receiving the request of learner requirements, broker examines key attributes such as Course title, course fee, course duration, certification level and internship to evaluate provider capabilities (or offers), on behalf of the learner. It prioritizes the attributes, based on learner’s choice.
Re-Negotiation of Learning Requirements

Figure 5.14 shows ADALP agents (LIA and SA) carrying out re-negotiations with provider agents (PIA) based on learner performance results on LO1 and LO2. It demonstrates the ADALP agent activity in updating learning targets with learner participation. In the process, DPLAN and E-Contract are updated with a new requirement, LO5, and re-aligned to reflect current learning status of the learner.

The update request, LO5, could be accepted and the learning components updated without elaborate re-negotiation; or it could be rejected (with or without an alternative proposal) by the provider(s) and subject to further negotiations. In the case of rejection, the learner may update LO5 and proposals based on LO5, by the provider(s), generated for consideration and confirmation by the learner. Initial learning objectives and target scores are also updated based on current learning/training achievements of the learner.

Figure: 5.14: Re-Negotiating Issues of Learning Plan and E-contract based on learning performance (Adopted from http://www.fipa.org).

Two-way Evaluation of Learning Performance and Provider Capabilities
The Two – Way evaluation of learning performance and provider capabilities is as shown in Figure 5.15. The “Decision tree flowchart-Rules”, for evaluating both learners’ performance and provider capabilities is triggered on three counts (Below Average performance score, above average and exceptional performance scores of learners) are summarized as follows:

**a) Below Average/LVI:**

1) Update supplementary course (S) and maintain provider;
2) Re-negotiate and Review (R) terms of contract (Extend or supply more course with supplementary fee) and switch providers, based on contract terms and conditions;
3) Update learning requirements and re-negotiate new courses (U) with obligation to existing providers;

**b) Above Average LVI:** Maintain DPLAN/E-Contract as scheduled;

**c) Exceptional Performance:** Propose advance courses; Re-Negotiate with existing and new providers.

The decision tree ensures two-way evaluation of learner performance and providers capabilities is effected by the approach.
Figure: 5.15: Flowchart of Two Way evaluation Rules

5.7.3 Negotiation Messages Sequence of ADALP approach
The sequence of messages (in Rounds) between LIA, SA and PIA with accompanying protocols is as follows:

Course specification and Request
LIA Receive CourseSpecification_1 from Learner;
LIA Informs CourseSpecification_1 to SA;
SA Receives CourseSpecification_1 from Learner (through LIA);

Processing Learner’s Message
SA calls for bids (CFP) – Sends CourseSpecification_1 to Provider_1 and other providers;
Provider_1 Agent – Receives CourseSpecification_1 from SA;

Processing Supervisor’s Message
Provider_1 sends a response for CourseSpecification_1 to SA;
SA receives and Accepts/Reject or Updates response for CourseSpecification_1 from Provider_1 (i.e. SA negotiation with Provider_1);

**Processing Provider_1’s Message**
SA sends response for CourseSpecification_1 to learner (through LIA); The Learner receives and Accepts/Reject the message or makes further Request / Counter-proposal) for CourseSpecification_1 from SA (i.e. learner could further negotiate with provider through SA - a broker);

CourseSpecification_1 could have a range of “learning issues”, as earlier specified in Section 5.7.1, hence multi-issue negotiation.

**Summary of the ADALP Approach**
In summary, ADALP agents adopt learning objectives of learners and translate them into tasks (goals), sub-tasks (sub-goals) and activities. Personalized learning information is communicated between the learning support agents (LIA, EAI, and SA) and provider agents (Section 5.6.5). Specified learner courses are negotiated with providers, applying knowledge-base resources of specified subject domains to generate feedback, for the benefit of the learners (Section 5.7).

The focus of the learning approach and agent support system is providing Dynamic **Personalized learning Plan and E-Contract with Multiple provider** (Section 5.5). The contributions of the approach are: 1) learning support process based on Multi-issue-Negotiation of Courses and Contracting with Multiple Providers; 2a) Re-negotiation of courses based on learning performance scores, aligning DPLAN with E-Contract; and 2b) Two-way evaluation of learner performance and provider capabilities. The next chapter implements a prototype of the ADALP approach.
Chapter 6: Feasibility Implementation

This chapter discusses prototype feasibility implementation of the ADALP approach demonstrating its contributions in learning support processes, based on negotiating and contracting courses, with learner-specified requirements.

6.1 ADALP Prototype

The ADALP approach agent system designed in Section 5.5.2, is implemented with BDI Jadex platform. From the Prometheus Methodology of agent systems design, the agent goals of the design are matched to Jadex platform agent Goals; while the Agent Definition File (ADF) structure of Jadex, matches the Prometheus agent requirements, where agent data is identified as belief and belief sets; and the agent functions / actions are identified as plans and capabilities.

6.1.1 Agent Beliefs and Beliefsets for ADALP approach

The E-Contract and DPLAN information, amongst others (See Table 5.6), specified for each learner in Chapter 5, constitute the belief sets which are accessed and updated by the supervisor agent and matched with corresponding learner performance course score and LVI values. Depending on the level of discrepancy between the target values and performance values, designated plans are triggered to: 1) feedback results to learner and 2) provide options for the learner to improve on their learning performance through request for supplementary courses or change of providers.

This is achieved by supervisor and co-supervisor agents through a defined set of goals, plans and triggering configurations of the Jadex agent platform. The relevant goal sets are to achieve the minimum target scores for each course, provide supplementary courses on request and switch providers as appropriate – based on contract terms. This ensures the learner performance scores for each course match or surpass target scores.

6.1.2 Summary of Agent Support Model

The intensity of learning events, arising from learner’s performances, triggers intelligent response from the designated supervisor agent. The reasoning behaviours of ADALP agents in supporting learners are set by learning goals constituted by the target scores for each course, provision for supplementary courses and switching providers as appropriate, based on learner-provider e-contract. Learning goals are also set to manage the learner’s access to and learning duration of the specified course(s).
6.2 Implemented Features of ADALP Approach Agents

From the design of the ADALP agent system detailed in Chapter 5, LIA, SA and PIA are responsible for the capture of learner course requirements, course recommendation, and negotiation of courses with learner participation and evaluation of learner performance. The features of SA and PIA involved with the negotiation of learner requirements, as well as SA which evaluates learner performance, while LIA interactively captures and formulates learner request; are implemented to demonstrate the two main contributions (Table 5.1, Section 5.2) of the ADALP approach. This is further discussed in Sections 6.2.1 and 6.2.2.

Implantation of the key actors (LIA, SA and PIA) of the ADALP approach is as follows:

1) **Supervisor Agent (SA):** Received messages which consist of specified learner requirements (e.g. course name, cost and delivery mode); and in turn request bids or Call for proposal (CFP) from providers, to initiate negotiation of course with the providers, with multiple issues e.g. course-name, cost and delivery mode. DPLAN and E-Contract are generated following negotiation between the providers and the broker agent (SA) on behalf of the learner. The negotiation process could be implemented with a range of options - straight java program that reads/writes a common file, applying iterating contract net negotiation or direct interchange of messages between the two agents concern. The latter, discussed in Section 5.5.2, is used.

2) **Learner Interface Agent (LIA):** Represented by a re-used agent, the Jadex Control Centre (JCC), capture learner requirements; collaborates with the Supervisor Agent, using a REQUEST protocol to communicate learner requirements.

3) **Provider Agent (PIA):** Confirms receipt of requested course(s) and proposes matching courses for the learner. The FIPA compliant PROPOSE protocols are used and provider agents captures the requirement (request) messages (i.e. - learner).

6.2.1 Requirements Composition and Negotiation Activities

Text messages by LIA, representing learner requirements, are generated with learner participation. This is composed of learner’s unique requirement that are spaces, “ “, or a “return” delimited (e.g. the course requirement “Computer Programming Applications for Online Learning Support” is provided as “CSC204 CSC302 CSC404” (separated
with spaces/return). LIA communicates the message to the supervisor agent (in the above format), who in turn calls for bids on the requirements from providers.

The provider agent(s) on receipt of the learner requirement message first identify and separately match each requested item with its available resources. Next, the provider agent(s) constitute a proposal, to the supervisor (broker) agent representing the learner. The proposal, most likely at first, may not be suitable for the learner and a counter proposal (or new requirement set) is resubmitted by the learner for consideration, hence negotiation ensues based on a range of criteria. Negotiation and criteria table is further discussed in Section 6.2.2. The supervisor and provider agent plans, developed in Java code/objects, processes the requirements according to the criteria set out in Table 6.1.

Negotiation of learner requirements is effected through exchange of “requirements messages” from the learner, (through JCC – an intermediary representing Learner Interface Agent), to the broker (or Supervisor) agent who interacts with the Provider agent(s), and feedback the results of negotiation to the learner. The learner could make further request or accept the negotiated results from the broker. In the latter case the broker generates a DPLAN and E-Contract between the learner and the provider or providers as the case may be.

**6.2.2 Course Negotiation Criteria**
The negotiation objectives are to match and agree on learner requirements (i.e. learner request message) with the available Course Titles, Course Duration, Course Content Summary, Delivery mode and cost from the providers.

The negotiation is carried out such that priority is given to the course title and summary of course content, course duration, internship and cost, in that order. When the first three criteria are met (i.e. course title, keywords of course content summary and course duration of learner request and provider offers are matched, then internship and price are negotiated. Hence, a two round negotiation is established for a direct match. However a proposed time limit is set by both parties to respond, for a successful negotiation to be established.

Where there is a mismatch of any of the first three items, the provider makes a proposal which could be accepted or modified by the learner through the broker agent (SA). Each party can make up to two proposals in the event of a mismatch; though negotiation is
initiated by the broker, when there is a mismatch, the provider in turn initiates a proposal on a similar topic based on the negotiation issues (i.e. learner requirements), as the criteria for proposal.

The learner may accept or modify the proposal made by the provider. Modification of the proposal is in two main parts: the course title, course content and delivery mode on the one hand and the price and course duration on the other. The provider could accept the updated proposal from the learner or make a second and final proposal, only when at least 50% matches of the counter proposal from the learner, (i.e. two out of four, three out of five or three out of six) on the negotiation issues, have been agreed upon. This condition could be updated in future transactions. The learner on the other hand could make a second and final proposal based on the cost, duration and delivery mode. Again this condition could be updated through the broker agent for future transactions.

Negotiation consensus is therefore reached after a direct match of learner requirement and the available provider offers, or after mismatch and two rounds of negotiation on a proposal from provide(s) that shows interest in the learner requirements.

**Accept or Reject Conditions:** A provider accepts to provide a course when the cost and duration negotiated in the second round has a variation of 20% (upper limit) of the learner and provider price offer, as well as 20% variance on the course duration. Exceptionally, a third round of negotiation could be carried out if the price is acceptable by both parties and the only issue is the duration; in which case a flexible duration range could be proposed by either party and agreed upon. Table 6.1 illustrates details of the negotiation process.

**6.2.3 Feedback and learner performance (Re-Negotiation Criteria)**

Feedback and evaluation of learning performance (by an evaluation/co-supervisor agent, see agent code Appendix C4), is carried out based on target performance scores of the courses enrolled by the learner.

The re-negotiation process is triggered by below average scores of learner performance on the specified courses; hence DPLAN could be updated with supplementary courses in the re-negotiation process. This is further detailed in Section 6.3.
6.2.4 Typical Reject Criteria

A provider may not bid for a course if the course title requested is available but the cost of the course is not within an acceptable value (e.g., learner's request value is less than 50% of provider offer). Providers may also decline to participate (or reject learners request) as a result of mismatch of provider course duration and the one requested, even when there is a match of the title and cost; as well as unavailable internship, despite a match of course duration and cost.

