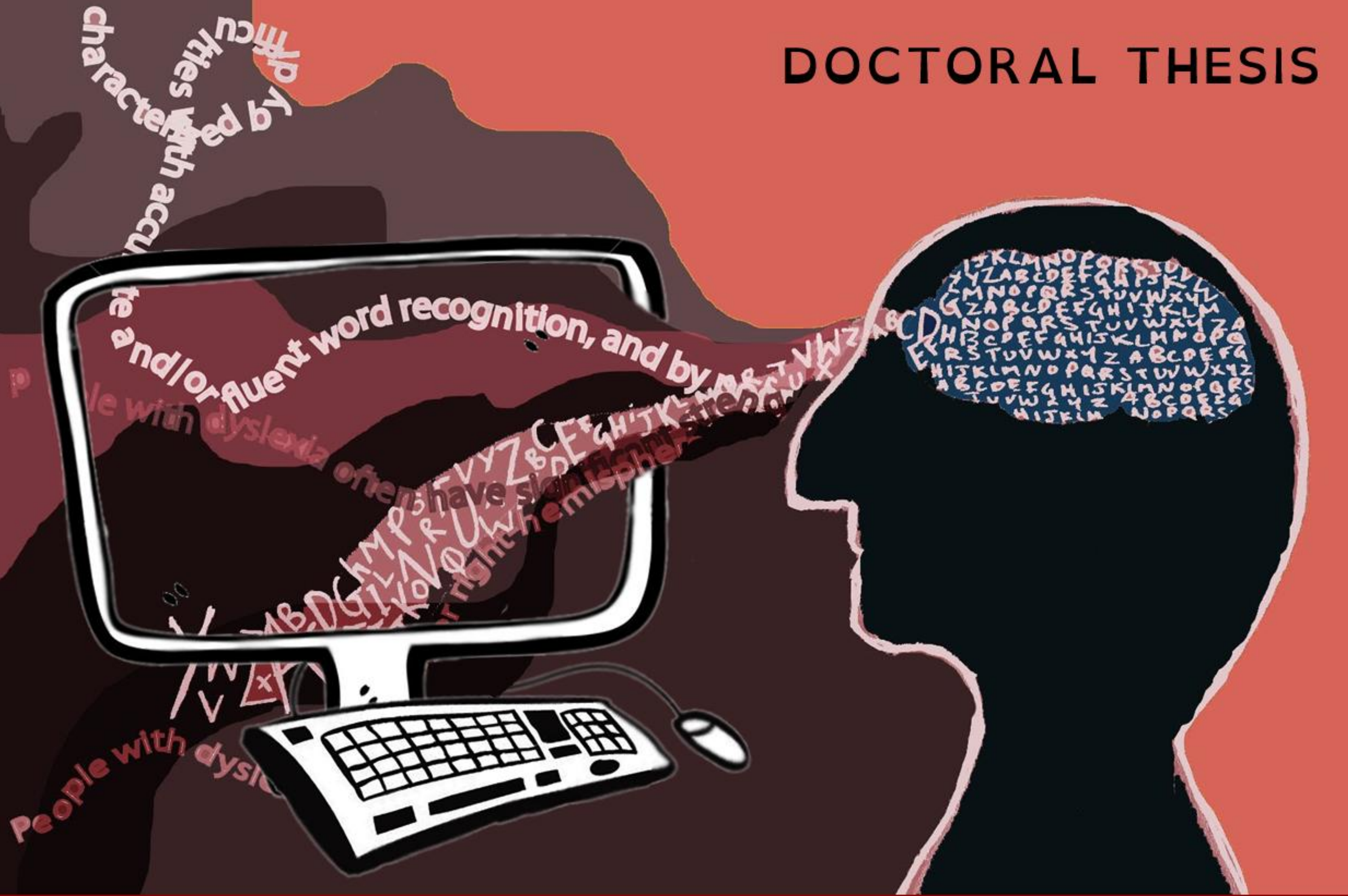
FRAMEWORK FOR DETECTION, ASSESSMENT AND ASSISTANCE OF UNIVERSITY STUDENTS WITH DYSLEXIA AND/OR READING DIFFICULTIES

Carolina MEJÍA CORREDOR

Dipòsit legal: Gi. 1503-2013
http://hdl.handle.net/10803/123976

DOCTORAL THESIS



Framework for Detection, Assessment and Assistance of University Students with Dyslexia and/or Reading Difficulties

Carolina Mejía Corredor

Universitat de Girona
2013

Ph.D. Thesis

Framework for Detection, Assessment and Assistance of University Students with Dyslexia and/or Reading Difficulties

BY: M.SC. CAROLINA MEJÍA CORREDOR

Thesis submitted in partial fulfilment of the requirements
for the degree of
Doctor of Philosophy by the University of Girona

ADVISOR: PH.D. RAMON FABREGAT GESA

Universitat de Girona

Program of Doctorate in Technology

Girona, Catalonia, Spain

September 2013

The research reported in this thesis was carried out as part of the following projects:

- Augmented Reality in Adaptive Learning Management Systems for All (ARrELS project). Funded by Spanish Science and Education Ministry (TIN2011-23930).
- Accessibility an Adaptation for ALL in Higher Education (A2UN@ project). Funded by the Spanish Government (TIN2008-06862-C04-02/TSI).
- Adaptation based on, modelling and planning for complex user-oriented tasks (ADAPTAPLAN Project). Funded by the Spanish Government (TIN2005-08945-C06-03).
- Transfer of knowledge to the company about computer-assisted evaluation and treatment in specific learning disabilities in reading and mathematics (TRACE project). Funded by Spanish Science and Innovation Ministry (PET2008_0225).

The research reported in this thesis was partially sponsored by:

- The research scholarship programme of the University of Girona, reference BR08/09.
- The mobility scholarship programme of the University of Girona, reference MOB12/6.
- A mobility grant of the Broadband Communications and Distributed Systems Group, Universitat de Girona.

The BCDS group (ref. GRCT40) is part of the DURSI consolidated research group COMUNICACIONS I SISTEMES INTELLIGENTS (CSI) (ref. SGR-1202).

To God once again, for giving me this one more opportunity in my life.

A Dios una vez más, por darme esta otra oportunidad en mi vida.

To my parents and sisters, who have been my unconditional support.

A mis padres y hermanas, quienes han sido mi apoyo incondicional.

To my lovely husband Sergio, who always has given me the support I needed to reach my goals.

A mi querido esposo Sergio, que me ha dado siempre el apoyo que necesitaba para alcanzar mis metas.

To my daughter Samanta, who was in my belly during the writing of this dissertation.

A mi hija Samanta, que estuvo en mi barriguita durante la escritura de esta tesis.

ACKNOWLEDGEMENTS

I would like to thanks first at all my thesis supervisor PhD. Ramon Fabregat, for his complementary work as supervisor in aspects regarding my research work, and for inviting me to work in the Broadband Communications and Distributed Systems (BCDS) research group, in Girona (Spain).

Many thanks to the University of Girona in Catalonia, Spain, for providing the funds to my research work received by the grant (BR) - Grant record BR08/09. Moreover, I also acknowledge the financial support by the mobility grant programme from the University of Girona for providing me with the funds for my research stay abroad Spain.

Also, many thanks to the Broadband Communications and Distributed Systems (BCDS) research group, for the partial financial support I have received during my doctoral studies for a 3-month research visit and to attend different conferences.

I am enormously grateful to PhD. Juan E. Jiménez, for hosting me during my stay at his research group "Learning Disabilities, Psycholinguistics and New Technologies (DEA&NT)", at the University of La Laguna (Spain), and for his continued contributions and feedback to my work related to psychological topics and Dyslexia.

Moreover, I extend these sincere thanks to my friend and co-worker during my stay PhD. Alicia Díaz Megolla from Department of Education at the University of Las Palmas de Gran Canaria (Spain), with whom I discuss various aspects relevant to the progress of this work related to assessment and assistance of cognitive processes in adults with dyslexia and with whom I shared special and nice moments during my doctoral process.

I am thankful to PhD. Almudena Giménez de la Peña, from Department of Psychology from University of Malaga (Spain), for her valuable comments and feedback regarding the detection of reading difficulties in adults. They played an important role in a relevant publication that emerges from our joint contribution.

I am also enormously grateful to PhD. Ravi Vatrapu, for hosting me during my second stay at his research group "Computational Social Science Laboratory (CSSL)", at the Copenhagen Business School (Denmark), and for his kind support and encouragement to work collaboratively with him, as well as his valuable comments and feedback to my work related to technological aspects regarding the learning analytics topic.

My sincere thanks to PhD. Susan Bull, for accepting my research stay request in her research group "Open Learner Modelling Research Group", at the University of Birmingham (United Kingdom). Although, I could not visit her, she has been always interested about my research work and she has been kind to me by providing valuable comments, feedback and suggestions regarding the open learner model in this dissertation.

I want to express a warm gratitude to Desiree, Julia, Isaac, Cristian, Natalia, Cristina, Elaine, Rebeca, Claudia and Eduardo who collaborate during my research stay in the "Learning Disabilities, Psycholinguistics and New Technologies (DEA&NT)" research group at the University of La Laguna (Spain). They were very kind with advices, help and support I would needed.

I extend this gratitude also to Attila, Erol, Signe, Nikhil, Janni, Helle, Abdul from the Computational Social Science Laboratory (CSSL) in the Copenhagen Business School (Denmark) and especially to Jan Damsgaard (Head of department) for being really kind during my second stay.

Thanks to PhD. Clara Inés Peña de Carrillo for motivating me from the very beginning to work in the valuable world of research. Her role as researcher and her continuous nice and funny stories were the force to start.

Thanks to my friend PhD. Beatriz Eugenia Florián from the University of Valle (Colombia). During our doctoral process we could share really special moments as well as we could work collaboratively so as to produce an important publication regarding the learning analytics topic.

Thanks to Ph.D. Montse Castro from the Program to Support People with Disabilities and Ph.D. Montse Tesauro from the Department of Education, both at the University of Girona, for the support they gave me to conduct some of the case studies in this research work.

I am especially thankful to all people who participated in the evaluation and validation procedures of this dissertation. I am really grateful to both named and unnamed students from the University of Girona (Spain), from the University of la Laguna (Spain) and from the University of Cordoba (Colombia), for their spent time and effort while participating in the case studies of this research work. Special thanks to academic coordinators and teachers (Jose Luis Marzo, Eusebi Calle, Antonio Bueno, María Jesús Gutiérrez, Xevi Cufi, Andrea Ordoñez, Moises Esteban, Antonio Lopez, Gloria Muñoz, Helena Benito, Raquel Camprubi, Carles Trèmols, Dolors Berga, Jaume Puig, Núria Fiol, Montserrat Vila, among others) from the University of Girona (Spain), who were very interested and trusted in my research work and accepted to get involved in the case studies by facilitating the data collection in their departments and courses.

Thanks to Verónica Gil from the University of La Laguna, for her feedback about the recommendations to assist of reading difficulties in adults, and her collaboration to conduct some of the case studies in this research work.

I am also grateful with Jonathan Clara (senior student pursuing a bachelor's degree in Computer Science in the 2010-2011 term) at University of Girona; as well as with Daniel Salas (associate lecturer), Julio Martinez, Marco Caballero and Randy Espitia (senior students pursuing a bachelor's degree in Systems Engineering and Telecommunications in 2012-2013 term) from the University of Cordoba (Colombia). The related labor they developed, derived from this thesis, was very useful to the progress of this work.

Also, many thanks to my co-workers at BCDS research group (Laury, Ceci, Jorge, Shivis, Juan, Nico, Ludy, David, Migue, German, Luisfer), who were also involved in a doctoral process similar to mine and with whom I shared not only pleasant and interesting discussions about the work in this dissertation, but also good moments of friendship.

Many thanks to Montse, Rosa and Cristina, secretaries of the Institute of Informatics and Applications (IIA) and Anna, secretarie of the Department of Architecture and Technology in Computers (ATC), who managed all the paper work needed for the different trips during this research work.

I do not only want to thank but to express my greatest satisfaction to be fortunate to have the unconditional support of my beloved husband Sergio E. Gómez and my family who are in Colombia. They have always known how to fill me with motivation (sometimes inadvertently) and they have always been my pillars to achieve any personal goal, including of course the great achievement of this work.

Also, thanks my little Samanta, your company in my belly during the writing of this dissertation was a great motivation and encouragement to complete this process.

Finally, in spite of not being a person but as if he were, thanks to Mego (my dog) for his company during the last two years.

Universitat de Girona

El Dr. Ramon Fabregat Gesa, Titular de Universitat del Departament d'Arquitectura i Tecnologies de Computadors de la Universitat de Girona,

CERTIFICA

Que aquest treball, titulat "Framework for Detection, Assessment and Assistance of University Students with Dyslexia and/or Reading Difficulties", que presenta Carolina Mejía Corredor per a l'obtenció del títol de doctor, ha estat realitzat sota la meva direcció i que compleix els requeriments necessaris. A més, certifico que aquesta tesi està optant a la Menció Europea.

Ramon Fabregat Gesa

Girona, 7 de juny de 2013

List of Acronyms

ADDA	Self-report Questionnaire to Detect of Dyslexia in Adults
ADEA	Self-report Questionnaire to Detect Learning Style
AHS	Adaptive Hypermedia Systems
APA	American Psychological Association
AT	Assistive Technologies
ATC	Department of Architecture and Technology in Computers
BCDS	Broadband Communication and Distributed System Research Group
BEDA	Assessment Battery of Dyslexia in Adults
CSCL	Computer Supported Collaborative Learning
CSSL	Computational Social Science Laboratory
DEA&NT	Learning Disabilities, Psycholinguistics and New Technologies Research Group
DSM-IV-TR	Diagnostic and Statistical Manual of Mental Disorders
EC	European Commission
ICD-10	10th revision of the International Classification of Diseases
IDRC	Inclusive Design Research Centre
IIA	Institute of Informatics and Applications
ILS	Index of Learning Styles
IQ	Intelligence Quotient
LA	Learning Analytics
LD	Learning Disability
LDA	Learning Disabilities Association of America
LLL	Lifelong Learning Program
LMS	Learning Management System
LOE	Organic Law of Education
LSIS	Learning and Skills Improvement Service

NJCLD	National Joint Committee on Learning Disabilities
NRP	National Reading Panel
OLM	Open Learner Model
PADA	Dashboard of learning analytics of dyslexia in adults
RADA	Recommender of Activities for Dyslexia in Adults
RQ	Research Question
TeL	Technology-Enhanced Learning
UML	Unified Modelling Language
UN	United Nations
WHO	World Health Organization

LIST OF FIGURES

Figure 2-1. Simple scheme of an Adaptive Hypermedia System (AHS). Adapted from Brusilovsky (1996) 23
Figure 2-2. Spectrum of adaptation proposed by Oppermann et al. (1997) 25
Figure 2-3. Schema representing the integration of a AHS in a LMS 27
Figure 2-4. The students pyramid considered to achieve a universal design. Extracted from Benktzon (1993) 29
Figure 2-5. Process evaluation to determine if students have dyslexia. Extracted from García (2004) 51
Figure 3-1. Framework's components 68
Figure 3-2. Learner model 71
Figure 3-3. Engeström's activity theory and educational technology extension 78
Figure 4-1. Use case diagram of detectLD 87
Figure 4-2. DetectLD's architecture 87
Figure 4-3. DetectLD interface: Expert module 88
Figure 4-4. DetectLD interface: Teacher module 88
Figure 4-5. DetectLD interface: Student module 89
Figure 4-6. DetectLD interface: Example of self-report questionnaire 89
Figure 4-7. Learning styles of dyslexic and possible-dyslexic students 107
Figure 5-1. BEDA's architecture 114
Figure 5-2. Multimodal communication input and ouput 116
Figure 5-3. Example of the scores profile of the BEDA report 119
Figure 5-4. BEDA interface: Menu of assessment modules 121
Figure 5-5. BEDA interface: Example item of phonemic location task 121
Figure 5-6. BEDA interface: Assessment item of number of syllables task 122
Figure 6-1. The activity-based learner-models technical framework adapted to PADA 147
Figure 6-2. Architecture and technology behind PADA 149
Figure 6-3. PADA interface: Tab of overview analytics 150
Figure 6-4. PADA interface: Tab of reading difficulties analytics 151
Figure 6-5. PADA interface: Analytics with summaries of reading and associated difficulties 151

Figure 6-6. PADA interface: Tab of learning style analytics 152
Figure 6-7. PADA interface: Tab of cognitive processes analytics 152
Figure 6-8. RADA's architecture 164
Figure 7-1. The framework's software toolkit 171
Figure 7-2. Use case diagram of the PIADA block 173
Figure 7-3. Activity diagram for PIADA 173
Figure 7-4. Folder structure of the PIADA block 174
Figure 7-5. PIADA interface: Access from a course in Moodle 175
Figure 7-6. PIADA interface: view of the students 176
Figure 7-7. PIADA interface: view of the teachers 177
Figure 7-8. Integration architecture of the framework's software toolkit with Moodle ...178
Figure 7-9. Representation of SOAP's data exchange 178

LIST OF TABLES

Table 2-1. Summary of common characteristics in people with LD 32
Table 2-2. LMS research projects that consider LD 36
Table 2-3. Summary of common characteristics in people with dyslexia 39
Table 2-4. Summary of common characteristics in people with dysgraphia 39
Table 2-5. Summary of common characteristics in people with dysorthography 40
Table 2-6. Summary of cognitive processes involved in reading 45
Table 2-7. Summary of learning styles' tools implemented in e-learning systems 50
Table 2-8. Intelligence tests 52
Table 2-9. General and specific aptitude tests 53
Table 2-10. Achievement tests 53
Table 2-11. Personality tests 54
Table 2-12. Reading and writing tests 54
Table 2-13. Summary of specific tasks to identify dyslexia provided by tests 55
Table 3-1. Summary of aspects to consider in the reading profile submodel 72
Table 3-2. Variable to consider in the learning styles submodel 73
Table 3-3. Variables to consider in the cognitive traits submodel 74
Table 4-1. Demographics data 85
Table 4-2. Results of the case study survey filled in by students 91
Table 4-3. Frequencies and percentages of participation by faculty, academic program, and gender 93
Table 4-4. Frequency and percentages of students with a history of LD 96
Table 4-5. Frequency and percentages of students with a previous diagnosis of LD 97
Table 4-6. Frequency and percentage of reading and writing disability diagnosis distributed by faculty and academic program 97
Table 4-7. Frequency and percentages from items about current reading-writing difficulties 98
Table 4-8. Correlations between previous diagnosis of reading and writing disability and reported difficulties 100
Table 4-9. Frequencies and percentages of participation by university and gender 105
Table 4-10. Students's preferences according to learning style 105

Table 4-11. Frequencies and percentages of learning styles for the students with reading difficulties 106

Table 4-12. Frequencies and percentages of satisfaction with the learning styles 108

Table 5-1. Assessment tasks for each cognitive process 115

Table 5-2. Example of converting direct scores to percentiles 119

Table 5-3. Results of the case study survey filled in by students 123

Table 5-4. Frequencies and percentages of participation by faculty, academic program, and gender in the BEDA's case study 125

Table 5-5. Measures of central tendency and variability of BEDA's tasks 129

Table 5-6. Mean and standard deviation of the scores obtained by men, women and the total sample 131

Table 5-7. Scale score of phonological processing tasks from BEDA 131

Table 5-8. Scale score of orthographical processing and lexical access tasks from BEDA 132

Table 5-9. Scale score of processing speed, working memory and semantic processing tasks from BEDA 132

Table 5-10. Percentile of cognitive processes from BEDA 133

Table 5-11. Analysis of the items of the task (1) segmentation into syllables 135

Table 5-12. Analysis of the items of the task (2) number of syllables 136

Table 5-13. Analysis of the items of the task (3) segmentation into phonemes 136

Table 5-14. Analysis of the items of the task (4) general rhyme 136

Table 5-15. Analysis of the items of the task (5) specific rhyme 136

Table 5-16. Analysis of the items of the task (6) phonemic location 137

Table 5-17. Analysis of the items of the task (7) omission of phonemes 137

Table 5-18. Analysis of the items of the task (8) homophone/pseudohomophone choice 138

Table 5-19. Analysis of the items of the task (9) orthographic choice 138

Table 5-20. Analysis of the items of the task (10) reading words 138

Table 5-21. Analysis of the items of the task (11) reading pseudowords 139

Table 5-22. Analysis of the items of the task (12) visual speed of letters and numbers 140

Table 5-23. Analysis of the items of the task (13) retaining letters and words 141

Table 5-24. Analysis of the items of the task (14) reading narrative text 141

Table 5-25. Analysis of the items of the task (15) reading expository text 141

Table 5-26. Measures of central tendency and variability of BEDA's tasks after debugging of the items 142

Table 6-1. Overview of PADA survey case study 154

Table 6-2. Results of inspection category 156

Table 6-3. C.8. and C.9 responses* diagnosis ... 156
Table 6-4. Results of awareness category ... 157
Table 6-5. D.4. and D.5. responses* diagnosis ... 157
Table 6-6. Summary of highlighted student's comments regarding awareness category ... 158
Table 6-7. Results of usefulness category ... 159
Table 6-8. F.4. responses* diagnosis ... 159
Table 6-9. Recommendation preferences ... 159
Table 7-1. Summary of requirements of the PIADA block in Moodle. ... 174
Table 7-2. Description of the functions created for the web services ... 179
Table 7-3. Overview of student's case study survey ... 181
Table 7-4. Results of the survey filled in by students ... 182

CONTENTS

Acknowledgements .... **V**

List of Acronyms .... **XI**

List of Figures .... **XIII**

List of Tables .... **XV**

Contents .... **XIX**

Abstract **1**

Resumen **3**

Resum **5**

CHAPTER 1 Introduction **7**

1.1 Motivation 7
1.2 Research Questions 11
1.3 Objectives 11
1.4 Research Methodology 12
1.5 Contributions 13
1.6 Outline of the Thesis 15
1.6.1 Chapter 2: Theoretical Foundations 15
1.6.2 Chapter 3: Thesis Proposal: Framework for Detection, Assessment and Assistance of University Students with Dyslexia and/or Reading Difficulties 16
1.6.3 Chapter 4: Detection of University Students with Reading Difficulties 16
1.6.4 Chapter 5: Assessment of University Students with Reading Difficulties 16
1.6.5 Chapter 6: Assistance of University Students with Reading Difficulties 16
1.6.6 Chapter 7: Integration of the Framework with a Learning Management System 17
1.6.7 Chapter 8: Conclusions and Future Work 17
1.6.8 Appendices 17

CHAPTER 2 Theoretical Foundations **19**

2.1 Introduction 19
2.2 Learning Management Systems (LMS) 21
2.3 Adaptive Hypermedia Systems (AHS) 23
2.3.1 Learner modeling process 24
2.3.2 Adaptation process 25
2.4 Open Learner Model (OLM) 27
2.5 Learning Analytics (LA) 28
2.6 e-Learning for All and Inclusion 28
2.7 Learning Disabilities (LD) 30
2.7.1 LD definition 31

2.7.2 LD classification 32
2.7.3 Influence of educational psychology 33
2.7.4 Computer mediated assistance in the teaching-learning process 34
2.7.5 LMS and LD 34
2.8 Dyslexia 37
2.8.1 Dyslexia definition 37
2.8.2 Dyslexia characteristics 39
2.8.3 Associated difficulties 40
2.8.4 Prevalence in university students 41
2.8.5 Compensatory strategies 42
2.8.6 Cognitive processes involved 43
2.8.7 Assistance through technology 46
2.9 Detection, Assessment and Assistance to Dyslexia 47
2.9.1 Detection of difficulties related to reading 47
2.9.2 Detection of compensatory strategies 48
2.9.3 Assessment of cognitive processes 50
2.9.4 Assistance to dyslexia in university students 57
2.10 Summary 59

CHAPTER 3 Thesis Proposal: Framework for Detection, Assessment and Assistance of University Students with Dyslexia and/or Reading Difficulties 63

3.1 Introduction 64
3.2 Framework's Components 67
3.3 Learner Model 70
3.3.1 Demographics 72
3.3.2 Reading profile 72
3.3.3 Learning styles 73
3.3.4 Cognitive traits 73
3.4 Adaptation Processes 75
3.4.1 Learning analytics 79
3.4.2 Recommendations 80
3.5 Integration with a LMS 80
3.6 Summary 81