Table: 6.1: Reject and Acceptance Criteria

<table>
<thead>
<tr>
<th>Negotiation Issues</th>
<th>Learner Request</th>
<th>Provider Offer</th>
<th>Negotiation Conditions</th>
<th>Action (Provider)</th>
<th>Action (Learner)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course Titles</td>
<td>L-Title</td>
<td>P-Title</td>
<td>If L-Title is Same as P-Title, Set % Counter, Accept&gt;50%, else consider proposal</td>
<td>Proposal</td>
<td>Counter-proposal</td>
</tr>
<tr>
<td>Course Duration</td>
<td>L-Duration</td>
<td>P-Duration</td>
<td>If L-Duration is Same as P-Duration, Set % Counter, Accept&gt;50%, else consider proposal</td>
<td>Proposal</td>
<td>Counter-proposal</td>
</tr>
<tr>
<td>Course Content</td>
<td>L-Summary</td>
<td>P-Summary</td>
<td>If L-Summary is Same as P-Title, Set % Counter, Accept&gt;50%, else consider proposal</td>
<td>Proposal</td>
<td>Counter-proposal</td>
</tr>
<tr>
<td>Summary</td>
<td>L-del-mode</td>
<td>P-del-mode</td>
<td>If L-del is Same as P-del, Set % Counter, Accept&gt;50%, else consider proposal</td>
<td>Proposal</td>
<td>Counter-proposal</td>
</tr>
<tr>
<td>Internship</td>
<td>LI</td>
<td>PI</td>
<td>If LI is Same as PI, Set % Counter, Accept&gt;50%, else consider proposal</td>
<td>Proposal</td>
<td>Counter-proposal</td>
</tr>
<tr>
<td>Course Cost</td>
<td>L-Price</td>
<td>P-Price</td>
<td>If L-Price is 80% and above – accept; 50% and above, Neg Proposal, Less than 50% - reject</td>
<td>Accept on 80% and reject&lt;80%</td>
<td>Offer 80% and above</td>
</tr>
</tbody>
</table>

L-Title = Learner Title, P-Title = Provider Title, L-Duration = Learner Duration, P-Duration = Provider Duration, L-del = learner delivery mode, P-del = Provider delivery mode, LI = Learner Internship, PL = Provider Internship, L-Price = Learner Price, P-Price = Provider Price, LS = learner course content summary, PS = Provider content course summary

Provider Capabilities: Each provider has learning and training resources (courses), indexed according to popular priority criteria such as internship, course title, course duration, cost and summary description of content information, hence its capability to assess learner request.

6.2.5 Provider and Broker agent behaviours

Provider agent behaviours: For a direct match of a provider's course to learner requirement, the provider accepts and commits to supply the required courses. For any mismatch of learner requirements to available provider courses, the provider generate a
proposal (for similar content) based on the requirements key words such course title and content summary.

On receipt of a counter proposal (within expected time frame), the participant provider either accepts the counter proposal or updates and makes a final proposal. With a second (and final) counter proposal from broker, accept or reject notification is issued based on cost, internship or course content of the requirement.

**Broker Agent Behaviour:** The broker agent (SA) accumulates all offers from providers (for a given request) and uses indexed resources to match learner’s request. It present list of matches, as well as optional proposals to learner and waits for learners’ response. It also:
- acknowledges and confirm offer from provider;
- make counter proposal (with learner interaction) to provider;
- Acknowledge and confirm second (and final) offer from providers

The behaviours of the broker (SA) agent and provider agents (PIA) are based on learning principles and theories of “Interactive Learning “, Reichert, Raymond (2004) in "Interactivity: A Forgotten Art", to motivate learners; “Continuous Assessment of Learners”, Baker and Stites (1991) – to alert and improve learning performance and build up learner capacities; as well as “collaborative learning”, (Stephenson J, 2001), through effective use of resources and resource sharing with multi provider support.

**6.2.6 Negotiation Criteria Summary**
While the negotiation issues of the learners’ course requirements (from course title to Internship) is 50% (and above) match of available provider resources, the provider offer is acceptable by the broker. This could be further refined with a counter proposal from the learner in the next and final rounds of negotiation.

The following section discusses screen shot demonstrating results at key stages of the negotiation process and also the contributions of ADALP approach.

**6.3 Walkthrough**

**6.3.1 Learning support multi-issue Negotiation**
Figure 6.1 shows composition of learner requirements, notification of learner request and composition of learner offers. The LIA (re-used JCC agent), on behalf of the learner,
sends request message to Supervisor Agent; Supervisor Agents receives the message and calls for bids/proposals from Provider Agents. LIA and Supervisor utilises request protocol to communicate the requirements / request messages to the provider agents; The supervisor agent applies a send-propose-handler and a conversation ID e.g. “Provider-aid”, to request courses from providers.

Figure 6.2 shows negotiation of courses, requested by a learner, applying FIPA request /propose protocol (see code snippet for Supervisor agent Plan and Provider agent Plan Appendix C4). It shows the scenario where multiple issues (aspects of a course, such as course delivery-mode, course-code, course-title or course-summary) could be entered (provided to the interface agent) and the flexible agent plans would generate request for the course, from multiple providers, based on each of the issues captured. Using a conversation id a messages such as (CSC205x CSC206x), representing multiple issues of a course requested by the learner; the supervisor agent sends the request messages to available providers, who in turn respond with proposals for the request.

Figure 6.3 shows details of courses request from and received by providers, and Figure 6.4 to 6.6 shows the matching process of requested courses and available provider courses.

Figure: 6. 1: Requirement composition and Provider offers
Figure: 6.2: Course negotiation – Supervisor Agent Request Courses from Providers using Request Protocol conversation ID

Figure: 6.3: Course Negotiation Details – Provider resources matching learner requirements; and proposed courses from provider agent
In order to make a proposal to the supervisor agent, the provider uses a propose protocol and a send-propose-handler, based on the conversation ID. The above screen shot also traces the path of a request from the learner, through the supervisor agent, to the provider agent; as well as shows the proposal from provider agent to supervisor agent, back to the learner, through JCC as the learner interface agent.

Figure: 6.4: Matching learner requirements with provider resources

Figure: 6.5: Matching requested Course fields (Course attributes) with available provider courses
Figure: 6.6: Three matching fields – 206 201 and 304…found from provider resources

6.3.2 Two way evaluation of Learner performance and Provider capabilities

The prototype implements the learner evaluation criteria of Table 6.2, and demonstrates the provider capabilities. As shown in the prototype, agent plans of the supervisor agent analyse captured performance scores, implementing the performance evaluation criteria. This is demonstrated in the prototype with an “evaluation Plan” of SA, Figure 6.8, providing learning options, as outlined on the table.

Performance Scores (and Performance LVI - PSC/PLVI,) are matched with Target Scores (and Target LVI - TSC/TLVI), which respond to changes in learning performance. With a learner evaluation plan, target scores / LVI are compared with performance / LVI and the various criteria applied.

The variables PSC/PLVI and TSC/TLVI are based on the established DPLAN and E-Contracts, which are generated after negotiation and confirmation of the required courses by the learner (Sections 5.3 and 5.4.6 – ADALP Agent System Design and Specifications of Systems interface of Learner-Provider Environment), respectively. The later key variables facilitate personalised and flexible learning. The learning support agents (i.e. SA and future support supplementary agents, Co-SA, EVA) utilise
these variables to analyse learning activities and give feedback to learners with recommended course of action (see prototype results, Figures 6.7 to 6.19).

On implementing two-way evaluation: Learner performance and provider capabilities (Section 5.7.2), the performance scores and target score variables are set-up at three levels: Below Average, Above Average and Exceptional Performance. Table 6.2 outlines the detail criteria of learner performance evaluation, with PSC/PLVI, TSC/TLVI and the pro-active behaviour (actions) of the learning support agents based on the values of the variables acquired in the cause of learning.

Table: 6.2: Evaluation of Learning Performance

<table>
<thead>
<tr>
<th>Target Score Variables</th>
<th>Performance Score Variables</th>
<th>Criteria</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSC, TLVI PSC, PLVI</td>
<td></td>
<td>PSC &lt; TSC; PLVI &lt; TLVI, P-Duration &lt; T-Duration</td>
<td>S</td>
</tr>
<tr>
<td>TSC, TLVI PSC, PLVI</td>
<td></td>
<td>PSC &lt; TSC; PLVI &lt; TLVI, P-Duration &lt; T-Duration</td>
<td>R (Learner option; if P-Duration &lt;0.2 T-Duration)</td>
</tr>
<tr>
<td>TSC, TLVI PSC, PLVI</td>
<td></td>
<td>PSC &lt; TSC; PLVI &lt; TLVI, P-Duration &lt; T-Duration</td>
<td>U (Learner option; if P-Duration &lt;0.2 T-Duration)</td>
</tr>
<tr>
<td>TSC, TLVI PSC, PLVI</td>
<td></td>
<td>PSC &gt;= TSC AND PSC &lt; 0.8TSC (80% TSC) P-Duration &lt;= T-Duration</td>
<td>Proceed with Current DPLAN / E-Contract</td>
</tr>
<tr>
<td>TSC, TLVI PSC, PLVI</td>
<td></td>
<td>PSC &gt; 0.8TSC (80% TSC) P-Duration &lt;= T-Duration</td>
<td>Re-Negotiate for Advance Courses</td>
</tr>
</tbody>
</table>

S – Update Supplementary courses; R – Renegotiate terms of Contract / change providers; U – Update learning requirements; P-Duration – Performance Duration; T-Duration – Target Duration;
Figure: 6.7: Processing Performance Score Results

Figure: 6.8: Details of learner performance score processing
Figure: 6. 9: Supervisor Agent – Captures performance results

With the evaluation criteria (Table 6.2), the learner may switch providers, take on supplementary courses which would be added to the learning plan or make decisions to further negotiate with providers to update DPLAN/E-Contract with other courses. A learner may not switch to another provider after taking supplementary courses, without a minimum penalty cost; and may take advance courses based on excellent performance on the subscribed courses.

Learners may also drop a course after commencing, on early review of the course content, and prior to any recorded evaluation, without any penalty cost. This could be a subjective or objective evaluation of the learner, and could earn low ratings for the provider. Hence the system empowers the learner with learning options and provides a two-way evaluation of learner performance and provider capabilities.

**Provider Evaluation:** The providers are maintained or dropped (and hence evaluated) by the learners based on satisfactory ratings by the learner considering the contract terms and conditions on the course modules, supplementary courses and cost. When all learner requirements are satisfied by a provider, the provider has a high rating (e.g. 3/5,
4/5 or 5/5) on a scale of 1 to 5, while the provider rating would be low (e.g. 2/5) when most learning requirements are not met, again considering the terms of negotiated course issues and learning objectives.

### 6.4 Real Life Application of ADALP: Scenario in schools and colleges

To make best use of available courses from multiple providers, taking into consideration synergies of sub-urban UK schools and colleges, the ADALP prototype features were matched with real life learning scenarios as follows:

#### 6.4.1 Typical Learner Requirements Capture in Schools and Colleges

In a walk through of the learner requirement capture process for typical school in South East London or and Greater Manchester Berry Community College, the role of hired mentors and supply teachers is complemented with the ADALP approach agent system as follows: The LIA, representing mentors and supply teachers use the *intended future career* information and *the current / expected field of work* information of requirements template (Section 5.4.3), to help clarify learner’s interest and fine-tune the learner’s goals and objectives. The *subject domain* information helps the expert interface agent (EAI), representing specialised student mentors, provide expert advice on the specific professional courses. The rest of the fields, (1) through (7), if and when completed by the learner, specify details that are utilised directly by the agents (LIA, and EAI) to process the learner requirements to determine suitable learning tasks for each student. Hence, learning objectives (or required courses matching specified requirements) are determined from partial descriptions of specific fields, LO1 and LO2, of the template with the help of “knowledge expert agents”.