CHAPTER 4 Detection of University Students with Reading Difficulties 83

4.1 Introduction 83
4.2 Demographics Data Forms 85
4.3 DetectLD: Software Tool to Detect Learning Difficulties 86
4.3.1 Architecture and implementation 86
4.3.2 Case study: functionality and usability 90
4.4 ADDA: Self-report Questionnaire to Detect Dyslexia in Adults 92
4.4.1 Study description 93
4.4.2 Method 93
4.4.3 Results 96
4.4.4 Discussion 101
4.5 ADEA: Self-report Questionnaire to Detect Learning Styles 103
4.5.1 Study Description 104
4.5.2 Method 104
4.5.3 Results 106
4.5.4 Discussion 108

4.6 Summary 108

CHAPTER 5 Assessment of University Students with Reading Difficulties 111

5.1 Introduction 111
5.2 BEDA: Assessment Battery of Dyslexia in Adults 112
5.2.1 Architecture 113
5.2.2 Implementation 119
5.2.3 Case study: functionality and usability 122
5.2.4 Case study: analysis and debug of items 124
5.3 Summary 143

CHAPTER 6 Assistance of University Students with Reading Difficulties 145

6.1 Introduction 146
6.2 PADA: Dashboard of Learning Analytics of Dyslexia in adults 147
6.2.1 Architecture and Implementation 147
6.2.2 Interfaces 149
6.2.3 Case study 152
6.3 RADA: Recommender of Activities for Dyslexia in Adults 163
6.3.1 Architecture and implementation 164
6.3.2 Case study 165
6.4 Summary 166

CHAPTER 7 Integration of the Framework with a Learning Management System 169

7.1 Introduction 169
7.2 The Framework's Software Toolkit 170
7.3 The LMS Module 171
7.4 Integration Architecture based on Web Services 177
7.5 Case Studies 180
7.5.1 Case study with students 181
7.5.2 Case Study with Teachers 183
7.6 Summary 184

CHAPTER 8 Conclusions and Future Work 185

8.1 General Summary 185
8.2 Conclusions 186
8.3 Future Work 191
8.4 Publications and Scientific Collaborations 194
8.4.1 Journal papers 194
8.4.2 Book chapters 194
8.4.3 Conference papers 194
8.4.4 Guides & reports 196
8.4.5 Final thesis reports 196
8.4.6 Invited talks 197
8.4.7 Scientific collaborations 197
8.5 Projects 197

APPENDIX A ADDA Items – First version 199

APPENDIX B ADDA Items – Second version 201

APPENDIX C Felder-Silverman's Index of Learning Styles 205

APPENDIX D BEDA Items 209

APPENDIX E BEDA Items after Debugging 217

References………… 223

ABSTRACT

During the past years, the adoption of Learning Management System (LMS) to support an e-learning process has been continuously growing. Hence, a potential need and meaningful factor to provide a personalized support, within the context of these systems, has been the identification of particular characteristics of students to provide adaptations of the system's elements to the individual traits. One particular characteristic that has been little studied in a personalized e-learning process are the learning disabilities (LD) of students. Dyslexia is a common LD in Spanish-speaking university students, which is specifically referred to the manifestation of different difficulties in reading. Dyslexia requires special attention by higher educational institutions to detect, assess, and assist affected students during their learning process. Thereby, an open challenge has been identified from this implication:

How to include Spanish-speaking university students with dyslexia and/or reading difficulties in an e-learning process?

In this dissertation, an approach to include the characteristics of these affected students with dyslexia in the context of an LMS is proposed and developed. To achieve this, as first step, it was detected students with or without a previous diagnosis of dyslexia that still show reading difficulties, it was detected the compensatory strategies that they could use to learn, and it was assessed the cognitive processes that they may have altered. Therefore, it was analyzed, designed and developed methods and tools for the detection and assessments of these students. Moreover, a learner model made up of demographics, reading profile, learning styles, and cognitive traits was defined.

As second step, in our research work was the essential support and assistance to these students in overcoming their difficulties. To do so, it was necessary to create awareness in these students of their reading difficulties, learning styles and cognitive deficits. This awareness promotes learning reflection by encouraging students to view and self-regulate their learning. Furthermore, it was necessary to provide specialized recommendations to support such self-regulation of the students. Thus, methods and tools that can be used to assist these students were analyzed and developed, as well as adaptation processes to deliver learning analytics and specialized recommendations were defined.

As third step, it was necessary to construct mechanisms to integrate these tools in an LMS to assist affected students during an e-learning process. Thus, a familiar environment that supports detection, assessment and assistance of these students is provided.

Finally, in this dissertation several case studies that evaluate the validity of the methods and tools proposed were implemented. Experiments with pilot groups of students to test the functionality and usability, jointly with larger groups of students to test the usefulness and validity of the tools were conducted. Descriptive analysis as well as reliability and correlation analysis were performed.

RESUMEN

Durante los últimos años, la adopción de Sistemas de Gestión del Aprendizaje (LMS por sus siglas en inglés) para apoyar los procesos de e-learning ha crecido continuamente. Por lo tanto, una necesidad potencial y un factor significativo para proporcionar un soporte personalizado, en el contexto de estos sistemas, ha sido la identificación de las características particulares de los estudiantes con el fin de proporcionar adaptaciones de los elementos del sistema a los rasgos individuales. Una característica particular que ha sido poco estudiada en un proceso de e-learning personalizado son las dificultades de aprendizaje de los estudiantes. La dislexia es una dificultad de aprendizaje común en estudiantes universitarios de habla española, que se refiere específicamente a la manifestación de diferentes dificultades en la lectura. La dislexia requiere de una atención especial por las instituciones de educación superior para detectar, evaluar y ayudar a los estudiantes afectados durante su proceso de aprendizaje. De este modo, un desafío abierto ha sido identificado a partir de esta implicación:

> *Cómo incluir a los estudiantes universitarios de habla española con dislexia y/o dificultades de lectura en un proceso de e-learning?*

En esta tesis, un enfoque que incluye las características de estos estudiantes afectados con dislexia en el contexto de un LMS es propuesto y desarrollado. Para ello, como primer paso, se detectó a los estudiantes con o sin un diagnóstico previo de la dislexia que aún muestran dificultades en la lectura, también se detectaron las estrategias compensatorias que podrían utilizar para aprender, y se evaluaron los procesos cognitivos que pueden tener alterados. Por lo tanto, se analizó, diseñó y desarrollaron métodos y herramientas para la detección y evaluación de estos estudiantes. Por otra parte, se definió un modelo del estudiante formado por la demografía, los perfiles de lectura, los estilos de aprendizaje, y los rasgos cognitivos.

Como segundo paso, en nuestro trabajo de investigación fue el apoyo y la asistencia esencial a estos estudiantes a superar sus dificultades. Para ello, fue necesario crear conciencia en los estudiantes de sus problemas de lectura, estilos y los déficits cognitivos de aprendizaje. Esta toma de conciencia promueve la reflexión en el aprendizaje, alentando a los estudiantes a ver y autorregular su aprendizaje. Además, fué necesario formular recomendaciones especializadas para apoyar la autorregulación de los alumnos. Por lo tanto, se analizaron y desarrollaron métodos y herramientas que se pueden utilizar para ayudar a estos estudiantes, como también se definieron procesos de adaptación para ofrecer análisis y recomendaciones de aprendizaje especializados.

Como tercer paso, fue necesario crear mecanismos para integrar estas herramientas en un LMS para ayudar a los estudiantes afectados durante un proceso de e-learning. Por lo tanto, se proporciona un ambiente familiar para apoyar la detección, la evaluación y la asistencia de los estudiantes.

Por último, en esta tesis se llevaron a cabo varios casos de estudios que evalúan la validez de los métodos e instrumentos propuestos. Se llevó la experimentación con grupos piloto de estudiantes para probar la funcionalidad y facilidad de uso, junto con grandes grupos de estudiantes para poner a prueba la utilidad y validez de los instrumentos. Se realizó el análisis descriptivo así como la fiabilidad y la correlación de los análisis.

RESUM

Durant els últims anys, l'adopció de Sistemes de Gestió de l'Aprenentatge (LMS per les sigles en anglès) per donar suport als processos d'e-learning ha crescut contínuament. Per tant, una necessitat potencial i un factor significatiu per a proporcionar un suport personalitzat, en el context d'aquests sistemes, ha sigut la identificació de les característiques particulars dels estudiantes con la finalitat de proporcionar adaptacions dels elements del sistema als trets individuals. Una característica particular que ha sigut poc estudiada en un procés d'e-learning personalitzat són les dificultats d'aprenentatge dels estudiants. La dislèxia és una dificultat d'aprenentatge comú en estudiants universitaris de parla espanyola, que es refereix específicament a la manifestació de diferents dificultats en la lectura. La dislèxia requereix d'una atenció especial per les institucions d'educació superior per detectar, avaluar i ajudar els estudiants afectats durant el seu procés d'aprenentatge. D'aquesta manera, un desafiament obert ha sigut identificat a partir d'aquesta implicació:

Com incloure als estudiants universitaris de parla espanyola amb dislèxia i/o dificultats de lectura en un procés d'e-learning?

En aquesta tesi, un enfocament que inclou les característiques d'aquests estudiants afectats amb dislèxia en el context d'un LMS és proposat i desenvolupat. Per a això, com a primer pas, es va detectar als estudiants amb o sense un diagnòstic previ de la dislèxia que encara mostren dificultats en la lectura, també es van detectar les estratègies compensatòries que podrien utilitzar per aprendre, i es van avaluar els processos cognitius que poden tenir alterats. Per tant, es va analitzar, dissenyar i desenvolupar mètodes i eines per a la detecció i avaluació d'aquests estudiants. D'altra banda, es va definir un model de l'estudiant format per la demografia, els perfils de lectura, els estils d'aprenentatge, i els trets cognitius.

Com a segon pas, en el nostre treball d'investigació va ser el suport i l'assistència essencial a aquests estudiants a superar les seves dificultats. Per a això, va ser necessari crear consciència en els estudiants dels seus problemes de lectura, estils i els dèficits cognitius d'aprenentatge. Aquesta presa de consciència promou la reflexió en l'aprenentatge, encoratjant els estudiants a veure i autoregular el seu aprenentatge. A més, fou necessari formular recomanacions especialitzades per donar suport a la autoregulació dels alumnes. Per tant, es van analitzar i van desenvolupar mètodes i eines que es poden utilitzar per ajudar a aquests estudiants, com també es van definir processos d'adaptació per oferir anàlisis i recomanacions d'aprenentatge especialitzats.

Com a tercer pas, va ser necessari crear mecanismes per integrar aquestes eines en un LMS per ajudar els estudiants afectats durant un procés d'e-learning. Per tant, es proporciona un ambient familiar per donar suport a la detecció, l'avaluació i l'assistència dels estudiants.

Finalment, en aquesta tesi es van dur a terme diversos casos d'estudis que avaluen la validesa dels mètodes i instruments proposats. Es va dur l'experimentació amb grups pilot d'estudiants per provar la funcionalitat i facilitat d'ús, juntament amb grans grups d'estudiants per posar a prova la utilitat i validesa dels instruments. Es va realitzar l'anàlisi descriptiva així com la fiabilitat i la correlació de les anàlisis.

CHAPTER 1

INTRODUCTION

This chapter presents an overview of the motivation focusing in the main topics of interest for the development of this research work, followed by a set of research questions, which emerge from identified research challenges, and a set of defined research objectives that aims to provide a solution to the research questions. Additionally, this chapter describes the followed research methodology so as to give details of the general scopes during the developed research work. This chapter concludes describing a list of contributions resulting from the research work and the description of the outline of the main parts of this document.

1.1 Motivation

In an e-learning process the development of ***Learning Management Systems (LMS)*** have been increasing, improving and applying to support traditional face-to-face learning and distance learning process, mainly because (Graf, 2007; Vélez, 2009; Vilches, 2007):

- They are spaces to provide tools that enable the participation and interaction between students and teachers.
- They support teachers and administrators in creating, administering, and managing online courses.
- They promote the accomplishment of learning objectives through activities and shared resources.
- They provide a great variety of educational features which can be included in the courses such as quizzes, forums, chats, assignments, wikis, and so on.
- They contain and present a lot of multimedia learning resources as text, images, videos, audios, links, documents, slide, etc.
- Individually and collaboratively, the internet and online interfaces are exploited and used.
- Thus, they have become very successful solutions and are commonly used by educational institutions and ***Technology-enhanced Learning (TeL)*** communities for research.