**Determining Learning Task (Courses) from Learner Requirements specification (in Real life Scenario)**

The information captured comprising the topic(s) of interest or subject (domain) - a brief description (of 20 to 30 words) by the learner, reveals key words that further clarify their learning objectives.

Developing the definitive learning request consists of two phases: Learner’s input data of learning requirements, which are parsed and filtered with an “expert processor”, to
identify the subject domain and a series of tasks (courses), based on the learner’s requirement identified in the process.

In phase 2, the process is finalised, based on interactions with the learner and a reference expert knowledge-base system of the subject domain in a course requirement analysis cycle.

**Course Requirement Analysis Cycle**
The task analysis process goes through the following basic steps. To identify learning tasks (i.e. matching courses to their specifications), the LIA:

- a. analyses learner requirements using a designated agent plan to pick up relevant key words;
- b. Presents feedback to the learner for observations and further response (including update of requirement, if necessary);
- c. Captures any further learner requirement, where applicable;
- d. Analyses additional requirements and updates the learner’s tasks list;
- e. Exit course analysis cycle on learner’s request (i.e. End-Of-Request).

Given that several courses could be identified from the learner’s request, the process of finalising the courses required goes through the cycle, illustrated in pseudo code of Figure 6.10.

```
1. While NOT (End-Of-Request) do
2.   Begin
3.   Case1: Update or Add Course
4.   Case2: Request (infer) expert resource for identifying course
5.   Case3: Make recommendations to learner on available Courses
6.   End.
```

**Figure: 6.10: Tasks (or Course) analysis algorithm**
The flowchart (Figure 6.11) further illustrates the process of constituting matching courses from learner requirement. In the event where no immediate matches are found, after several tries, a notification is feedback to the learner (an appointment with suggestions to consider other options. The condition “End-Of-Request” is met when the learner is satisfied with his or her request and his/her learning objectives are sufficiently clarified.

6.4.2 Course Negotiation with Schools and College Providers
Learning providers could be classed in two main categories in the schools and college environments; Teaching agencies that recruit and deploy supply teachers to various learning institutions; and mentors who are university graduates (yet unemployed) but on short term contract, to support learner on various subjects.

The supply teachers negotiate their contracts with the teaching agencies and the teaching agencies negotiate their contracts with schools and colleges. All negotiations are based on students learning requirements. Hence the application of ADALP approach in automating and capturing learner requirements, analysing learning tasks, provider-to-provider negotiation and learner-to-provider negotiations (through a broker agent); with teaching agencies and colleges as learning providers. The role of ADALP in this scenario facilitates (and even replace substantially), workload of the teaching agencies.
and supply teachers; as well as address mutual interest of learners, teaching agencies, the schools and colleges.

6.4.3 Learning Evaluation: A Real life Learner Performance Scenario

Tables 6.3 and 6.4 presents a real life scenario, evaluating learners from performance data Quiz/Test, Assignments, Exam and Practical-Work-Placement scores based on specified targets. Table 6.3 represents target scores of various learners, while Table 6.4 shows a sample set of learners and their performance scores on various courses.

**Table: 6.3 Expected learning target scores**

<table>
<thead>
<tr>
<th>S/N</th>
<th>Learner ID</th>
<th>Course ID</th>
<th>Quiz &amp; Test /20</th>
<th>Assignments /20</th>
<th>Exam /20</th>
<th>Practical-Wk-Plc /</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UM100001</td>
<td>CSC201</td>
<td>12</td>
<td>14</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>UM100001</td>
<td>CSC202</td>
<td>12</td>
<td>14</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>UM100001</td>
<td>CSC203</td>
<td>12</td>
<td>14</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>UM100001</td>
<td>CSC204</td>
<td>12</td>
<td>14</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>UM100001</td>
<td>CSC205</td>
<td>12</td>
<td>14</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>UM100001</td>
<td>CSC206</td>
<td>12</td>
<td>14</td>
<td>14</td>
<td>15</td>
</tr>
</tbody>
</table>

**Table: 6.4 Performance results of learner activity**

<table>
<thead>
<tr>
<th>S/N</th>
<th>Learner ID</th>
<th>Course ID</th>
<th>Quiz &amp; Test /20</th>
<th>Assignments /20</th>
<th>Exam /20</th>
<th>Practical-Wk-Plc /</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UM100001</td>
<td>CSC201</td>
<td>14</td>
<td>16</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>UM100001</td>
<td>CSC202</td>
<td>17</td>
<td>18</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>UM100001</td>
<td>CSC203</td>
<td>19</td>
<td>18</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>UM100001</td>
<td>CSC204</td>
<td>16</td>
<td>14</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>UM100001</td>
<td>CSC205</td>
<td>12</td>
<td>17</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>UM100001</td>
<td>CSC206</td>
<td>19</td>
<td>18</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td>7</td>
<td>UM100002</td>
<td>CSC201</td>
<td>11</td>
<td>13</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>8</td>
<td>UM100002</td>
<td>CSC202</td>
<td>10</td>
<td>12</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>9</td>
<td>UM100003</td>
<td>CSC201</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>UM100003</td>
<td>CSC203</td>
<td>17</td>
<td>15</td>
<td>14</td>
<td>19</td>
</tr>
<tr>
<td>11</td>
<td>UM100003</td>
<td>CSC205</td>
<td>14</td>
<td>18</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>12</td>
<td>UM100004</td>
<td>CSC204</td>
<td>12</td>
<td>11</td>
<td>18</td>
<td>13</td>
</tr>
</tbody>
</table>

The learning evaluation indicators (Table 6.5), for each course in addition to target scores are processed for a given learning duration. To illustrate the intelligent support of agents and demonstrate personalised and flexible learning the following analysis are made by an evaluation plan of SA, for each learner:
Table: 6. 5 Learner Evaluation Indicators (LVI)

<table>
<thead>
<tr>
<th>S/N</th>
<th>Learner ID</th>
<th>Course ID</th>
<th>Duration (Months)</th>
<th>Frequency of Access</th>
<th>Intervals (hrs)</th>
<th>Breaks (Min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UM100001</td>
<td>CSC201</td>
<td>24</td>
<td>6</td>
<td>60</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>UM100001</td>
<td>CSC202</td>
<td>24</td>
<td>5</td>
<td>60</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>UM100001</td>
<td>CSC203</td>
<td>24</td>
<td>7</td>
<td>120</td>
<td>5</td>
</tr>
</tbody>
</table>

Given the sample target scores of learner UM100003, for Quiz/Test, Assignment, Exam and Placement Work are 12, 14, 14, and 16 respectively on the course unit, CSC203; and the actual scores attained by the learner, 17, 15, 14 and 19 which are above target, the learner is notified to proceed to the next course, CS204, as scheduled on the learner plan. In the case where the actual score of 6, 7, 8 and 8 (which are below average) for this learner on another course (CSC201) with similar targets, the evaluation agent (Co-SA) triggers feedback message to the learner recommending supplementary courses to CSC201, which would enable the learner meet-up with the required targets.

On the other hand the learner UM100001, with scores above targets of 19, 18, 20, and 20 (which is excellent performance) on the CSC203 course unit, triggers feedback recommending advanced courses such as CSC204 for the learner. Before recommending supplementary or more advanced courses to a learner, the evaluation agent in collaboration verifies the performance indicator tables of the learner, especially the course access frequency and the intervals between each access (see Table 6.4). If the performance is low (i.e. below target) but the access frequency is less than the target, the learner will not be alerted for any urgent action that may include considerations for supplementary courses. The agent assumes in this case that the learner might meet the target when the target frequency is attained. But when the target scores stay low and the frequency is attained, the trigger for supplementary courses is activated.

When the course duration expires (for example when the time from the date of enrolment of CSC202 exceeds 24 months) and target scores have not been met, the evaluation agent generates an alert proposing replacement of the course and review of the learner plan, indicating the chosen courses were not appropriate for the learner. Once the learner plan is reviewed and amended, E-contract is also updated to reflect the changes to DPLAN. When a course is dropped and a new one added or its provider replaced, the cost and accreditation values for the learner are also updated. The above analysis illustrates contribution C2b, (two-way evaluation of learner performance and provider capabilities).
The following sample agent plans (for future implementation in real life scenarios) extents the prototype in various tasks including, switching between multiple providers, and adding more learning time, amongst others:

**Plan 1:** Adding more learning evaluation time: The plan’s triggering condition T1 is activated when performance scores on the course is low (<average) and LVI within target range for specified course, it adds more learning and evaluation time.

**Plan 2:** Adding catch-up time and supplementary courses: The triggering condition T2 comes into effect when performance scores are above average and the LVI out of range, it adds Catch-up time and supplementary courses to the learner.

**Plan 3:** Switching to second provider (provider2) AND/OR Providing Supplementary Courses: The Triggering condition T3, takes account of the fact that the performance score on the course is low and the LVI out of range, to provide supplementary courses. (This is a default condition). Triggering condition T4 is also activated when the performance scores are low (<average) and supplementary courses already provided, it switches to a backup or second provider. Another triggering condition, T5 is activated when scores are low (<average) and learner makes an express request for second provider, as previewed in the DPLAN.

**Plan 4:** Re-evaluation of learners’ request, Update learning plan and e-contract occurs when: Triggering condition T6 is activated, indicating that more than two providers had already covered the same course for the learner and additional supplementary course also provided.

**Plan 5:** Assessment of learning Scores: This is when triggering condition is T7; scores are above average and LVI within range; it assesses learning results for a Pass, Merit, or Distinction grade and moves to the next course or completes the course.

**6.5 ADALP Approach prototype results and analysis**

**6.5.1 Prototype Results Analysis**

From the research findings and developments of the ADALP approach prototype, the results demonstrate agent deliberation capabilities, hitherto applied in commercial trading activities (buying and selling of goods), could now be applied in a six-step learning-support process: (1. Capture of learning requirements, generating learning request; 2. Negotiating learning requirements with providers; 3. Devising dynamic
learning plan (DPLAN), as well as: 4. learner-provider e-contract; 5. Evaluating and updating learning plan and alignment with e-contract; 6) Revising steps (1) to (5) as appropriate). This was carried out with agent-support algorithms for personalised flexible learning. It applied multiple issue negotiation, with algorithms developed with flexible BDI agent plans, for online learning support, formalised online learning contracts and updatable dynamic learning plans.

Steps 1 through 4 involving the capture of course requirements, negotiation of the course requirements with providers, apply Request and Propose FIPA compliant Protocols of Jadex agent platform (Figure 6.10), to generate a Dynamic Learning Plan (DPLAN) and formalised E-Contracts (Not shown) for each learner. The DPLAN/E-Contract keeps the personalised record of the learner, based on templates that are developed on customised needs (Section 5.4.6). The later also keeps record of the negotiation results, outlining the selected courses, target scores required for each course and the providers involved.

Steps 5 and 6 of the learning support process steps capture results of the courses subscribed by the learner. This process is triggered by learning events, configured in the BDI agent structure and processed by the supervisor agent. Depending on the discrepancy between target and performance scores, the learner is provided with options to go for supplementary courses, change providers or revise their learning plan and hence update DPLAN and E-Contracts.

As shown (in Figures 6.5 to 6.7) evaluation of learning performance with flexible agent-support algorithms, could result in re-formulating a learning request, hence the process iterates from (1) to (5). The algorithm exits when learning target scores set-up in the learning plan (and specified learning goals), are accomplished or when the designated learning duration expires.

6.5.2 ADALP Contribution Analysis
The prototype results demonstrate two contributions of the ADALP approach in the context of personalised and flexible e-learning; demonstrating how a wide provider coverage and coalition could be realised, for each learner, applying flexible agent plan of the BDI agent model.
The results also demonstrated learning performance of learner, generated with agent planning capabilities, and the advantage of this approach over conventional standard object oriented programming approaches with SQL query.

The contributions, C1, C2a and C2b, demonstrated by the results are categorised (Section 4.3) as:

1) A six-step agent support process that clarifies learner objectives/learning goals and negotiates learner requirements at critical stages of learning (Section 4.4. Figure 4.3);
2) Agent algorithms support for intelligent analysis of learner performance, with feedback on recommended learner activity, for improved learning performance.

The six-step agent-support learning process and the algorithms developed in the ADALP approach and implemented with the flexibility of agents plans, address continuous assessment of learner performance and learner requirements, to generate useful options that meet the learner-specified learning goals.

The agent algorithm developed for the approach are implemented by the supervisor agent, as well as provider agents, making use of a range of agent plans, which carry out co-ordinated learning-support activities. The supervisor, (broker) agent plans for example, receives learner requirements, sends request for courses, receives proposals from providers, as well as process performance results (see Figure 6.12), which are generated from learner activities, hence implementing a goal-oriented, flexible learning-support algorithms of the approach.

The number of agent plans per agent, could be increased at any time, to carry out required and updated learner activities in the future, without recourse to modifying all or any other existing agent plans of the system. This capability enables provider agents to effect coalition to cover learner requirements, from independent and distributed resources; as well as enables the implementation of a range of algorithms, to analyse various aspects of performance results, beyond the usual traditional database query or object oriented programming approaches. As shown in the prototype results, the consequence of the analysis of learner performance could include recommendations to switch providers, re-negotiating learning goals/objectives to match updated learner requirements.
6.5.3 E-learning issues addressed by ADALP Approach and Contributions

The contributions address learning issues shown in Section 4.5, Table 4.2. C1 and C2 address the need for personalized and flexible learning, clarifying learner goals and objectives; C2a and C2b also address the issue of “Evaluation of learning progress". The issue of “Predefined or fixed/inflexible Learning model” current amongst existing systems, is addressed by contribution C2a – re-negotiating learner requirements (i.e. courses and learning objectives) based on learner performance results; while the issue of “Ineffective use/ distribution of learning resources” is addressed by the negotiation process (C1) and agent algorithms supporting learning performance evaluation (C2a and C2b).

6.6 Future Agent Behaviours of ADALP Prototype

The features specified for the ADALP approach anticipated for future work, on key agents include:

1) **Supervisor Agent Behaviours** to implement alternative courses to learner; Make recommendations to learner and Negotiate with multiple providers simultaneously.

2) **Provider Agent Behaviour** to implement provider to provider (P-P) interactions (i.e. negotiation and collaboration with peer providers would be developed to match learner course requirement. This is in the case where a provider acknowledges receipt of a
request, but does not have sufficient resources to provide the learners’ requirement, provider coalition is envisaged, where the request is communicated to a second and possibly third providers), with the first provider as initiator.

**Anticipated Contributions by feature Agent behaviours to be implemented**

With the above updated behaviours for the broker and provider agents, the System behaviour information flow would be more efficient. Further feedback mechanism would be also enabled that further helps in achieving learner objectives and addressing drawback of existing systems.

### 6.7 Conclusion

In this Chapter, a prototype of the ADALP System was implemented and scenarios of real life learning environment discussed. It was demonstrated that agent plans communicated and negotiated learner requirements and relevant courses for the learner, hence supporting personalised and flexible learning. In the process, bids from providers are submitted “for scrutiny” by the learning support agents (SA and LIA), based on learner requirements, with options to set priority criteria such as internship/duration/cost, as a negotiation issues with providers. The coding of CFP message as course issues (Course name, cost, mode of delivery etc) by a broker agent on behalf of the learner) and decoding by provider agents in a negotiation decision making process, uniquely implemented personalised and flexible learning with BDI agents. An SA-PIA algorithm based on the six-step learning process of the approach was developed to support FIPA compliant agent interaction (request, propose, and inform) protocols.
Chapter 7: ADALP Evaluation

7.1 Introduction
This chapter presents an effective comparison of ADALP, as an Intelligent Brokering Learning System (ILS) with other approach, highlighting Intelligent Tutoring Systems (ITS) and Education Brokering systems as the main competitors. The approach is compared and contrasted with existing ones, based on the evaluation framework proposed in Table 3.2. The unaddressed learning issues of other approaches, highlighted in Section 3.6, are discussed and the research objectives and hypotheses are re-visited.

ADALP approach contributions are classified into innovative six-step learning process and agent support algorithms that are evaluated by prototype demonstrations and effective comparison with existing systems. Table 7.1 illustrates the classification and evaluation methods.

Table: 7.1 Classification and Evaluation method of ADALP contributions

<table>
<thead>
<tr>
<th>Notes</th>
<th>ADALP Process Steps and Contributions</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribution Classification</td>
<td>Steps 1 and 2: Learner Requirements composition; Negotiation with Providers</td>
<td>Steps 3 and 4: Devising DPLAN and E-Contract</td>
</tr>
<tr>
<td></td>
<td>Process of six steps which recycle</td>
<td>C1: Multi-issue negotiation of courses and contracting with multiple providers based on learner requirements, underpinned by a six-step iteration process that ensures specified learning objectives are met.</td>
</tr>
<tr>
<td></td>
<td>Supporting Agent Algorithm</td>
<td>C2a: Re-negotiation of courses based on learning performance scores; aligning DPLAN and E-Contract Dynamic.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>By comparison with existing systems, Prototype demonstrations and Real life scenarios</td>
</tr>
</tbody>
</table>

7.2 Comparison of ADALP and other approaches
Unlike other approaches that have attempted to personalise e-learning, ADALP provides learning flexibility with e-contracting features and multiple provider options. Learner and provider evaluation feedback feature of ADALP approach, which includes reviewing learning task, collaboration and coalition of providers in the provision of learning requirement, are unique. Table 7.2 illustrate e-learning issues addressed by ADALP, compared to existing approaches, while Table 7.3, elaborates the unique features of ADALP approach.
The interaction of LIA and the learner in composing learner requirements, submitting the latter for negotiation with multiple providers to ensure exact, equivalent or alternative courses matching learners’ objectives are provided; and eventual generation of DPLAN and E–Contract, establishes unique course based on specified learning objective, hence addressing issue 5, Clarifying learning goals and learning objectives for targeted and personalised learning.

Table: 7.2: Summary issues of Adaptive E-learning Approaches

<table>
<thead>
<tr>
<th>S/N</th>
<th>E-Learning issues</th>
<th>ITS</th>
<th>BD&amp; WCT</th>
<th>Adv</th>
<th>AD</th>
<th>KLG</th>
<th>EBK</th>
<th>ADALP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Personalised learning: Meeting expectations of Learners - Planning of learning activity; Online Task support</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>D</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Evaluation of Learning Progress (IEL)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Modelling Learner’s need</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Effective distribution and re-usable learning resources</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Improving Clarity of learning goals &amp; learning objectives for targeted and personalised learning (IEL) - Unaddressed</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

The ADALP approach uniquely addresses issues (5) and complements (1) through (4), which are partially addressed by other approaches. The innovative approach institutes a new dimension of distributed and re-usable learning resources by applying agent reasoning, collaboration and coalition. Learning plans that are dynamically generated and aligned with e-contracts; and also with learner participation provides a new model of online learning support.

The approach types discussed in Section 3.8, for comparison purposes are summarised as follows: Type A (ITS): Intelligent tutoring systems – mostly proprietary, prefixed and inflexible; Types B (BD/WebCT): Commercial systems (Blackboard, Learn-Direct, etc) with limited feedback and learning evaluation features; Type C (E-adviser): A proprietary systems with limited support for planning learning and training activities
online; Type D (ADELE, Knowledge-Tree): A Systems with fixed and inflexible learning content with limited personalised features, without provider options; Type E (EBK): Non-intelligent educational brokering systems. These approaches are compared with the ADALP, which applies BDI agent capabilities to provide personalised and flexible online learning, with provider options and learner participation features in determining learning objectives. Table 7.3 summarised unique features of ADALP, which addresses the identified issues compared to other existing approaches.

Table: 7.3 ADALP Features and issues addressed, compared to other Learning Approaches

<table>
<thead>
<tr>
<th>Issues</th>
<th>Other Approaches</th>
<th>ADALP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need for personalised learning content according to learner objectives, skills and available provider capabilities</td>
<td>Approaches A and C</td>
<td>√ (Use of DPLAN and E-Contract); multi-issue negotiation</td>
</tr>
<tr>
<td>Evaluation of learning progress, feedback and support for online learners</td>
<td>Partially addressed, Approach B</td>
<td></td>
</tr>
<tr>
<td>Improve modelling learners’ needs (learning requirements and learning styles)</td>
<td>Partially addressed by D</td>
<td>√ (Use of Agent Support Algorithms for two-way evaluation)</td>
</tr>
<tr>
<td>The need for effective distribution and re-usable learning resources</td>
<td>Partially addressed by D and E</td>
<td>√ (E-contracting with Multiple providers)</td>
</tr>
<tr>
<td>Lack of clarity in designing learning goals and objectives of courses on existing e-learning platforms; improving perception of learning goals and objectives for online courses (online mentoring)</td>
<td>Currently Unaddressed</td>
<td>√ (Agent support algorithms for Specification of Learner requirements)</td>
</tr>
</tbody>
</table>

The following sections detail comparisons based on ADALP approach contributions to flexible online learning.

7.3 Negotiation of courses with providers (C1)

Unlike other approaches, this feature makes provision for learners to define and clarify learning requirements and objectives. Negotiation with providers and e-contracting courses from various providers offers further flexibility of the approach. Other approaches (Table 7.2) have predefined courses with fixed learning goals and objectives that are not modifiable by the learner.

The agent system also makes provision for learners to achieve their learning objectives by “bidding” for “Equivalent Level courses” as prerequisite for certain courses from learning providers and including these as “additional task” for their learning plan. It enhances current and existing intelligent tutoring systems (ITS) designed for restricted “tutoring” on predefined topics (e.g. “adding fractions in Maths” or “configuring a CISCO 2500 router, in network Communications Engineering”).
Traditional ITS system turns to have fixed learning resources (without the flexibility of consulting or involving multiple providers) and fixed learning or training objectives. ADALP provides flexibility with dynamic learning objectives and multiple provider support options.

### 7.4 Re-Negotiating courses based on learning performance; aligning DPLAN and E-Contract (C2a)

In renegotiating courses for learners, based on pro-active evaluation of target scores and specified learner requirements/learning goals, ADALP applies deliberative agent capabilities to deliver on the learner’s goals and objectives. This improves on Knowledge Tree (Brusilovsky, 2003) learning approach, which is based on “Fixed and predefined model of student learning style and learning preferences within limited resources and environment”. It keeps track of a personalised learning plan for each learner and hence re-negotiates with providers, in collaboration with the learner, to update dynamic learning plans (DPLAN) aligned with learning e-contracts. This also contrast with Kay’s approach (Kay, 2001) which deals with a fixed learner model based on existing learner skills, individual traits and environment data (equipment, network bandwidth, location, learning platform, style and preferences).

### 7.5 Two-way evaluation of learning performance and provider capabilities (C2b)

The two-way evaluation feature of the ADALP Approach, covers limitation of current approaches in structuring, managing and processing learning abilities of learners, vis-à-vis available learning resources (Table 7.2, KLG, ADV, ITS). This addresses issues of learning progress and effective use of available resources unlike other approach types (Table 7.2). The ADALP features provide a unique approach to developing diversified skills/knowledge of learner (or trainers) with heterogenous background in a distributed environment, applying multi-issue negotiation with multiple providers. It provides learners with a wide range of subject domains and multiple provider support.