Moreover, one more characteristic about these LMS that have got TeL researchers attention, and is one focus of this research work, is their capability to let implementing adaptations in order to achieve personalization of learning. More specifically, some LMS can incorporate different data models (e.g. learner, learning flow, assessment, and contents) that can be processed and inferenced so as to deliver different educational information tailored to the students' needs.

Consistently, adaptations of an LMS can be achieved by incorporating ***Adaptive Hypermedia System (AHS)*** methods. In (Brusilovsky, 1996) it is stated that "*AHS are hypermedia systems which reflect some features of the user in the user model and apply this model to adapt various visible aspects of the system to the user*". There is also an explanation of some of the methods for adapting different educational elements such as activities and contents. These AHS are formed basically by an hypermedia system (e.g., a LMS), a learner model (e.g., student characteristics), and an adaptive component (e.g., adaptation/decision engine). Commonly, outcomes of integrating these three components are adaptations to the contents, activities, and tools, among other educational elements.

During the past years diverse adaptation processes in the architecture of an LMS have being built in different levels so as to achieve adaptations to the contents, activities, competences, navigation, evaluation, and services (e.g., forums, chats, etc.) (Brusilovsky & Millán, 2007; S. Bull, Jackson, & Lancaster, 2010; Carmona, Castillo, & Millán, 2007; Fontenla, Caeiro, & Llamas, 2009; Gaudioso, 2002; Graf, 2007; Gutierrez et al., 2009; Laroussi, 2001; Virvou & Tsiriga, 2001). In this sense, it worth noting that the BCDS group[1] has been involved in several research works on these processes achieving satisfactory results and a high research experience (Baldiris, 2012; Florian, 2013; Gómez, 2013; Huerva, 2008; Mancera, 2008; Mejia, Mancera, Gómez, Baldiris, & Fabregat, 2008; Mejia, 2009; Merida, Fabregat, Arteaga, & Cannataro, 2004; Moreno, 2008; Peña, Gómez, Mejia, & Fabregat, 2008; Peña, 2004; Vélez, 2009).

Bassically, the implementation of these processes takes into account individual characteristics of students such as knowledge, interest, preferences, learning styles, skills, beliefs, misconceptions, as well as the applications of e-learning standards, the implementation of accessibility and usability guidelines, and the considerations of access context (i.e., technology, mobility, etc.). Additionally, within the context of ***e-Learning for All***, the inclusion of special needs or impairment in students can be considered in the implementation of those processes to support and personalize the learning acquisition. Thus, factors such as the place from where students are accessing, the students' age, their physical or psychological disabilities, their learning disabilities, their cultural deficiencies, among others, can be taken into account. Some research studies have discussed different characteristics of students with regards to their special needs and accessibility (Gelvez, Baldiris, & Fabregat, 2011; Judge & Floyd, 2011; Mancera, Baldiris, Fabregat, Viñas, & Caparros, 2011; Mejia & Fabregat, 2010; Moreno, 2008; O. C. Santos, Baldiris, Boticario, Gutierrez, & Fabregat, 2011). According to (Echeita, 2007), ***inclusion*** refers to the presence, participation and performance of all students, regardless of their special learning needs.

In this context of inclusion, the European Commission (EC) has promoted projects such as IRIS[2], TATE[3], BenToWeb[4], MICOLE[5], SEN-IST-NET[6], ALPE[7], EU4ALL[8], ALTER-

---

[1] http://bcds.udg.edu/
[2] www.irisproject.eu
[3] http://www.tateproject.org.uk/
[4] http://www.bentoweb.org/home
[5] http://micole.cs.uta.fi/

NATIVA[9], ALTERNATIVE-eACCESS among others with the purpose to aim both education and labor inclusion and promote the independence of people in need, creating training activities, web portals, methodologies, accessibility guidelines and assistive technologies.

Among people with special needs there is a group of interest of this research work that is, those who present ***Learning Disabilities (LD)***, i.e., students who may manifest difficulties in listening, speaking, reading, writing, and even in mathematical calculation abilities. In this sense, since the 1980s, the fields of psychology and education have made important contributions to understanding students' LD. ***Dyslexia*** is a common LD in education, which is specifically referred to the manifestation of different difficulties in reading. However, in recent years, there has been a particular concern among researchers and practitioners about reviewing their teaching practices to improve the processes involved in reading and learning and how to assess, intervene and assist affected students during their learning process. Several studies have explored dyslexia in children: identifying the population of children with dyslexia, evaluating cognitive processes involved, determining their etiology, specific deficits, and developing intervention programs to reduce their deficits in learning to read and write (Guzmán et al., 2004; Luque, Bordoy, Giménez de la Peña, López-Zamora, & Rosales, 2011; Metsala, 1999; Nicolson & Fawcett, 1990). Many of those programs have been supported by information and communication technologies (e.g., software) that tend to increase student's motivation and personalize the learning process (Barker & Torgesen, 1995; Rojas, 2008; Wise & Olson, 1995).

Considering dyslexia at university level is a current research challenge since difficulties do not disappear with age or training (Callens, Tops, & Brysbaert, 2012; Hatcher, Snowling, & Griffiths, 2002; Swanson & Hsieh, 2009). Some research studies have borne out that, in spite of the manifested ***reading difficulties***, i.e. dyslexia symptoms, dyslexic students could develop compensatory strategies (e.g., learning preferences) to help them succeed in their studies (Firth, Frydenberg, & Greaves, 2008; Lefly & Pennington, 1991; Mellard, Fall, & Woods, 2010; Ransby & Swanson, 2003) and get into university, although they still underperform in reading-related tasks (Callens et al., 2012; Hatcher et al., 2002). However, despite their efforts, when compared to their peers, affected students still show significant difficulties in reading tasks (Eden et al., 2004; Hatcher et al., 2002; Lyon, Shaywitz, & Shaywitz, 2003; Miller-Shaul, 2005; Ramus et al., 2003; Sally E. Shaywitz, Morris, & Shaywitz, 2008).

Surprisingly, not all students whose performance is affected by dyslexia are diagnosed and/or assisted before starting their studies at university; therefore, there are many students with reading difficulties who have not been diagnosed with dyslexia by means of an official psychoassessment procedure. Consequently, a considerable number of students enter university without having expected reading skills, and would require support to cope with high reading demands. Therefore, the number of dyslexic students in university could be higher.

---

[6] http://saci.org.br/?modulo=akemi&parametro=16078
[7] http://adenu.ia.uned.es/alpe/
[8] http://www.eu4all-project.eu/
[9] http://titanic.udg.edu:8000/www_alternativa/

Thus, higher educational institutions are in clear need of specific resources to detect students with or without a previous diagnosis of dyslexia that still show reading difficulties, and to provide assistance to them. These students was called in this disse

In this research work, the ***Spanish-speaking university students*** who have a previous diagnosis of dyslexia and/or are affected with reading difficulties which may be related to dyslexia are addressed as a current research challenge. Since, at present, there are no tools to detect adult Spanish-speaking population with dyslexia and/or reading difficulties, to assess the cognitive processes that they can be altered, and to assist them in overcoming their difficulties. Furthermore, this research work focuses on Spanish-speaking population because, particularly, in Spain, this existing current challenge is the interest of some universities (Univeristy of Girona, University of La Laguna, University of Malaga, University of La Palmas de Gran Canaria), which have collaborated in the development of this dissertation. Thus, the research outcome of this fruitful collaboration was a framework for detection, assessment and assistance of university students with reading difficulties who may have dyslexia.

It is worth remarking that assisting dyslexia on adult population in Spain is difficult mainly because:

- There are many tools that focus on children excluding the adult population (e.g., there are no standardized tests for adult assessment).
- The Organic Law of Education (LOE) (adopted in May 3, 2006) which recognizes dyslexia as a Learning Disability and ensures resources for affected students has a limited scope to compulsory education levels (primary and secondary) and therefore be exempt from its application not mandatory in higher levels such as the university level.
- Moreover, the adult population has developed compensatory strategies enabling them to overcome (or hide) their difficulties making more difficult the detection.

In addition, as another novelty of this dissertation, the integration of this proposed framework with a LMS is considered. Thus, it is achieved extend the reach of the LMS to include characteristics of students with dyslexia, including investigations about how to automatically identify their symptoms or diagnosis, compensatory strategies and cognitive traits, and how to provide assistance that fit their particular characteristics.

To address this issue, the proposed framework has to consider a ***learner model*** of students with dyslexia and an ***adaptive component*** to deliver adapted and personalized support to those students. In this way, the learner model can be designed by defining variables related to demographics, reading profile, learning styles, and cognitive traits. These variables can be used by an adaptation engine to deliver learning analytics and specialized recommendations that best suit each student's performance.

Finally it is worth clarifying that the description "dyslexia and/or reading difficulties" is used in this dissertation because dyslexia is analyzed independently of reading difficulties. That is, in this research study students were asked if they had a previous clinical diagnosis of dyslexia, as well as using the tools developed in this work was detected if the student had reading difficulties, leaving the possibility that either of the two cases could be given at the same time (dyslexia and reading difficulties) or independently (dyslexia or reading difficulties).

1.2 Research Questions

Taking into account the challenges mentioned in the previous section, and considering the issue of extending the LMS to students with dyslexia and/or affected with dyslexia-related symptoms (i.e., reading difficulties), the main question addressed in this dissertation is:

> ***RQ. How to include Spanish-speaking university students with dyslexia and/or reading difficulties in an e-learning process?***

To help answer the main research question (RQ) four subordinate research questions were posed:

> *RQ.1. How can university students with dyslexia and/or reading difficulties be detected?*
>
> *RQ.2. How can cognitive traits of the students with dyslexia and/or reading difficulties be assessed in order to inquire which cognitive processes related to reading are failing?*
>
> *RQ.3. How can students with dyslexia and/or reading difficulties be assisted?*
>
> *RQ.4. How can the detection, assessment and assistance of university students with dyslexia and/or reading difficulties be provided in a LMS?*

The answers of these questions should enable the identification of a concise set of information elements, methods and tools that enable support for university students affected with dyslexia and/or reading difficulties through an LMS.

1.3 Objectives

In order to achieve and contribute to the development of "e-Learning for All", the main objective of this dissertation is to:

> ***OB. Including students with dyslexia and/or reading difficulties in an e-learning process, so as to define methods and tools to detect, assess and assist them in overcoming their difficulties during their higher education.***

To carry out this objective (OB), six subordinate objectives were posed:

> *OB.1. Defining a framework for detection, assessment and assistance of university students with dyslexia and/or reading difficulties that can be integrated into a LMS.*
>
> *OB.2. Analyzing and developing methods and tools for the detection of university students with dyslexia and/or reading difficulties.*
>
> *OB.3. Analyzing and adopting methods and tools for the detection of learning style of university students with dyslexia and/or reading difficulties.*
>
> *OB.4. Analizing cognitive processes associated with reading that can be altered in university students with dyslexia and/or reading difficulties in order to develop methods and tools needed to determine which specific processes are failing.*
>
> *OB.5. Analyzing and developing adaptation methods and tools that can be used to assist university students with dyslexia and/or reading difficulties.*

OB.6. Integrating the tools developed for the detection, assessment and assistance of university students with dyslexia and/or reading difficulties with a LMS.

Since each objective corresponds to a tool implementation, each specific objective is completed following the phases of the engineering methodology. This methodology is presented in next section.

Basically, this research work is focused on identifying and supporting Spanish-speaking university students that are affected with dyslexia and/or reading difficulties. Thus, their reading profiles, learning styles, and cognitive deficits can be studied by defining a learner model in order to understand how they can be assisted and how, in a TeL approach, this can support a personalized learning process.

1.4 Research Methodology

TeL is the encompassing research field to which the work done in this thesis belongs. As presented in previous section, this works focuses on contributing to the development of "e-Learning for All", considering in LMS the inclusion of students with dyslexia and/or reading difficulties, and develop methods and tools to detect, assess and assist these students in overcoming their difficulties during their higher education. Therefore, an engineering research supported by researchers and practitioners in dyslexia was applied and the used methodology must be understood as such. According to (Richards, 1993), the methodology of an engineering research (which has been followed in the presented research work) is composed of the following four phases:

1. **Information phase**. The aim of this first step is to identify the existing characteristics of the problem domain and to clearly state the subject under research. This phase usually consist in the revision of the existing literature. Thus, the information gathered by the author of this dissertation, comes from the following sources:
    - The review of relevant related literature with LMS, AHS, e-Learning for All and inclusion, LD (particularly dyslexia) as well as its detection, assessment, assistance and technological support, learning styles, open learner models, and learning analytics solutions, which provided a theoretical background of the problem domain and the existing work in the educational sciences and information and communication technologies areas.
    - The identification of researchers and research groups working on similar problems that enriched the discussions of the matter in question. Besides, along with the source, visiting related research groups and the participation in conferences and workshops, in educational sciences and information and communication technologies oriented research projects and the development of coordinated field experiences.
    - The number of documented practical case studies and experiments in the research field, which suggests the development of experiences that contributed to the literature with empiric knowledge and research on the problem domain.
2. **Definition phase.** The information gathered from the previous phase results in the definition of proposals and approaches of implementation in order to find and produce a solution that overcomes the limitations presented in the existing alternatives. In this dissertation, such solution consists in the implementation of a

framework for detection, assessment and assisstance of university students with dyslexia and/or reading difficulties that can be integrated into a LMS. Thus, to achieve this proposal was defined and briefly include (further details of this proposal will be presented in Chapter 3):

- Definition of a learner model which comprimes four submodels: demographics, reading profile, learning styles, and cognitive traits.
- Desing and developing of a tool to detect students with dyslexia and/or reading difficulties.
- Adopting the Felder-Silverman's Index of Learning Styles (ILS) (Felder & Silverman, 2002) to detect the learning styles of students with dyslexia and/or reading difficulties.
- Desing and developing of a tool to assess the cognitive processes involved in reading of students with dyslexia and/or reading difficulties.
- Desing and developing of a tool to open the learner model in order to help increase awareness of the students with dyslexia and/or reading difficulties and to support reflection and self-regulation about their difficulties and learning strategies in reading.
- Providing of specialized recommendations to support such self-regulation of the students with dyslexia and/or reading difficulties.
- Desing and developing of web services to integrate the previous tools for detection, assessment and assistance of students with dyslexia and/or reading difficulties with a LMS.

3. **Implementation phase.** The implementation of the proposal evaluates its practical feasibility and allows the deployment of case studies oriented towards the validation of the proposed methods and tools. The solution proposed in this dissertation has been implemented considering, first capturing the learner model information (i.e., demographics, reading profile, learning styles, and cognitive traits), second opening the learner model using learning analytics solutions, third delivering personalized recommendations, and finally integrating the learner model, learning analytics and recommendations with a LMS.
4. **Validation phase.** The last step of the applied methodology is the definition and deployment of experiments that evaluate the validity of the proposal, in order to show and document how the proposed solution overcomes the limitations identified in the information phase. In this dissertation, the validation consisted in the deployment of case studies that used the proposed implemented solution. Experiences with pilot groups of students to test the functionality and usability, jointly with larger groups of students to test the usefulness and validity of the tools were conducted. Descriptive analyzes as well as reliability and correlation analyzes were performed.

1.5 Contributions

The following list summarizes the contributions of this dissertation to the research areas involved (i.e., educational science and information and communication technologies):

1. The first contribution is the definition of a **Framework for Detection, Assessment and Assistance of University Students with Dyslexia and/or Reading Difficulties**

(Mejia & Fabregat, 2012). This framework is proposed to support students with dyslexia and/or reading difficulties so as they can overcome their difficulties during the learning process in the higher education. The framework architecture identifies concise elements, procedures, methods and software tools to support reading difficulties in LMS of higher educational institutions.

2. The second contribution is the design and development of a software tool, called **detectLD**, devoted to the delivery and review of self-report questionnaires to detect learning difficulties (Mejia, Clara, & Fabregat, 2011). In particular, in this dissertation it was used to store a self-report questionnaire for detecting reading difficulties, as well as for embeding a Spanish translation of the Felder-Silverman's Index of Learning Styles (ILS).
3. The third contribution is the creation of a self-report questionnaire for detection of reading difficulties in adults, called **ADDA** (acronym for the Spanish name *Autocuestionario de Detección de Dislexia en Adultos)* (Mejia, Giménez de la Peña, & Fabregat, 2012, 2013). A first version of ADDA, which consisted of 67 items, was created in collaboration with the Department of Psycology at the University of Málaga (Spain), and later this version was extended to 100 items in collaboration with the Research Group on Learning Disabilities, Psycholinguistics and New Technologies (DEA&NT) at the University of La Laguna (Spain). Futhermore, it also contributes with a dataset collected during six months from 513 students who completed ADDA.
4. The fourth contribution is the definition of an automated battery for the assessment of cognitive processes involved in reading, called **BEDA** (acronym for the Spanish name *Batería de Evaluación de Dislexia en Adultos*) (Díaz, Jiménez, Mejia, & Fabregat, 2013; Mejia, Díaz, Jiménez, & Fabregat, 2011, 2012). BEDA consists of eight modules: six for the assessment of each cognitive process involved (i.e., phonological processing, orthographic processing, working memory, lexical access, processing speed, and semantic processing), one for the analysis of results, and one for administration purposes. BEDA was created in collaboration with the Research Group on Learning Disabilities, Psycholinguistics and New Technologies (DEA&NT) at the University of La Laguna (Spain). Futhermore, it also contributes with a dataset collected during four months from 119 students who completed BEDA.
5. The fifth contribution is the integration of a **voice recognition system** into an automated battery such as BEDA. This integration consist of capturing students' spoken answers, detecting their reaction times, and validating their answers with a set of correct answers to support some BEDA's tasks that require the use of the voice to complete them (Mejia, Díaz, et al., 2011; Mejia, Díaz, Jiménez, et al., 2012). Besides the integration involves the adoption of a dictionary, grammar and a corpus trained with Spanish-language voices. Futhermore, it also contributes with a dataset of 10500 words collected during the development of the BEDA's case study in order to improve the corpus of the voice recognition system.
6. The sixth contribution is the definition of the **BEDA's items**. BEDA includes 15 assessment tasks; each task consists of set of items or exercises that assess the differente cognitive processes. Each item has an associated stimulus to complete it (e.g., a word, a sound, a question, etc.). There are example items and assessment items. In total 308 items were defined (35 of example and 273 of assessment). These

items were created in collaboration with the Research Group on Learning Disabilities, Psycholinguistics and New Technologies (DEA&NT) at the University of La Laguna (Spain).

7. The seventh contribution is the definition of a dashboard of learning analytics of dyslexia and/or reading difficulties in adults, called **PADA** (acronym for the Spanish name *Panel de Analíticas de Aprendizaje de Dislexia en Adultos*) (Mejia, Bull, Vatrapu, Florian, & Fabregat, 2012; Mejia, Díaz, Florian, & Fabregat, 2012; Mejia, Florian, Vatrapu, Bull, & Fabregat, 2013). PADA is a tool designed to help with the understanding and inspecting of the learner model, promote awareness and facilitate reflection on reading difficulties. This tool was created in collaboration with the Computational Social Science Laboratory (CSSL) at the Copenhagen Business School (Demark), the Open Learner Modelling Research Group at the University of Birmingham (UK), and the Department of Education at the University of La Palmas de Gran Canaria (Spain).
8. The eighth contribution is the **extension to Outcome-based Learner-models** of the technical framework of Activity-based Learner-models proposed by (Florian, Glahn, Drachsler, Specht, & Fabregat, 2011). Thereby, the monitoring and assessment can be either activity centered and outcome centered. Furthermore, new roles are considered in an independent software tool such as PADA (Mejia, Florian, et al., 2013).
9. The ninth contribution is a repository for storing and delivering of specialized recommendations for adults with cognitive deficits, called **RADA** (acronym for the Spanish name *Recomendador de Actividades para la Dislexia en Adultos*) (Mejia, Díaz, Florian, et al., 2012). A total of 36 recommendations were designed to support the 6 cognitive processes assessed. These recomendations were created in collaboration with the Research Group on Learning Disabilities, Psycholinguistics and New Technologies (DEA&NT) at the University of La Laguna (Spain) and the Department of Education at the University of Las Palmas de Gran Canaria (Spain).
10. The tenth contribution is the definition of a block of Moodle to integrate the Framework for Detection, Assessment and Assistance of University Students with Dyslexia and/or Reading Difficulties with Moodle (Mejia & Fabregat, 2012). This block is called **PIADA** (acronym for the Spanish name *Plataforma de Intervención y Asistencia de Dislexia en Adultos*). PIADA allows visualizing and use the framework's software toolkit with Moodle. This block was created in collaboration with researchers and undergraduated students from University of Cordoba (Colombia).

1.6 Outline of the Thesis

This document is organized into 8 chapters, including this one, and additionally the appendixes at the end.

1.6.1 Chapter 2: Theoretical Foundations

This chapter presents a review of concepts related to LMS and AHS, including learner modeling and adaptation concepts. Moreover given the inclusive approach of this dissertation, topics related to achieve an e-Learning for All such as LD and dyslexia are studied and presented. In this dissertation, the research was focused on university students with dyslexia, symptoms, compensatory strategies, cognitive processes, and assistance. The chapter continues with the studies about tools to detect reading difficulties and learning styles, and tools to assess the cognitive process involved in reading in order to determine cognitive deficits. Later, assistance strategies that can be used with these affected students for personalization and improvement of their learning are studied. Finally, a summary is presented.

1.6.2 Chapter 3: Thesis Proposal: Framework for Detection, Assessment and Assistance of University Students with Dyslexia and/or Reading Difficulties

This chapter presents the thesis proposal of this dissertation, namely *Framework for Detection, Assessment and Assistance of University Students with Dyslexia and/or Reading Difficulties*. Firstly the framework architecture was defined, on the basis of the studies in previous section. Then, considering the characteristics of the affected students, a learner model and a set of tools to collect data from the learner model are defined. Furthermore, the definition of adaptive components that allows assistance to these students as well as a set of tools to provide the adaptation effects are presented in this chapter. Later, the integration of the framework with a LMS is defined. Finally, a summary is presented.

1.6.3 Chapter 4: Detection of University Students with Reading Difficulties

This chapter presents, firstly, the design and development of a software tool, called **detectLD**, devoted to the delivery and review of self-report questionnaires. Then, it presents three parallel ways in which the detection of university students with reading difficulties could be made. One way is the detection of the students'demographics using forms. The second way is the detection of *reading profile* using **ADDA**. The other way is the detection of *learning styles* using **ADEA**. This chapter is also dedicated to present the findings of a case study to test the functionality and the usability of detectLD, and to check the comprehensibility of ADDA. In addition, two cases studies are conducted to evaluate the usefulness of ADDA and ADEA. Finally, a summary is presented.

1.6.4 Chapter 5: Assessment of University Students with Reading Difficulties

This chapter presents the definition of an automated battery for the assessment of cognitive processes, called **BEDA**, which is proposed to capture cognitive deficits in university students with reading difficulties. BEDA has been built based on a multimodal communication mechanism that delivers evaluation tasks using the visual, auditory, and speech communication channels of human-computer interaction. The chapter also includes some case studies to test the functionality and usability of BEDA, as well as to recover the score scales defining when a student presented or not a cognitive deficit and to analize and debug the BEDA's items used to assess each of the cognitive processes. Finally, a summary are presented.

1.6.5 Chapter 6: Assistance of University Students with Reading Difficulties

This chapter presents, firsly, the definition of a dashboard of learning analytics of dyslexia and/or reading difficulties in adults, called **PADA**, which is proposed to facilitate the creation of descriptive visualizations required for a better understanding of university students with reading difficulties about their learner model. Then, this chapter dedicates to present the findings of a case study to evaluate the usefulness of PADA. The chapter also presents the definition of a repository of specialized recommendatios for adults with cognitive deficits, called **RADA**, which is proposed to support the self-regulation of university students with reading difficulties during their learning process. Finally, a summary are presented.