From the design and prototype implementation, ADALP’s contributions enhances existing approaches such as ADELE (which utilises physical sensors for adaptive online learning), e-adviser that applies agents in a restricted task intensive training environment.

Compared to ‘Distributed Learning Environment (DLE), Fuhua Lin (Lin, 2005)’, that utilises facilitator agents and group learning scenario, where agents carry out task and
various activities for the group, evaluating participation of group members in order to attain “group learning goals” (Dounish & Bellotti, 1992); ADALP provides a ‘Two-way evaluation approach’ different but complementary to the DLE approach where learner-support agents devise dynamic learning plan and e-contracts for each learner to match their personalised learning needs.

7.5.1 Evaluation of the ADALP Model and Concepts

For effective comparison of ADALP features with existing learning support systems, and to address real life learning environment issues (Section 2.2.1), the following learning aspects are examined: Basic learning information feedback (FBG), Updatable Learning Objectives and Learning Plan (FBO), Personalised Learning Objectives and Learning Plan (PLOB), Meta Switching between Multiple Learning Providers (SMLP), Static (pre-defined and fixed) learning model (FLM), and Dynamic learning model (DLM). Table 7.4 highlight concepts of the ADALP approach and features that distinguishing it from similar learning approach types discussed above. The theoretical concepts underpinning the latter are as follows:

<table>
<thead>
<tr>
<th>S/N</th>
<th>E-Learning Approach Elements</th>
<th>AD</th>
<th>Adv</th>
<th>KLG</th>
<th>ITS</th>
<th>EBK</th>
<th>ADALP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Concepts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- FBG</td>
<td>√</td>
<td></td>
<td></td>
<td>√</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td>- FBO</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td>- PLOB</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td>- SMLP</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td>2</td>
<td>Models</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- DLM</td>
<td>X</td>
<td>Λ</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Λ</td>
</tr>
<tr>
<td></td>
<td>- FLM</td>
<td>X</td>
<td>Λ</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Λ</td>
</tr>
<tr>
<td>3</td>
<td>Personalised learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Support</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Learning path</td>
<td>X</td>
<td>√</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td>- Learning Plan</td>
<td>X</td>
<td>√</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td>- learning objectives</td>
<td>X</td>
<td>√</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td>- Cognitive tools</td>
<td>Φ</td>
<td>O</td>
<td>Φ</td>
<td>Φ</td>
<td>Φ</td>
<td></td>
</tr>
</tbody>
</table>

**Codes:** Adv = E-Adviser, AD=ADELE; KLG= Knowledge-Tree; EBK = Education Brokerage

**Legend**

<table>
<thead>
<tr>
<th>√ = Yes</th>
<th>Ω = Low</th>
<th>∆ Bottom – up</th>
</tr>
</thead>
<tbody>
<tr>
<td>X = No</td>
<td>Ø = Medium</td>
<td>Λ Top-Down</td>
</tr>
<tr>
<td></td>
<td>Φ = high</td>
<td>◊ -Both Bottom-up and Top-down</td>
</tr>
</tbody>
</table>

133
Theoretical concepts

ADALP concepts are based on: a) Improving “targeted” learning, ‘away from one-size-fits-all’; b) Empowering learning with adaptive learning components (DPLAN, E-Contract and Personalised Learning Resources); ‘focus on flexible learning goals and objectives’); c) ‘Merging Pedagogy and Learning technology’ and improving learning performance.

Improving Targeted learning: This involved online learning feedback on learning objectives and learning plan and updating Learning Objectives and Learning Plan (FBO). In this context, modifying learning objectives also implies updating learning plan, but the reverse, i.e. updating a learner plan does not imply update of learning objectives. A learning plan could be updated without modifying the learning objectives by changing the learning providers or task to be accomplished. A Bottom-up and Dynamic Learning Model (DLM) as opposed to Static (pre-defined and fixed) learning model (FLM) are underpinned by elements such as current learner skills, learning performance and updatable learning requirements.

Empowering learning involves providing more control on learning targets with Personalised Learning Objectives and learning plan (PLOB); and Merging Pedagogy and Learning Technology underpins courses recommendation based on learning requirements and feedback on available provider capabilities; provider coalition for suitable courses and “Meta Switching” between multiple learning providers (SMLP).

7.6 Revisiting Hypotheses and Research Questions

On reviewing the research questions: 1) could software agent’s Belief-Desire-Intentions (BDI) model, support specification and Negotiation of learner requirements, in a multiple provider environment? 2) Could software agent technology support learners of heterogeneous backgrounds, in flexible and personalised learning, in a multiple provider environment?

Question (1) was realised with agents based on the BDI model of Jadex platform, designed using Prometheus Agent Design Methodology. The Beliefs, Desires and Intention agents, with AI capabilities, (designed with a range of planning capabilities), such that LIA captures and adopts the learning objectives and performance scores as beliefs; agents were implemented to process learner requirements and learning performance scores, with options from multiple provider; deliberate on the beliefs
(based on set learning targets) and collaborate (e.g. SA and PIA,) using conversation IDs and designated messages, integrated with FIPA compliant Agent protocols (Request, Propose, Inform), implementing multiple plans to achieve target scores. Broker agent (SA), on behalf of learners, re-negotiate with providers (PIA1, PIA2 etc), as the case may be, to improve on learning targets and learning evaluation indicators (LVI), on the Jadex platform.

Question (2) was achieved in designing and implementing multiple learning support agents (LIA, SA) that captured and processes learner requirements and learner performance results. Provider agents (PIA1 and PIA2), responded to learner requirements with proposals, matching specified learning objectives; and the broker agent analysed offers from providers, providing options and flexibility of available courses from the multiple providers.

7.6.1 Evaluation of ADALP Hypotheses
The hypotheses that: The ‘Believe, Desire, Intention’, (BDI) model support learning processes by: 1) Negotiating learner requirements with multiple providers (HP1); and 2) Matching learner requirements with provider resources (HP2);

The Supervisor (or broker) agent engaged suitable agent plans that capture learner requirements (such as course titles, course delivery mode, course codes, amongst others) and communicates these through a representative message to the providers in a negotiation process (HP1). The providers match these requirements with available resources, applying a provider capability template (HP2), generating course offers or proposals that may suite the learner. Learners, with the help of the Interface and broker agent could updated their request or make a counter-proposals.

Learning goals, specified as courses with specific target scores that reflect intended learning objectives of the learner, formulated for the prototype, constituted unique learning needs, which were sourced from multiple providers, applying multi-issue negotiation techniques.

While the providers benefit in the approach by being able to provide courses to a wide range of learners at a competitive cost, and the opportunity of a coalition to provide specific learner requirements; the agent-support learning approach provides learners with the prerogative to decide on the offers of available courses from multiple providers.
Other features of the prototype that confirmed hypothesis HP2 include: implemented learning support agent plans that apply learning request template to match specified objectives with suitable courses; specialised agents (LIA, TAA and EAI) that ensured learning goals matched pedagogic and professional requirements of the learner; the generated dynamic learning plan (DPLAN) for each learner, with unique learning targets, which updatable based on progress or failure to achieved specified learning targets. Implemented agent plans also supported different learning activity: re-evaluation of learning needs, when learning “targets” are missed, switching providers and providing supplementary courses. They “sense” low performance scores compared to set learning target scores, encountered by the learner and recommend supplementary or alternative course offers, and in some cases switch between providers of the course requirements.

With flexible plans of the BDI based Jadex agent platform, the above hypotheses, which merge agent technology and flexible/personalised e-learning, is realised.

7.6.3 Evaluation of ADALP Research Objectives

The research objectives: a) To provide flexible learning, applying software agent “reasoning”, “planning” and “collaboration” capabilities to track learning performance, learning goals / objectives (RO1); b) Generate learning options; enabling learners make best use of available courses (resources) matching their learning goals /objectives from multiple providers (RO2), were realised as follows:

RO1 (providing flexible learning with agents), was achieved by generating target scores and learning evaluation indicators (LVI) in a prototype environment, applying agent planning and belief capabilities of Jadex platform. Agents’ strategy to provide personalised and flexible learning support, which included ongoing evaluation of learner’s activities and supportive feedback messages, enabling learners make prompt and informed decisions in the course of learning or training. The second objective, RO2 (making best use of available courses and resources from multiple providers) was achieved with specialised agent (TAA, EAI and SA) and sample providers (PIA1 and PIA2) offering courses that match specified learning requirements. The next and final chapter discusses future work and concluding remarks on the ADALP approach.
Chapter 8: Conclusion and Future Work

8.1 Summary
The e-learning industry has grown significantly since the early days of computers and the Internet. Today there are many products and services out in the market place both proprietary and open source to choose from. The ADALP system employs the automated collaboration features of software agents, enabling learners and instructors to work in close collaboration, with an emphasis on achieving defined and specific learning objectives, unique to the circumstances of the learner.

ADALP presents an innovative online learning approach that supports flexible learning with dynamic e-contracts and learning plans. It also extends existing systems such as Intelligent Tutoring Systems (ITS) with dynamic learning objectives specifications, options for flexible learning and multi-provider support.

More companies are turning to e-learning solutions to meet their training and knowledge management challenges. Online training yields large dividends that result in reduced employee turnover, decreased new employee ramp-up time, increase productivity, actual cost savings, return on investment and more (e-skills UK, 2000-2012, http://www.e-skills.com/research/research-publications/). The application of this artefact in e-learning contributes a more flexible approach with dynamic learner/training plans, supported by software agent deliberation capabilities. Its BDI agent features support the innovative “Goal-Oriented” learning and training model.

As shown in Chapters 4, 5, 6 and 7, the contributions (C1 and C2) improved on existing e-learning systems. This is highlighted in Table 7.2 with improvements on clarifying learning goals and objectives, effective exploitation and management of distribution and re-usable learning resources, compared to existing systems. The contributions are supported with prototype demonstrations, real life scenarios and effective comparison with existing systems.

Major Contributions
The contributions C1 and C2 highlighted in Table 7.1 improve on existing e-learning systems and approaches as follows:
C1) Learning support process based on Multi-issue negotiation of courses with multiple provider; (a six-step iteration process, which ensures specified learning objectives are met;  
C2a) Re-negotiation of courses based on learning performance scores; aligning DPLAN and E-Contract;  
C2b) Two-way evaluation of learner performance and provider capabilities; 

8.2 Applications of ADALP Approach in Real Life Situations

From Chapter 5, Figure: 5.16: the Learner Requirement Template is used (see sample application in Figures 8.1 and 8.2), to generate a message string. Which in effect is the learning goals/objectives of the learner

<table>
<thead>
<tr>
<th>Learner Request Template</th>
</tr>
</thead>
<tbody>
<tr>
<td>1). Learning / Training of interest (LO1): <strong>Informatics</strong></td>
</tr>
<tr>
<td>2) specialisation / Specific interest (LO2): ……CSC206, CSC304</td>
</tr>
<tr>
<td>3) Course Title (if know) …………</td>
</tr>
<tr>
<td>4) Course Duration (if known)…..</td>
</tr>
<tr>
<td>5). Brief description of Subject / Field of Interest – LO3 (20 to 30 words)… <em>Computers and Communications</em></td>
</tr>
<tr>
<td>6) Internship / Work placement / Practical or Laboratory training– LO4 (Yes / No)</td>
</tr>
<tr>
<td>7) Current or expected employment / Job title (if applicable – LO5)…N/A</td>
</tr>
</tbody>
</table>

**Learning Goals and objectives (LO = LO1 + LO3+LO4 =**  
**Informatic;CSC206;CSC304**

Figure 8.1 Application of Learner Request Template in Real life Environment
Figure: 8.17: Learners-Compose A Request to multiple Providers through Broker agent (SA)

The request message (Informatics, CSC206, and CSC304) is Captures by LIA (as demonstrated in Figure 8.3 and communicated to multiple providers for consideration and offer of proposals. A typical response is as in Figure 8.4.
8.2.1 Commercial applications

From the above demonstration, the learning-support approach, with software agent, for personalised and flexible e-learning, could be integrated with existing Learning Management System (LMS) such as MOODLE, to cater for specific learning needs of learners (and/or trainees), with diverse professional and academic backgrounds.

The approach is applicable to companies and establishments with specific staff development skills needs. The multiple issue scenario and negotiation with multiple providers could help establishments to carry out cost effective staff training. Given ADALP unique features, it would address specific training requirements; identify suitable resources, from multiple providers, as well as provide flexible time management options. Specific aspects of a training program (multiple issues, as demonstrated in the prototype), could be sourced from different providers, cost effectively, with more flexibility and efficiency on the use of resources.

8.2.2 Academic application of ADALP Approach

It was also shown in Chapter 6 (Section 6.4) how the ADALP approach is applied in real life learning situations, in College and University environments: from the capture of learning requirements of students (exemplified in Figures 8.1 to 8.4), the negotiation and enrolment of courses; to the evaluation of student performance and update of devised dynamic learning plans, with target scores and learning evaluation indicators.
Educational establishments and training enterprises could benefit in adopting the ADALP approach, to exploit the current trend of software agent technology. The innovative intelligent agent-support approach enables learning providers, facilitators of educational and training sectors to address a wide range of the learning needs for learners with heterogeneous backgrounds. It also presents an opportunity for providers, to provide effective and efficient deployment and use of online learning resources, improving current e-learning technology.

The ADALP approach could increase positive competitiveness of online learning and training, with customised and personalised requirements features, supporting capacity building and quality of local education and training.

### 8.2.3 Future Work

Future work on the ADALP approach would include the extension of the prototype, implementing remaining system specifications, with real life test-runs with academic institutions as well as business establishments with specific / specialised staff development requirements.

Further work could also be carried out in developing a learning ontology that would further facilitate communication between designated ADALP agents and its components (DPLAN, E-Contract and P-Resources). Case-Based Reasoning (CBR) as a plug-in or alternative to the Jadex ‘reasoning engine’ could be further examined and explored for the implementation of ADALP approach.

### 8.3 Conclusion

The results of this research is a contribution to the increasing demand for cost effective e-learning and online learning technology (E-skills UK Sector Council, 2008); and further provides inroads to further research for efficient e-learning and online learning technology.
References:


Anthony Basiel, 2006, “TAM e-learning Model”, www.mdx.ac.uk; Last accessed on 23\textsuperscript{rd} Feb 2012

AutoTutor: available from www.autotutor.org; ; Last accessed on 23\textsuperscript{rd} Feb 2012

Baker and Stites, 1991, “Continuous assessment...and formal assessment of learner’s affective characteristics and motivation”


Balas E and M. W. Padberg, 1976; Set partitioning: A survey. SIAM Review;

Bauer et al. 2001, Agent UML: Formalism for Specifying Multiagent Interaction;

Beetham H. et al. JISC 2004 www.jisc.ac.uk/elp_outcomes.html ; Last accessed on 23\textsuperscript{rd} Feb 2012


Bonk C. 2006, Blended Learning Handbook – British Council 2004 for IUG project Award;


Brachman et al. 1991, The Ontolingua ontology library (http://www.ksl.stanford.edu/software/ontolingua/); Last accessed on 23\textsuperscript{rd} Feb 2012
, distributed with the CLASSIC knowledge representation system;

Bratman, M. E, 1999, Intention, Plans, and Practical Reason (CSLI Publications. ISBN 1-57586-192-5);


Braubach, A. Pokahr, and W. Lammersdorf. L, 2005; Extending the Capability Concept for Flexible BDI Agent Modularization;


Castellini, C., E. Giunchiglia, and A. Tacchella, 2001, “Improvements to SAT-Based Conformant Planning,” in Proc. of the 6th European Conf. on Planning;


Commercial ontologies : UNSPSC (www.unspsc.org); RosettaNet (www.rosettanet.org); DMOZ (www.dmoz.org); Last accessed on 1st Feb 2010

DAML ontology library (http://www.daml.org/ontologies/; Last accessed on 1st Feb 2010

Darina Dicheva and Lora Aroyo, 2006, “Application of Semantic Web Technologies in E-learning”;

Dalziel, 2003, Implementing learning design: the learning activity management system (LAMS);


Horton W. 1999, Web-based Training, (Wiley Press, London);


Huber M. JAM, 1999: A BDI-Theoretic Mobile Agent Architecture. O. Etzioni, J. Müller, and J. Bradshaw;


Kakas et al, 2004, European Conference on artificial Intelligence, Valencia, Spain, August (2004) and KGP_ Agent model;


Hummel, 2004, Educational modelling language and learning design: new opportunities for instructional reusability and personalised learning;


Learning and Other Forms of Continuing Education and CPD” www.mdx.ac.uk/;


Liyan Song, Ernise S. Singleton, Janette R. Hill and Myung Hwa Koh, 2004, “Improving online learning: Student perceptions of useful and challenging characteristics”;

Lora Aroyo, Arthur Graesser, Lewis Johnson, 2007; “Intelligent Educational systems of the present and the future”, IEEE INTELLIGENT SYSTEMS;


Middlesex University, 2006; Policy Statements; Middlesex University 2005, “Accreditation of Short Courses, Prior Learning, Experiential Learning, Work Based Learning”;


NESTA Future lab, 2004; Educational Research and the Design of Interactive Media – ESRC Seminar Series;


QAA (2006): http://www.qaa.ac.uk/academicinfrastructure/codeofpractice/distanceLearning/default.asp; last accessed on 1st Feb 2010


Reichert, Raimond (2004) in "Interactivity: A Forgotten Art"


Robert S. Engelmore and Edward Feigenbaum, 1993, "EXPERT SYSTEMS AND ARTIFICIAL INTELLIGENCE"


Schoppers, M., 1987, “Universal plans for reactive robots in unpredictable environments,” in Proc. of the 10th Int’l. Joint Conf. on Artificial Intelligence, 1987;


Staley A, 2004; U. Central England, Learning Technology Development Unit;

Stephenson J, 2004; http://www.johnstephenson.net/jsdownloads.htm; last accessed on 23rd Feb 2012

Teruaki Ito and Mohd Rizal Salleh, 2000; “Blackboard-based negotiation for collaborative supply chain system”.


Winikoff M, 2005, JACK Intelligent Agents: An Industrial Strength Platform;

Wooldridge, M, 2000; Reasoning about Rational Agents. (The MIT Press ISBN 0-262-23213-8);
Appendix

Appendix A

A.1 DfES e-Learning Strategy Summary

<table>
<thead>
<tr>
<th>Our aims for a 21st century system…</th>
<th>Personalization and choice (Opening up services)</th>
<th>Flexibility and independence (Staff development Partnerships)</th>
</tr>
</thead>
<tbody>
<tr>
<td>through our strategies for reform…</td>
<td>Children (Primary)</td>
<td>Secondary (11 – 13), (14 – 16)</td>
</tr>
<tr>
<td>will need the contributions ICT and e learning can Make…</td>
<td>Transforming teaching, learning and support Connecting with hard to reach groups Improving efficiency and effectiveness</td>
<td></td>
</tr>
<tr>
<td>through sector based Actions…</td>
<td>ICT in Schools Strategy</td>
<td>Post16 e-Learning Strategy</td>
</tr>
<tr>
<td>all underpinned by the priority system actions</td>
<td>An integrated online information service for all citizens Integrated online learning and personal support for children and learners; A collaborative approach to personalised learning activities A good quality ICT training and support package for practitioners A leadership and development package for organisational capability in ICT A common digital infrastructure to support transformation and reform</td>
<td></td>
</tr>
</tbody>
</table>

Details of established learning theories used with existing VLE models include: Association’s /empiricist perspective – learning as activity, Cognitive (Individual Constructive/ Social Constructive) perspective – learning as achieving understanding, Situative perspective – learning as social practice. JISC (2004) e-Learning report summary refines them as follows:

Table A.2 Adaptation of JISC e pedagogy summary

<table>
<thead>
<tr>
<th>Learning Perspective</th>
<th>Epistemology</th>
<th>Illustration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Associative perspective</td>
<td>learning as acquiring competence</td>
<td>Progressive difficulty / individualised pathways (i.e. – Work Based Learning student learning agreements)</td>
</tr>
<tr>
<td>Individual Constructive</td>
<td>achieving understanding</td>
<td>Activities to discover principles. Support for reflection</td>
</tr>
<tr>
<td>Social Constructive</td>
<td>achieving understanding</td>
<td>VLE with activities to discover Principles. Support for reflection and peer review</td>
</tr>
<tr>
<td>Situative perspective</td>
<td>social practice</td>
<td>Social learning communities of enquiry</td>
</tr>
</tbody>
</table>
Reflection on learning is a common thread going through most learning perspectives (Or theories), to some degree. Dewey recognized it as far back as 1916, while Cowan (1998) sees reflection as a necessary pedagogical method and Kolb (1984) includes it in his experiential learning cycle (in Mayes T. 2004)

Constructivism is currently seen as a dominant theory to support VLE design and development. Mayes (2004) summarizes this view of learning as a process which is cumulative, goal-orientated, self-regulated and dependent on prior knowledge/experience through active construction of understanding. He offers these key components to promote online pedagogy through: Ownership of task, Coaching and modelling of thinking skills, Scaffolding, guided discovery, Reflection opportunity and Problem solving.

Other learning theories include the Zone of Proximal Development (ZPD), commonly referenced in current e-Learning research as alternative learning (ALT e-Learning Theory Workshop 2005). As these elements are not integral to this research work, further elaboration on this is left to future work.

Jonassen (1998) sees scaffolding as a type of ‘mind tool’ which support different forms of reasoning about content. That is, they require students to think about what they know in different, meaningful ways. Expanding on this, Brown (in Mayes 2004) sees concepts as tools to be understood through use, rather than as self contained entities to be delivered through instruction (AKA Constructivism). In this context, VLE tools, such as, physical (books, software) and cognitive (memory, concepts, language) tools enable and constrain activity through their affordances (Mayes T. 2004).

VLEs are moving away from a ‘Transmission Model’ (Generation 1– Table 1) to take on a problem or project-based approach. This requires enquiry-oriented pedagogies according to Mayes (2004), such as: Problem based learning, Goal-based scenarios and Project-based learning.