1.6.6 Chapter 7: Integration of the Framework with a Learning Management System

This chapter presents the integration of the *Framework for Detection, Assessment and Assistance of University Students with Dyslexia and/or Reading Difficulties* (proposed in Chapter 3) with a LMS. The exemplary LMS used was *Moodle*. To carry out this integration, firstly, a cluster of software tools was defined in what is called *Framework's Software Toolkit*. Then, a block of Moodle, through which it is accessed, displayed and used the information of the framework was designed and developed. Besides the development and implementation of web services required to achieve communication between the *Framework's Software Toolkit* and *Moodle* was performed. The result of the integration process is the detection, assessment and assistance to university students who may present dyslexia and/or reading difficulties using *Moodle*. The chapter also describes two case studies, with students and teachers, to validate the integration. Finally, a summary are presented.

1.6.7 Chapter 8: Conclusions and Future Work

This chapter presents conclusions and some ideas that may be worth exploring for future research. The chapter also presents the author' publications and scientific collaboration. Finally, the projects where this dissertation has contributed are described.

1.6.8 Appendices

There are four appendices: *Appendix A* presents the first version of the self-report questionnaire for detection of reading difficulties in adults –ADDA–, *Appendix B* presents the second version of this self-report questionnaire, *Appendix C* presents the Spanish translation of the Felder-Silverman's Index of Learning Styles (ILS) (Felder & Silverman, 2002), *Appendix D* presents the BEDA's items used in the different assessment tasks, and *Appendix E* presents the BEDA's items after debugging performed in Chapter 5.

CHAPTER 2

THEORETICAL FOUNDATIONS

This chapter starts with a review of concepts related to Learning Management Systems (LMS) (Section 2.2) and Adaptive Hypermedia Systems (AHS) (Section 2.3). Moreover, learner modeling and adaptation concepts (related to the field of AHS) are presented in Section 2.3, so as to apply these concepts to an LMS and ensure that these systems are able to provide an adequate adaptive and personalizing learning. The chapter continues with the concept of Open Learner Model (OLM) (Section 2.4), considering that opening the learner model to the students has been a successful learning strategy to promote awareness-raising, reflection on learning, and self-regulation or ability to make decisions about the learning process. Then, it presents the concept of Learning Analytics (LA) (Section 2.5) as the techniques to opening the learner model. Moreover given the inclusive approach of this dissertation, in this chapter are studied concepts of e-Learning for All and Inclusion (Section 2.6) focusing on the definition of Learning Disabilities (LD) (Section 2.7). LD classification and the influence of educational psychology on them are presented also in Section 2.7, as well as some projects related with LMS implementation that support affected students with LD. Then, an overview of dyslexia (Section 2.8), the targeted learning disability worked in this dissertation; author focus on university students with dyslexia, symptoms, compensatory strategies, cognitive processes, and assistance. The chapter continues with Section 2.9 presenting studies about tools to detect dyslexia symptoms and learning styles, and tools to assess the cognitive process involved in reading in order to determine cognitive deficits. Later, in Section 2.9 assistance strategies that can be used with these affected students for personalization and improvement of their learning are studied. Finally, a summary is presented (Section 2.10).

2.1 Introduction

Comparing with the traditional face-to-face style teaching and learning, e-Learning is indeed a revolutionary way to provide education in life long term. Nowadays more and more people have benefited from various e-learning systems. However, high diversity of the students on the Internet poses new challenges to the traditional "one-size-fit-all" learning model, in which a single set of learning activities or resources is provided to all students. In fact, the students could have different characteristics; even share some, they may have different levels of expertise, and hence they can not be treated in a uniform way. It is of great importance to provide a personalized system which can automatically adapt to the characteristics and levels of students.

In this sense, adaptive and personalized technologies have demonstrated some capabilities and successes in the field of ***e-Learning*** (Alfonseca, Carro, Martín, Ortigosa, & Paredes, 2006; Brusilovsky & Millán, 2007; Fontenla et al., 2009; Hsiao, Sosnovsky, & Brusilovsky, 2010; O. C. Santos et al., 2011; Zhang, Almeroth, Knight, Bulger, & Mayer, 2007). For instance, while, ***Learning Management Systems (LMS)*** are systems that manage students and learning resources (like images, animations, videos, etc.), providing tools to develop learning activities of a course as collaboration tools, monitoring of students, evaluation systems, etc., ***Adaptive Hypermedia Systems (AHS)*** are systems that are able to provide students with adaptive and personalized experiences based on processing information from a "learner model" (Bra & Stash, 2002; Brusilovsky & Millán, 2007; Graf, 2007; Hsiao, 2012; Peña, 2004). This model describes the student characteristics and it is used to "adapt" different aspects of a system to the student. Thus, the combination of these two technologies, i.e., implementing adaptation processes within an LMS considering concepts proposed by the AHS can be used to personalize and enhance the students' learning process. Typically, the implementation of these processes takes into account: on the one hand, characteristics of students such as knowledge, preferences, learning styles, previous knowledge, skills, beliefs, misconceptions, among other students' characteristics, and on the other hand, the application of e-learning standards, the implementation of accessibility and usability guidelines, and the considerations of the access context (i.e., technology, mobility, etc.), among other technical issues. However, in recent years, there has been a particular concern among researchers and practitioners with the inclusion of impaired students or students with special needs, such as physical or psychological disabilities, aging, learning disabilities, and cultural deficiencies, so as to achieve a "Learning for All" (Gregg, 2007; Judge & Floyd, 2011; Petrie, King, & Hamilton, 2004).

According with the European Commission (EC), the Life-long learning program (LLL) and the United Nations (UN), establishing action plans that contribute to "Learning for All" and ensure equal opportunities for impaired people or people with special needs is necessary. For this reason, the author of this dissertation is interested on contributing to the development of ***e-Learning for All*** (Bjork, Ottosson, & Thorsteinsdottir, 2008; Donnelly & Mcsweeney, 2008; Moreno, 2008), considering in e-learning the inclusion of students with special needs related to cognitive issues and low academic progress and achievements as ***Learning Disabilities (LD)***.

General speaking, LD are disorders presented by students related mainly to the acquisition and use of listening, speaking, reading, writing, reasoning or mathematical abilities. LD may affect people throughout their entire lives. For this reason, affected people with LD can be categorized in: i) children with LD, ii) adolescents with LD and iii) adults with LD. Moreover, LD has been also classified with regards to the abilities that are affected. Many different theories provide the basis for LD classification (Molina, Sinués, Deaño, Puyuelo, & Bruna, 1998; Padget, 1998; Wong, Butler, Ficzere, & Kuperis, 1996). In this research work, a classification for LD in 4 types has been considered, namely: 1) Dyslexia or difficulties with reading skills and reading comprehension, 2) Dysorthographia or difficulties with spelling, 3) Dysgraphia or difficulties with written expression, and 4) Dyscalculia or difficulties with calculations and mathematical reasoning.

Thereby, considering the LD of students during the process of learning and providing adaptive and personalized experiences to these students have been seem as research challenge (National Academy of Engineering, 2012) that needs researchers' attention so as to achieve the development of a personalized "Learning for All".

Thus, this research work is focused on university students with dyslexia, a population that has been studied very little (Gregg, 2007; Jiménez, Gregg, & Díaz, 2004; Sparks & Lovett, 2010).

2.2 Learning Management Systems (LMS)

An LMS – also referred to as virtual learning environment, online learning environments, course manament system or e-learning platform – is an hypermedia system that automates the management processes of teaching and learning (i.e., an educational software system). A LMS can be basically used to: create structured lessons, publish tests and/or surveys, and share educational multimedia resources and documents, among other things to support the teaching/instruction process; as well as to enable educational resources, tools and services that can support the learning process. Moreover, some LMS may include: competences management, planning sessions, certification controls, accessibility characteristics, e-learning standards, metadata description, etc. Currently, there are many commercial LMS, such as: Blackboard[1], WBTmanager[2], Intralearn[3], Fronter[4] Desire2Learn[5], and SumTotal[6]. However, in recent years there has been an increasing attention and construction of these systems under the open source phylosophy. Some open source LMS are: dotLRN[7], ATutor[8], Moodle[9] Claroline[10], OLAT[11], and Sakai[12]. A feasible and atractive alternative adopted by many researchers have been the open source alternatives of these systems since they are considered ideal and flexible options for applying research initiatives in the field of education. These LMS have been also considered as targets to apply the proposal made in this research work. This approach will be further described in Chapter 7.

Although all LMS have similar functionalities, a real difference between them for research rely on the characteristic of being flexibles to incorporate new features that allow achieving adaptivity and personalization of the work environment considering individual aspects of students (Graf, 2007). Moreover, the work presented in Vélez (2009) and Vilches (2007) presents a comparison between LMS in order to identify those who offer suitable features to achieve adaptivity and personalization. These studies found that basically a LMS must meet the following criteria: 1. be able in multiple languages, 2. be deployed in multiple operating systems, 3. be integrated to heterogenous educational

1 http://www.blackboard.com/
2 http://www.wbtmanager.com/
3 http://www.intralearn.com/
4 http://com.fronter.info/
5 http://www.desire2learn.com/
6 http://www.sumtotalsystems.com/
7 http://www.dotlrn.org/index.html
8 http://atutor.ca/
9 https://moodle.org/
10 http://www.claroline.net/
11 http://www.olat.org/
12 http://www.sakaiproject.org/

contexts, 4. be actively maintained and supported by at least two permanent developers, 5. be supported by an active community of people, 6. present and have available basic learning tools, 7. present and have available basic documentation. Thus, from that comparison only five LMS met these criteria, namely: ATutor, Claroline, dotLRN, Moodle and OLAT. Besides, all these systems provide basic learning functionalities such as educational communicative, productive, partcipative tools among others, as well as management supportive functionalities such as administrative, course delivery, content development tools.

However, considering relevant aspects to this research work such as personalization, adaptivity and accessibility, in those studies was concluded that only Moodle, dotLRN and ATutor are the most capable LMS to support these aspects. Below, a brief description of these three LMS is presented:

- **dotLRN**. Also known as .LRN, was initially developed by MIT. dotLRN is currently supported by a global consortium of educational institutions, nonprofit organizations, companies and open source developers. dotLRN is appropiated for learning and research communities, since it has course management, online communities, content management and learning management capabilities. Consortium member institutions work together to support the progress of each member and to accelerate and expand the adoption and development of dotLRN. The consortium ensures software quality certifying components through software development plans coordinated and maintaining ties with OpenACS[13].
- **ATutor**. It was first released in late 2002. It came in response to two studies conducted by the developer in the years prior that looked at the accessibility of e-learning systems to people with disabilities. Results of the studies showed none of the popular LMS at the time even provided minimal conformance with accessibility guidelines. It is supported by IDRC (Inclusive Design Research Centre)[14] from the University of Toronto, and has a community of developers who make constant updates and enhancements on the LMS. ATutor is the first LMS to comply completely with the accessibility specifications of W3C WCAG 1.0 at the AA+ level. ATutor is also cited in numerous technical reviews and scholarly articles; and many third-party extensions have been developed and distributed for use with the software.
- **Moodle**. Moodle is a software package for producing Internet-based courses. Moodle is an acronym that stands for Modular Object-Oriented Dynamic Learning Environment. Moodle has been developed as an open source educational application with a free software license and is mostly useful to programmers and instructors. It has been designed to support an educational framework based on the social constructivist philosophy. Moreover, this LMS maintain educational contents centralized in a database and provides these contents to students through a web-oriented interface. Moodle can be installed on any web server with a PHP interpreter and it has a complete support for the use of the MySQL and PostgreSQL database managers. Adittionally, it has a broad

[13] http://openacs.org/
[14] http://idrc.ocad.ca/

development community, which ensures the quality of software by certifying developed components.

However, it is worth noting that Moodle is a LMS with great pedagogical and technological flexibility and usability, and with the support of a large community of users around the world. Besides, it is currently the LMS used at the University of Girona.

Next section presents the concepts of Adaptive Hypermedia Systems (AHS) including learner modeling and adaptation concepts, so as to apply these concepts to an LMS and ensure that these systems are able to provide an adequate adaptive and personalizing learning.

2.3 Adaptive Hypermedia Systems (AHS)

An hypermedia system is an educational software system that is based on providing hypermedia content, which can be accessed interactively navigating through them. An adaptive hypermedia system (AHS) can be defined as "*hypermedia systems which reflect some features of the user in the user model and apply this model to adapt various visible aspects of the system to the user. In other words, the system should satisfy three criteria: it should be a hypertext or hypermedia system, it should have a user model, and it should be able to adapt the hypermedia using this model (i.e. the same system can look different to the users with different models)*" (Brusilovsky, 1996).