Table A.3: Summary of e-learning issues and justifications

<table>
<thead>
<tr>
<th>e-Learning issues</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) The need for new and innovative e-learning tools and technologies for time management and course structure design</td>
<td>From the survey by Larsen et al. (2005): need for new organisational innovation, “new knowledge management practices”, to be able to move to e-learning adoption cycles (or phases). The majority of the participants of (Song et al., 2004) survey identified the design of the course program, the online technologies used, and time management as helpful in their online learning:</td>
</tr>
<tr>
<td>2) A paradigm shift in academic environment, e.g. scepticism about the use of technologies in education and teacher-centred culture.</td>
<td>From the forefront of e-learning development report (OECD, 2005): need for tailored and customisable e-learning.</td>
</tr>
<tr>
<td>3) A role of a ‘facilitator’ for online learning processes, ‘team worker’, and ‘learner-centred culture’.</td>
<td>as above</td>
</tr>
<tr>
<td>4) The necessity for targeted e-learning and training relevant to learners and Departments/Faculty, as well as ownership of the development process of new e-learning material by academics.</td>
<td>as above</td>
</tr>
<tr>
<td>5) Effective use of open source material Digitisation and the potential for instant, low-cost global</td>
<td></td>
</tr>
</tbody>
</table>
Godwill Vegah  Page 150 of 162, GV ADALP Thesis

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>(including available pedagogic, professional and academic learning resources) ; Adapting “global OER initiatives” to local needs and providing dialogue between the doers and users of the OER</th>
<th>communication have opened tremendous new opportunities for the dissemination and use of learning material. This has spurred an increased number of freely accessible OER initiatives on the Internet including open courseware</th>
</tr>
</thead>
<tbody>
<tr>
<td>6)</td>
<td>Finding better ways of “sharing” and re-using e-learning material.</td>
<td>A more cost effective online learning system, given the growing OER initiative; the need for users of OER to be advised on the quality of the learning material stored in open repositories.</td>
<td></td>
</tr>
<tr>
<td>7)</td>
<td>Inadequate online learning support</td>
<td>71% of online learning participants compared to traditional classroom learning felt that a lack of community within the online environment.</td>
<td></td>
</tr>
<tr>
<td>8)</td>
<td>Problems with understanding “set learning goals/objectives” of existing systems.</td>
<td>From the later survey 60%of the participants reported having difficulty understanding the goals / objectives of the course and 50% indicated technical problems as a barrier.</td>
<td></td>
</tr>
<tr>
<td>9)</td>
<td>Improving perception of learning goals and objectives</td>
<td>There are many models and processes that can be used to assist with the creation of learning goals and objectives, particularly as they link into a larger course infrastructure (Dick et al., 1999). The ability to clarify perceptions of learning goals and objectives is very important.</td>
<td></td>
</tr>
<tr>
<td>10)</td>
<td>Expectations of e-learning systems – collaboration without the need for physical presence</td>
<td>There are scarce but available online learning resources and experts from which learners, institutions and enterprise can benefit.</td>
<td></td>
</tr>
<tr>
<td>11)</td>
<td>Online learning technical problems</td>
<td>“So many technical things that seemed to take up the whole focus of the course”.</td>
<td></td>
</tr>
<tr>
<td>12)</td>
<td>Online communication features (relevant feedback to learners).</td>
<td>Overall, participants of Song et al.’s (2004) survey, indicated that participation in the bulletin board, for example, could be driven by the instructor/facilitator in order to facilitate communication with learners; one-to-one interaction, feedback and chatting online suggest that an online mentor, advisers/expert could help improve response to learner specific queries for online e-learning.</td>
<td></td>
</tr>
<tr>
<td>13)</td>
<td>Combination of robust online learning tools and robust pedagogy</td>
<td>Appropriate online learning tools supported by a flexible and robust pedagogy may better meet the needs of the distance learner.</td>
<td></td>
</tr>
</tbody>
</table>

**Appendix B**

**B.1 ADALP Agent collaboration**

<table>
<thead>
<tr>
<th>S/ N</th>
<th>Agent Roles</th>
<th>Comments (Collaborating Agents)</th>
<th>Agents’ Beliefs (facts)</th>
<th>Agents’ Goals (desires)</th>
<th>Agents’ Plans (intentions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LIA</td>
<td>1. Capture (via request template) learner’s goals, objectives and personal queries (GOPAQ) ; 2. Store learner query following interaction with learner to confirm and clarify details. 3. Feedback recommendations and advice to learner</td>
<td>LIA agent utilise questionnaires, templates to setup learner specific profiles - learner details and specifications, to match learner needs with suitable provider courses. LIA tracts changes of learner circumstances and updates learner profile accordingly, gathering</td>
<td>Data captured from learner</td>
<td>Deliver messages from learner to PA/EAI; and deliver messages from EVA / PA and EAI to the learner</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Make use of learner comments and feedback in specific occasions, as update to learner request.</td>
<td>necessary data to support adaptive learning, useful for the adaptive learning plan and adaptive learning paths. Collaborates with TAA, RAA and SA.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>TAA</td>
<td>1. Process (Parse) GOPAQ to identify learning goals and objectives and set up learner’s profile; Match learner queries, learning goals and objectives with expert resources. 2. Generate feedback for learner comments, learner confirmation or further specification; 3. Set up specific tasks to achieve the desired learning goals and objectives using relevant expert resources.</td>
<td>Work with LIA to identify tasks from learner goals and objectives; utilise suitable parsing algorithms and tools (e.g. XML/compilers). Liaise with EAI.)</td>
<td>Messages from PA and EAI containing learner’s request</td>
<td>Analyse and classify messages according to professional and pedagogic standards</td>
</tr>
<tr>
<td>3</td>
<td>EAI</td>
<td>1. Use expert resources to provide or generate specific professional advice and recommendations to learners on specific queries and performance, on a given subject before and during enrolment on a course.</td>
<td>Collaborate with LIA, TAA and RAA</td>
<td>Data from TAA, PA and RAA regarding learner request or performance</td>
<td>Analyse, classify and provide professional feedback on the subject</td>
</tr>
<tr>
<td>4</td>
<td>EVA</td>
<td>In collaboration with RAA, interpret results of the learner performance (utilising scores and matching with expert resources on the subject); provide log and results details of learning activities to SA and feedback comments / recommendations to learner.</td>
<td>Collaborates with SA and LIA</td>
<td>Learner activity data – test, quiz, course navigation, assignments, etc.</td>
<td>Analyse and carry out comparisons with target results, defined in the learner plan; feedback to learner via LIA</td>
</tr>
<tr>
<td>5</td>
<td>PA</td>
<td>1. Prompt users to clarify their request as and when necessary; schedule learner appointments according to their learning needs; Utilises general educational and training resources to advice on learning paths and on overall performances of the learner …</td>
<td>Use pedagogic resources for general advice and recommendations to the learner, before and during online enrolment of identified learner specific courses. Collaborates with EVA and LIA</td>
<td>Messages from LIA concerning learner request</td>
<td>Consult with TAA, EAI and RAA, and SA occasionally on best advice for learner based on their request or performance</td>
</tr>
<tr>
<td>6</td>
<td>RAA</td>
<td>1. RAA specialises in analysing results of learner performance and activities in the course of learning. Learner evaluation; Analysis learners log</td>
<td>Monitor and Generate learning results relevant to learning plan. RAA works with EAI to interpret results of the learner performance</td>
<td>Data from EVA, WA and PVA on learner’s performance</td>
<td>Analyse and inform EVA, after consulting with EAI</td>
</tr>
<tr>
<td>7</td>
<td>PIA</td>
<td>1. Advertise courses to learner agents (SA, Co-SA); utilises scores and matching with expert resources on the subject) and passing on details to SA…. In a case study (MOODLE) – utilises MOODLE report log database which logs all activities – cause modules assessed, time spent on them, quiz/test taken and other results etc.</td>
<td>2. Negotiate with learner through SA, to provide the best and cost effective learning resources to learners; and with other providers for service level agreements (SLA).</td>
<td>3. Deliver courses in various formats to match learners needs; update course details</td>
<td>Collaborates with EAI</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>8</td>
<td>ESA</td>
<td>1. Interacts with the provider environment (Course Content Management Systems – CMS) to extract, convert relevant learner data to generic agent formats to ease information sharing between agents 1. Utilise specialised expert resources to evaluate results; generate informative feedback to learner.</td>
<td>ESA – liaises with EVA and RAA where and when necessary (considering local environment factors) to support learners on different platforms (learning environments) and convert learner results to a standard format for evaluation…</td>
<td>Request for course format conversion between providers or between providers and learners</td>
<td>Analyse and utilise generic protocols (algorithms), to ease course delivery between providers and learners.</td>
</tr>
<tr>
<td>9</td>
<td>SA</td>
<td>1) Create and Update learning plan – adapting learning plan to new learning situations as well as 2. Identify relevant courses and providers for learner. 3) Negotiate with Providers (PVA) for suitable courses to match learner’s needs 3. Create and update learner-provider contract for learner. 4) Keep track and details of LIA-PVA negotiation (to update and adapt learner plan / provider –learner contract</td>
<td>SA –utilise feedback from EAI and RAA agents to update the learner plan (matching obtained results with targeted results, and either recommending next course or supplementary courses…. In Updating learner plan (Which may include ticking the boxes for courses learnt or updating a learner plan with new requirements such as supplementary courses based on results, to ensure</td>
<td>Messages and data from PA and EVA.</td>
<td>Generate and update learner plan (LP) and contracts (LPC); consult Co-SA to assist with all tasks (task sharing).</td>
</tr>
</tbody>
</table>
5) Provide relevant feedback to both learner and provider.

In effecting an adaptive learning path (APATH), this involve updating learning plan with supplementary material and other relevant learning providers. APLN & APATH are achieved simultaneously.

| 10 | Co-SA | 1. Enrol learner on a course matching based on defined learning goals and objectives.  
2. Execute learner plan, learner-provider and evaluate learner.  
3) Assist SA in its entire task for “load balancing”. | The search for course providers is initiated by SA / Co-SA; matching identified learning task with specific courses and course providers; The supervisor and co-supervisor agent ensures designated agents tasks, to be carried out on behalf of the learner is achieved and hence achieving targeted learning goals. | Data and request from SA | Schedule various tasks in collaboration with SA | Deliver and keep track of LP and LPC in collaboration with SA; work load balancing and communication traffic management. |

B.2 Provider Capabilities

Multiple providers involved for the provision of courses to learners, may have Common or Unique Capabilities (Course Attributes), which are applied by the provider interface agent to make offers (or proposals) for bids on learner requirements. The requested courses (Task1, Task 2, for example) may also be common to more than one provider. But specific courses with attributes such as CCNT could be unique to some providers. Hence the learner (and supervisor agent) evaluates the providers based on their unique and common capabilities. The providers may also be evaluated by the percentage match of the learner requirements with the provider course attributes. Table 5.4 demonstrates typical provider capabilities; a course placement module for example is unique to provider 2, while BTECH in ICT is common to provider 1 and provider 2. Table 5.5 illustrates a sample DPLAN and E-Contract, Personalised resources based on the provider options and capabilities. Courses in a DPLAN are selected based on the provider capabilities, hence a personalised resource is generated and a corresponding contract between the learner and provider established for the chosen course or courses.
Table 5.4: Sample Provider Details

<table>
<thead>
<tr>
<th>Providers Capabilities (course attributes)</th>
<th>Common Capabilities</th>
<th>Unique Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provider1 (P1A)… LO1, Task1, Task2, Sub-Task1</td>
<td>LO1= <em>BTECH in ICT</em>, Task1= CSC203, Task2 = CSC204, Sub-Task1 = CSC201</td>
<td>NON</td>
</tr>
<tr>
<td>Provider2 (P1A2)… LO1, CPLM, Task1, Task2 Sub-Task1, Sun-Task2</td>
<td>LO1= <em>BTECH in ICT</em>, Task1 = CSC203, Task2 = CSC204, Sub-Task1 = CSC201</td>
<td>Course Placement (CPLM) – internship</td>
</tr>
<tr>
<td>Provider3 (P1V3)… LO1, LO2, CNNT, etc. Task1, Task2, Task3</td>
<td>LO1 = <em>BTECH in ICT</em>, LO2= Diploma computer Science Task1 = CSC203, Task2 = CSC204</td>
<td>Task3 = CSC206</td>
</tr>
</tbody>
</table>

(CSC203 = Data Structures; CSC204 = System Analysis; CSC206 = Computer Architecture; CSC201 = Office Application Packages)

Table 5.5: Sample Learner DPLAN, E-Contract, P-Resource and Results Details (*Task = Specified courses for learner – see table 5.4*)

<table>
<thead>
<tr>
<th>Learner Plan (Based on Learner Request)</th>
<th>Learner-Provider Contract</th>
<th>Personalised Resource</th>
<th>Learning (results) Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPLAN</td>
<td>E-Contract</td>
<td>Provider1: LO1, Task1, Task2 Provider2: LO2, CPLM, Task3, Task2 Targets: (Task1 = 10, Task2=15, Task3=20)</td>
<td>Time=2 months; Task 2 = 4 months; Task3 = 3 Months; Extension: 30 days; Cost1=£300; Cost2: 250; Ext. cost (total):=150;</td>
</tr>
<tr>
<td></td>
<td>Duration:</td>
<td></td>
<td>R- Resources</td>
</tr>
<tr>
<td></td>
<td>Task 1 = 2 months; Task 2 = 4 months; Task3 = 3 Months; Extension: 30 days; Cost1=£300; Cost2: 250; Ext. cost (total):=150;</td>
<td>Tasks: Task1, Task2, Task3 Duration: Ext-Duration:</td>
<td>Task1: Score= 9; Time=2 months; Task2: Score=12; Time =4; months; Task3: Score=16; Time = 2.8 months;</td>
</tr>
<tr>
<td></td>
<td>P- Resources</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tasks:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B.3 Summary of designated agent activities and codes

Table B.2: ADALP agent activity and events code table

<table>
<thead>
<tr>
<th>S/N</th>
<th>Agent Activities / Events</th>
<th>Activity / Events code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Select (sort ACL messages)</td>
<td>SAACL</td>
</tr>
<tr>
<td>2</td>
<td>Process learner request</td>
<td>PLRQ</td>
</tr>
<tr>
<td>3</td>
<td>Set up events for identified messages, e.g. consult (contact) providers first from enrolled provided database then through provider facilitator</td>
<td>SMSG</td>
</tr>
<tr>
<td>4</td>
<td>Respond to messages from learner confirming request or requesting clarification</td>
<td>RMFL</td>
</tr>
<tr>
<td>5</td>
<td>Message (or contact) expert or pedagogic resource agent (PA or EAI) on behalf of learner</td>
<td>MEXP</td>
</tr>
<tr>
<td>6</td>
<td>Receive feedback from PA or EAI</td>
<td>RFPE</td>
</tr>
<tr>
<td>7</td>
<td>Forward message from PA/EAI to learner</td>
<td>FMPA</td>
</tr>
<tr>
<td>8</td>
<td>Receive confirmation message of learner request</td>
<td>RCLR</td>
</tr>
<tr>
<td>9</td>
<td>Recommend courses and learning provider (SA and LIA)</td>
<td>RCLP</td>
</tr>
<tr>
<td>10</td>
<td>Receive choice of learning courses and learning providers</td>
<td>RCLC</td>
</tr>
<tr>
<td>11</td>
<td>Negotiate with learning provider on behalf of learner – terms of study</td>
<td>NLT</td>
</tr>
<tr>
<td>12</td>
<td>Generate learning timetable, learning goals and objectives (LP)</td>
<td>GTLP</td>
</tr>
<tr>
<td>13</td>
<td>Generate learner provider contract (LPC)</td>
<td>GLPC</td>
</tr>
<tr>
<td>14</td>
<td>Generate profile and recommendation details (from PA, EAI) for</td>
<td>GPPE</td>
</tr>
</tbody>
</table>
learner’s record

15 Set up learning and evaluation indicator factors. Target scores and activity timetable SLEI

16 Feed back comments and learner progress report at scheduled intervals FBLP

17 Recommend supplementary courses based on performance and target results RSCP

18 Update LP based on performance and target results ULPP

19 Update LPC based on performance and target results ULPC

20 Generate learning or course progress appointment messages GLCP

21 Generate end of course message and results GECR

22 Enrol learner for a course ELFC

23 Enrol provider courses into the ADALP resources database EPRD

24 Modify provider resources MPRS

25 Carry out provider-to-provider service level agreements (SLA) CSLA

Table B4 are messages and codes designed for the ADALP system (not implemented) that could be added to the prototype of Section 6.2 in a real life agent support learning system.

**Appendix C: Sample Agent Functions**

Agent behaviours (see function specifications, Table 5.1, Chapter 5) designed for ADALP approach system that may be coded in Java, for the Jadex platform) or similar object oriented programming languages are as follows:

1) **LIA Class Functions**

   a) Display template for learners request (LRQ)
   b) Capture LRQ and call on EAI for Validation
   c) Query feedback from PA and update LRQ or Inform SA of completed or validated LRQ
   d) Display learning / training course options based on LRQ, along with multi-provider options on feedback from SA
   e) Confirm learner options and terminate learner request and evaluation or engage learning activity
   f) If applicable (on missed targets), process feedback results from EVA/SA to update LRQ, when learning activity is engaged.

2) **PA Class Functions**

   a) Relay confirmed LRQ or feedback options from EAI to Learner and provide option to update LRQ
   b) Display and update learning performance on specified times in collaboration with SA and EVA
3) **SA Class Functions**
   a) Notify Provides and request for BID on the LRQ from LIA/PA
   b) Collate and Analysis BIDS (see algorithm)
   c) Notify LIA (see LIA/PA activities below) to present learning/training options to learner
   d) Assign co-SA tasks to generate or update DPLAN and e-contract based on confirmed / selected options
   e) Align DPLAN with e-contract.

4) **EVA Class Functions**
   - Access and update Specified learning resources (established course modules) to learner
   - Track learning progress (update LVI, Course performance scores
   - Keep tract of course duration according to established terms and conditions of e-contract

5) **EAI Class Functions**
   a) Process LRQ for validation based on expert knowledge-base on the subject domain (in collaboration with TAA)
   b) Process performance results to validate and match with targeted standards based on expert knowledge-base on the subject domain (in collaboration with RAA)

6) **TAA Class Functions**
   a) Analyse key words / phrases in LRQ
   b) Match with subject domain knowledge-base
   c) Accessing Match conditions
   d) Display “NO-Match” conditions
   e) Feedback to EAI

7) **RAA Class Functions**
   a) Analyse performance scores and match with targeted standards based on expert knowledge-base on the subject domain.
   b) Feedback to EAI
With the above agent class functions, they access database resource structure that include details of learning request (LRQ), provider capabilities, Biding process, Personalised Resources, DPLAN, E-Contract to implement designated activities.

C.2 Agent platforms

A summary agent tools and products

<table>
<thead>
<tr>
<th>Type</th>
<th>Academic</th>
<th>Commercial</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free</td>
<td>Agent Tool</td>
<td>Bee-gent</td>
<td>Kaariboga</td>
</tr>
<tr>
<td></td>
<td>DECAF</td>
<td>Comet Way</td>
<td>SEMOA</td>
</tr>
<tr>
<td></td>
<td>EXCALIBUR Agent</td>
<td>CORMAS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>JAT Lite Bean</td>
<td>Cougaar</td>
<td></td>
</tr>
<tr>
<td></td>
<td>JESS</td>
<td>FIPA-OS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LEE</td>
<td>MAML</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MAP / CSM</td>
<td>ZEUS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MASSYVE KIT</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Repast</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SIM_AGENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Star Logo</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Xraptor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Licensed</td>
<td>IMPACT</td>
<td>ADK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>JAFMAS / JIVE</td>
<td>Agent Sheets</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RETSINA</td>
<td>CABLE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tucson</td>
<td>Grasshopper</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>IDOL</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>JACK</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>JADE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>JADE / LEAP</td>
<td></td>
</tr>
</tbody>
</table>

These are the products, reported by return of questionnaire, include the most important offerings. There are however other tools for Multi-Agent Systems (MAS) development (see the Agent-Link, http://www.agentlink.org/admin/docs/2002/2002-47.pdf).

C2.1.1 Jadex Agent Structure

The ADALP approach agent system designed in Section 5.5.2 is implemented with BDI Jadex platform. From the Prometheus Methodology of agent systems design, the agent goals of the design are matched to Jadex platform Goals; while the Agent Definition File (ADF) structure of Jadex matches the Prometheus agent requirements where agent data is identified as belief and Belief sets; and the agent functions / actions are identified as plans and capabilities.

Figures C2.1 illustrate Jadex agent structure consisting of two main parts: the agent header (ADF) and the Body (agent plans). The header ADF file is in conformity with XML schema, while the Plan (e.g. the Supervisor Plan1 of the Supervisor Agent), in Java programming code, defines the functionality of the agent. The agents execute plans to achieve its goals.
Figure: C2.13 Structure of Jadex agent: The Supervisor Agent

Package declaration (e.g. the package of supervisor agent, specifies where the agent first searches for required classes (containing plans, beliefs etc). The packages correspond to the directory of XML files. Additionally packages are specified using the <imports> tag.

Figure: C2.2 Jadex agent XML schema

The <imports> tag (Figure C2.2) specifies classes used by expressions throughout the agent definition file. For modularity, agent functionality is decomposed into capabilities, which are specified and referenced in the <capabilities> tag.

The main specifications of agents - the beliefs, goals, and plans, are placed in corresponding <beliefs>, <goals>, and <plans> tags, respectively of the agent definition.
file. Known events by the agent are defined in the <events> section; conditions for predefined queries for plans are specified with the <expressions> tag. The <configurations> section predefines configurations of initial beliefs, goals, and plans; and the <properties> tag is for custom settings, used in debugging and logging options.

C2.1.2 Agent Plans
The Jadex agent platform hosts a library of agent plans which are complemented by designated ADALP agent plans to administer agent learning support activities. With Jadex agents, activities are classified and treated as Events, which are processed with Agent Reasoning Capabilities. Events are dispatched to running plans or new plans instantiated from the plan library, based on results of the deliberation. Running plans may access and modify agent beliefs, send messages to designated agents, create new top-level or sub goals and trigger internal events. This is useful as the Jadex agent model is designed to closely match “human reasoning and mental states” that are important to support efficient and flexible learning in the ADALP approach. Hence Jadex implements the Belief, Desire, Intention (BDI) model, which reflects human reasoning processes. The reaction and deliberation mechanisms are generally the same for all agents.

The behaviour of a specific agent is determined solely by its concrete beliefs, goals and plans. Incoming messages (Figure C2.3) to an agent trigger the deliberation mechanism (the reasoning engine) which evaluates a belief base and trigger the internal events. Depending on the deliberations, this could in turn lead to the selection and execution of instantiated library plans; eventually generating a message or messages that are communicated to other agents. Hence agent intentions are communicated through messages, which may include specified agent language structure and ontology to interpret intended meanings of the messages.
C.3 Database tables for agent activities

Main fields of **LRQ Table**:
- Learner ID (LID)
- Course Placement (CPLM)
- Course Content (CCNT)
- Course ID (course title (LO1), career prospects (LO2) and job titles (LO3), CID)

Main fields of **Provider Offers (capabilities) Table**
- Provider ID (PID)
- Course Placement (CPLM)
- Course Content (CCNT)
- Course ID (course title, career prospects and job titles, CID)

Main fields of **BID Table**
- Match1 (can offer only one of learner requirement)
- Match2 (can offer two of learner requirement)
- Match3 (can offer three of learner requirement)
- Match4 (can offer four of learner requirement)
- Rank (1 to 4)
Main Fields of **Personalised Resource Table**
Course Title,
Work Placement
Career options
Course contents summary

Main fields of **Learner Plan (DPLAN) Table**
1) Learner ID
2) Course ID
3) Provider ID
4) Second Provider ID
5) Other Provider ID
6) Course Duration
7) Target Course scores
8) Work Placement
9) Course cost
10) Delivery format

Main Fields of **E-Contract Table**
1) Learner ID
2) Learning Providers
3) Courses list
4) Negotiable Course Duration
5) Confirmed Enrolment/payment
6) Balance Due (Pending payments)
7) Fully Paid
8) Total Course payment
9) Course start-date
10) Official Course End date

---------------------------------------------------------------------------------------------------------------------------------------
Figure C.3: ADALP and Example Learning Environment (with MOODLE)

### C.4 Agent platforms

See agent codes on CD provided with thesis.