Taking into account these criteria, a SHA in the educational context is formed by three elements, namely: an *hypermedia system*, a *learner model* (i.e. user model) and an *adaptive component*. Figure 2-1 depicts these elements.

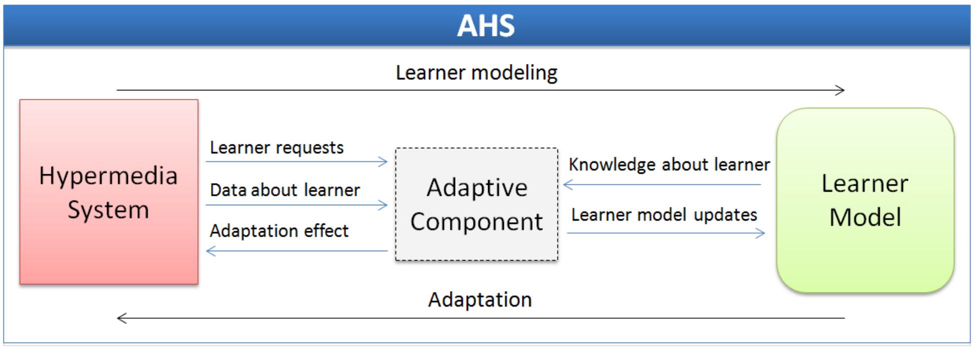


Figure 2-1. Simple scheme of an Adaptive Hypermedia System (AHS). Adapted from Brusilovsky (1996)

- The *hypermedia system:* which gathers a collection of learner data, whether supplied to the system or inferred by itself from learner's interaction, as well as provides the functionalities and visible aspects that can be adapted.
- The *learner model:* which is generated from the available data in the collection of learner data provided by the *hypermedia system* and that describes the current status of a learner in relation with a set of defined learner's characteristics.
- The *adaptive component:* which is able to adapt the functionalities or visible aspects of the *hypermedia system* by processing the *learner model*. The adaptation process is carried out by an adaptation/decision engine (adaptive component), which: i) receives the information of the learner (i.e. *learner requests*, *data about learner*,

knowledge about learner), ii) automatically processes this information, and iii) responses with adaptation results/decisions (i.e. *adaptation effect*) and *learner model updates*.

According with Brusilovsky (1996), the critical feature of an AHS is the possibility of providing hypermedia *adaptation* on the basis of an *learner modeling*. That is, the fundamental idea of an AHS is the need to know the specifics of who uses the system and thus be able to offer what he/she needs (e.g., support, hints, activities, materials, etc.) according to his/her characteristics in a specific domain or domains. This involves: determining which features are defined and taken into account in the model, how these characteristics are represented, how the learner model is updated, and what adaptations shall be applied according to the model and domain(s) in which the learner is(are) working.

Some related work (Baldiris, 2012; Brusilovsky & Millán, 2007; Carmona et al., 2007; Florian, 2013; Laroussi, 2001; Peña, 2004; Virvou & Tsiriga, 2001) remarks that learner model is the element that needs more attention in a SHA, since it is responsible for storing the data that represents the learner of the system and that will be used to provide the learner with appropiated adaptative and personalizing aspects of the system.

2.3.1 Learner modeling process

A learner model is responsible for storing the student information. Basically, this model represents knowledge, interests, preferences, goals, background, and individual traits of the students during their learning process, allowing for personalized learning and adaptation towards their current needs (Brusilovsky & Millán, 2007; De Bra, 1999).

According to Brusilovsky and Millán (2007), the learner modeling process defines and maintains up-to-date learner models. Different categorizations exist for learner models. For example, Brusilovsky and Millán (2007) define two types, *feature-based* models and *stereotype-based* models. The feature-based models attempt to model specific features of individual learners such as knowledge, interests goals, etc., and consider changable learners features. The stereotype-based learner models attempt to cluster all possible learners of an adaptive system into several groups, called stereotypes. It is worth noting that S. Bull, Brna, La, and Pain (1995) suggested that the model should contain information about domain knowledge (including errors and misconceptions), and also other learning issues, for example analogy, learning strategies and the promotion of awareness and student reflection. In Cook and Kay (1994), authors proposed the division of the model into two parts: *public* and *private*, so that students could choose what information they prefer private and what they prefer to share. Then, in S. Bull and Nghiem (2002), authors proposed that the model could be *inspectable* by the students, i.e., they may view the contents of their models to help them to better understand their learning. In addition, S. Bull (2004) also proposed that the model could be *co-operative*, i.e., modeling tasks are shared between student and system, *editable*, i.e., students may modify the contents of their learner models according with their beliefs, and *negotiable*, i.e., students and system discuss the model contents and come to an agreed representation. According to Rueda, Arruarte, and Elorriaga (2007), learner models could be classified in r*aw data models*, *visual models* and *decision support models*. A raw data model is a direct view of the internal data representation, a visual model converts the internal representation to a graphical conceptualization, and a decision support model can be defined as a visual representation that allows the learner to make pedagogical decisions in the learning process.

On the other hand, a review of the literature shows that currently being modeled learner general information such as demographics, competences, knowledge, interest, goals, and background (Baldiris, 2012; Florian, 2013; Laroussi, 2001; Mejia et al., 2008; Peña, Mejia, Gómez, & Fabregat, 2008; Peña, 2004; Virvou & Tsiriga, 2001). Additionally, there are some studies that model the cognitive styles (Graf, 2007; Lin & Kinshuk, 2005), learning styles (Baldiris, 2012; Carmona et al., 2007; Graf, 2007; Mejia, 2009; Ortigosa, Paredes, & Rodriguez, 2010; Peña, 2004), emotion and affective states (Baldiris et al., 2011; Conati & Maclaren, 2005; Mancera et al., 2011; Picard, 1997), personality (F. García, Amandi, Schiaffinoa, & Campoa, 2006), metacognitive skills (Conati, Larkin, & VanLehn, 1997), and attitudes and perceptions (Arroyo & Woolf, 2005), as well as some work in progress about motivation, responsibility, and perseverance. While, other studies are focusing on physical and cognitive disabilities as visual and hearing impairment (Gelvez et al., 2011), attention deficit hyperactivity disorder (Baldiris et al., 2011; Mancera et al., 2011), and learning disabilities (Mejia, Fabregat, & Marzo, 2010), as well as cultural diversity as multiliguism (Bacca, Baldiris, Fabregat, & Avila, 2013; Bacca, Baldiris, Fabregat, Guevara, & Calderon, 2012).

2.3.2 Adaptation process

The concept of adaptation has been an important issue of research in the hypermedia systems area (De Bra, 1999; Oppermann, Rashev, & Kinshuk, 1997). The research has shown that the application of adaptation process can provide better learning environments and consequently students can reach a better performance (Baldiris, 2012; Gaudioso, 2002; Gómez, 2013; Kavcic, 2001; Mejia, 2009; Peña, 2004; Vélez, 2009).

According to Oppermann et al. (1997) , two kinds of systems have been developed for supporting the learners' adaptation: *adaptable* and *adaptive* (see Figure 2-2). Adaptable systems allow the learner to change certain system parameters (i.e., parameters that can be modified on explicit user request) and adapt their behavior accordingly to this changes. While adaptive systems adapt to the learners automatically, based on the assumptions they make about learner needs (i.e., knowledge, interest, competences, etc.).

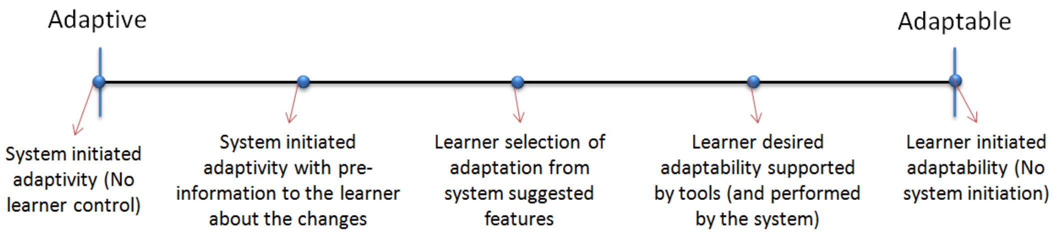


Figure 2-2. Spectrum of adaptation proposed by Oppermann et al. (1997)

According to De Bra (1999) in an adaptable system the learner can provide a profile (through a dialog or questionnaire). This profile may include certain presentation preferences (e.g., colors, media type, learning style, etc.) and learner background (qualifications, knowledge, etc). While an adaptive system monitor the learner behavior and adapt the presentation accordingly. The evolution of the learner preferences and knowledge may be deduced (partly) from page accesses. Sometimes the system may need questionnaires or tests to get more accurate information of the learners.

Thus, an *adaptive* adaptation process requires: learner characteristisc (knowledge, goals, cognitive style, learning style, motivation, preferences, etc.), learner modeling techniques (feature-based, stereotype-based, etc.), tasks to be performed (nature, priority, level, etc.), teaching strategies, and other relevant information (nature, purpose, etc.). In addition, this process also requires the definition of adaptation methods and techniques (Brusilovsky, 1996). On the one hand, techniques refer to methods of providing adaptation in an AHS. These techniques are a part of the implementation level of an AHS. Each technique can be characterized by a specific kind of knowledge representation and by a specific adaptation algorithm. On the other hand, methods are defined as generalizations of existing adaptation techniques. Each method is based on a clear adaptation idea which can be presented at the conceptual level. For example, "...insert the comparison of the current concept with another concept if this other concept is already known to the learner", or "...hide the links to the concepts which are not yet ready to be learned". The same conceptual method can be implemented by different techniques. At the same time, some techniques are used to implement several methods using the same knowledge representation.

Numerous studies have been carried out to implement adaptation processes in different application domains. For example, in E. Brown, Stewart, and Brailsford (2006), Mejia, Baldiris, Gómez, and Fabregat (2009), and Wolf (2002), authors describe adaptation processes based on learning contents. Fullick, Bajraktarevic, and Hall (1993), Paredes and Rodriguez(2004), and Yudelson and Brusilovsky (2008) describe adaptation processes based on navigation. Marcos, Martínez-Monés, Dimitriadis, and Anguita (2006) describe an adaptation process based on the identification of the students' roles. (Alfonseca et al., 2006; Baldiris, Fabregat, Mejia, & Gómez, 2009; Olguin, Delgado, & Ricarte, 2000; Paredes & Rodriguez, 2006) adapt tools and collaborative activities. Florian, Baldiris, and Fabregat (2010) and Marcos, Martinez, Dimitriadis, and Anguita (2006) propose an adaptation process based on the assessment of students. E. Brown et al., (2006), Marcos, Martínez-Monés, et al. (2006), and Wolf (2002) describe adaptations to the graphical interfaces level. Finally, even thought the literature shows several studies (implemented, proposed or in progress), it is highlighted the works of Arteaga, Fabregat, Eyzaguirre, and Mérida (2004), Blanco-Fernandez (2005), Duval (2011), O. C. Santos et al (2011), and Schafer, Konstan, and Riedl (1999) who propose adapting recommendations.

Finally, it is also highlighted that there exist a prominent research tend in TeL to focus in the integration of AHS aspects with LMS, so as to apply studied adaptation concepts of the field of AHS to an LMS and ensure that these systems are able to provide an adequate adaptive and personalizing learning (see Figure 2-3). Some examples of related research work done on these aspects can be found in Arteaga et al. (2004), Arteaga, Fabregat, and Mérida, (2006), Baldiris(2012), Bra and Stash (2002),and Graf (2007), Huerva, Vélez, Baldiris, Fabregat, and Mérida (2008); Mejia (2009), Vélez (2009), and Wolf (2002).

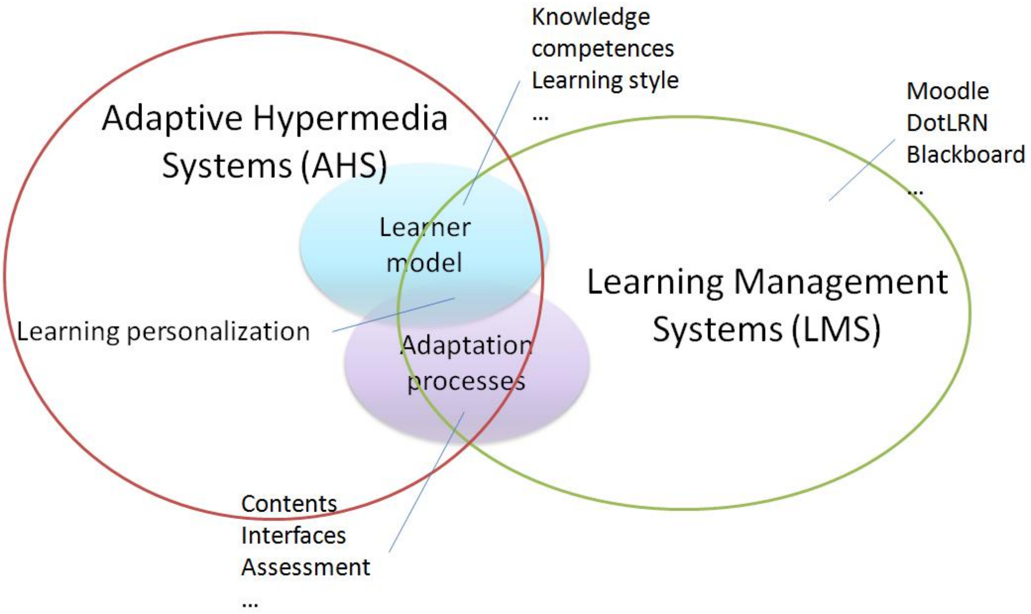


Figure 2-3. Schema representing the integration of a AHS in a LMS

Next chapter presents the concept of Open Learner Model (OLM), considering that opening the learner model to the students has been a successful learning strategy to promote awareness-raising, reflection on learning, and self-regulation or ability to make decisions about the learning process.

2.4 Open Learner Model (OLM)

An OLM is a learner model that is accessible to the student. Traditionally the information in the learner model is closed to the students. However, benefits of opening the learner model to students to encourage awareness, reflection and even self-regulation of their learning have been argued (S. Bull & Kay, 2008, 2010; Hsiao et al., 2010; Mitrovic & Martin, 2007). Furthermore, achieving an accurate learner model with the help of students has also been argued (S. Bull & Kay, 2010).

Basically, if a student views the learner model, information is provided about his/her knowledge, interests, preferences, goals, background, and individual traits; such information has been recovered during the learner modeling process. A review of the literature shows that an OLM allows access to the learner model content in a variety of forms (S. Bull & Kay, 2010). The most common of which are skill meters, textual descriptors and tables for each topic or concept to be accessed (Corbett & Bhatnagar, 1997; Mitrovic & Martin, 2007; Papanikolaou, Grigoriadou, Kornilakis, & Magoulas, 2003), to more complex structured representations of understanding such as hierarchical trees (Mabbott & Bull, 2006); Bayesian networks (Zapata-Rivera & Greer, 2004); and concept maps (Mabbott & Bull, 2006; Perez-Marin, Alfonseca, Rodriguez, & Pascual-Neito, 2007). Others include simulation (Morales, Pain, & Conlon, 2000); animations (Johan & Bull, 2010); and Fuzzy Models (Mohanarajah, Kemp, & Kemp, 2005). Recent work has also used treemaps to visualize the learner model (Bakalov, Hsiao, Brusilovsky, & Koenig-Ries, 2011; S. Bull et al., 2012; Kump, Seifert, Beham, Lindstaedt, & Ley, 2012).

Currently, an emerging area for the visualization of the learner model have been explored: Learning Analytics (LA) (Campbell & Oblinger, 2007; Ferguson, 2012; Siemens et al., 2011; Vatrapu, Reimann, & Hussain, 2012; Vatrapu, Teplovs, Fujita, & Bull, 2011; Verbert et al., 2011). Its primary goal is closely tied to, a series of other fields of study including business intelligence, web analytics, academic analytics, educational data mining, and action analytics (Elias, 2011). In recent years, however, there has been particular concern among researchers with using the LA to improve teaching and learning. Next section gives a brief description of concept and actual contribution of this emerging area.

2.5 Learning Analytics (LA)

The LA was defined in the 1st International Conference on Learning Analytics & Knowledge (LAK2011)[15] as "*the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs*". Thereby, particularly works in this area are based on the aggregation and analysis of students' data collections in their social contexts, for understanding and optimizing their learning process.

LA seeks to select, capture, aggregate, report, predict, use, refine, and share data during the learning processes for teachers and students (Elias, 2011). The aim of LA is to provide useful support for understanding and decision making during learning and teaching. Thus, LA focus on the detection of key-activity and key-performance indicators which can be based on statistical and data mining techniques, so that for instance recommendations can be made for learning activities, resources, training, people, etc. that are likely to be relevant. Alternatively, the data can be processed so that they can be further extended to support other educational roles in decision-making, as remarked in Donald Norris, Leonard, Pugliese, and Lefrere (2008), Vatrapu et al. (2011), Verbert et al. (2011), and Zhang et al. (2007).

Thus, OLM and LA are two areas tightly related to learner model visualization. Open learner modeling is more centered on personalization and learning contexts while learning analytics do more emphasis on semantic aggregation, statistical analyses, and results towards prediction and recommendation.

Further sections expose the theoretical foundations of e-Learning for All and Inclusion, since this dissertation considers the inclusion of university students with Learning Disabilities (LD) in an e-learning process.

2.6 e-Learning for All and Inclusion

The main focus on LMS has so far been on technical issues for ordinary students (i.e., with skills and competences according with their ages and academic level). Other student groups with totally different needs and abilities have so far not been much focused on by LMS developers apparently caused by low knowledge about for example special needs or impairments of some kind, elderly people's life conditions and their needs of Internet and related technologies. Figure 2-4 shows a pyramid to describe the different types of students who can access a LMS (Benktzon, 1993). At the end of the pyramid appear the

[15] https://tekri.athabascau.ca/analytics/

ordinary learners who are individuals with good physical and mental ability. Then appear the learners with special needs who are individuals with some kind of difficulties but who have no recognized physical or mental impairment. For example, learning disabilities (e.g., dyslexia), attention deficit disorder, or elderly people with minor disabilities such as reduced strength, impaired hearing, etc. At the top of the pyramid appear the impaired (or disabled) learners who require assistive devices due to severe mobility problems and reduced body functions. For example, deafness, blindness, mobility-impaired, cerebral palsy, etc.

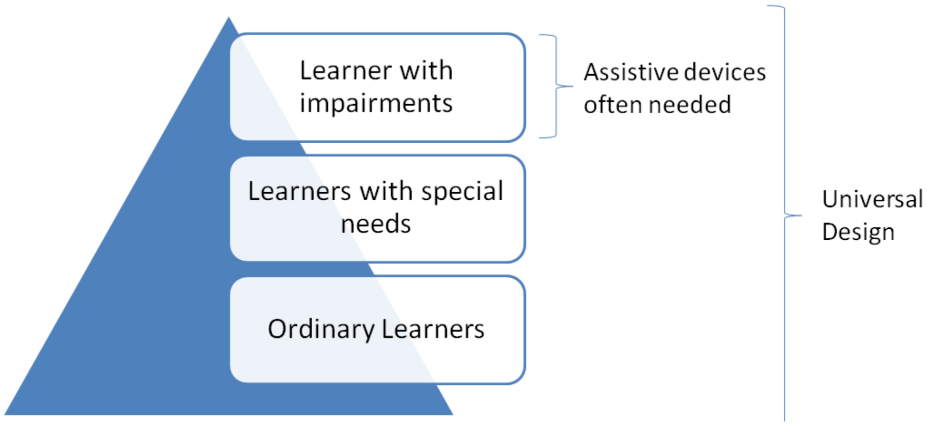


Figure 2-4. The students pyramid considered to achieve a universal design. Extracted from Benktzon (1993)

A universal design as well as quality assurance to create contents, lessons, resources, learning activities, or tests to assure long lasting knowledge achievements by the student taking part in e-learning are additional areas in need of more development and research. Thus, today, a need of LMS accessible for all students in the society is growing (Gutierrez et al., 2009; IMS, 2003; Judge & Floyd, 2011; Paciello, 2000; Petrie et al., 2004; WAI, 2008; Zhang et al., 2007). Research has started in the field of "e-Learning for All" and the interest for people in need is intensively discussed among researchers (Bjork et al., 2008; Donnelly & Mcsweeney, 2008; Moreno, 2008).

The *e-Learning for All* is the term that is associated with the fact of the inclusion of these students in need to e-learning. Basically, e-Learning for All means ensuring that all students, not just the most privileged (see Figure 2-4), acquire the knowledge and skills supported by the use an educational software system (such as a LMS). Thus, individual differences must be accommodated and catered for, by ensuring the maximum range and variety of learning opportunities. Embracing "e-Learning for All" philosophy can benefit students of all ages and abilities thus widening participation, access and inclusion.

The idea of *inclusion* is the modification of the educational system to respond to the needs of all students. In terms of curriculum, methodologies, teaching strategies, guidance, etc. In this context, the European Commission (EC) has promoted projects such as IRIS[16], TATE[17], BenToWeb[18], MICOLE[19], SEN-IST-NET[20], ALPE[21], EU4ALL[22], ALTER-

[16] www.irisproject.eu
[17] http://www.tateproject.org.uk/
[18] http://www.bentoweb.org/home
[19] http://micole.cs.uta.fi/

NATIVA[23], and ALTERNATIVE-eACCESS with the purpose to aim both education and labor inclusion and promote the independence of people in need, creating training activities, web portals, methodologies, accessibility guidelines and assistive technologies.

In different Communities and Territories of the Spanish State some regulations have been deployed to realize different practical aspects of inclusion in educational contexts. In the context of Catalonia it can be cited the *Action Plan of Inclusive Education* (2008/2015)[24] (in Spanish *Plan de Acción de la Educación Inclusiva*) that among other elements it focused on actions related to specific material and financial resources, support systems, training expertise and personal resources, implementation of coordination between services. Other example, can be found in the Universitat de Girona with the *Program to Support People with Disabilities*[25], which is responsible for supporting students with disabilities and manage seminars to promote awareness in instructors.

However, in this frame in which, progressively new regulations and social discourses has been developed and implemented to support "inclusive practices", there is still the challenge to put in practice day to day these principles within the educational institutions. In this sense, education supported by technology and more specifically in LMS could be of relevant help to facilitate the road towards a real "inclusion".

As mentioned before, among people with special needs there is a group of interest of this research work that is, those who present Learning Disabilities (LD). Thus, next section describes the LD definition, their classification and the influence of educational psychology on them, as well as some projects related with LMS implementation that support affected students with LD.

2.7 Learning Disabilities (LD)

Within the group of learners with special needs (see Figure 2-4) there are included the students with LD (Barca & Porto, 1998). That is, students who develop problems in language comprehension and difficult use of the language, which may be manifested in the inadequate capacity of think, listen, speak, read, write, and even in mathematical calculation abilities.

Although students with LD appear normal at first glance, without any apparent psychological or physical disability, they cannot achieve the general learning objectives proposed in the curriculum they are following (McLaughlin et al., 2006; Santiuste & González-Pérez, 2005). Generally the LD may exist when there is a discrepancy between the intelligence quotient (IQ) and the academic performance of a student, without such student presenting sensory, physical, motor problems or educational deficiencies.

The study of LD focuses on identifying the conditions that affect the student's personal development and justify the provision of certain aids or special services, such as

[20] http://saci.org.br/?modulo=akemi&parametro=16078
[21] http://www.bentoweb.org/home
[22] http://www.eu4all-project.eu/
[23] http://titanic.udg.edu:8000/www_alternativa/
[24] http://www.gencat.cat/index_eng.htm
[25] http://www.udg.edu/discapacitats

adaptations to the tools they can use for certain process such as adaptations to access, assistance, intervention, and learning.

Here, it is worth noting that two terms are used along this study, namely: *Disability* and D*ifficulty*. *Disability* is usually used to refer to the diagnosis (e.g., dyslexia, dysgraphia, dyscalculia, so on), whereas *Difficulty* is used to refer to the symptoms that occur in students when they present some disability (e.g., a student diagnosed with dyslexia may present the need to read at a slow pace, poor written fluency, so on).

2.7.1 LD definition

Different definitions of LD have been made by some organizations such as the United States Office of Education (USOE), the Learning Disabilities Association of America (LDA), and the National Joint Committee on Learning Disabilities (NJCLD) (Hallahan & Mercer, 2000). However, the more accepted definition by a majority and addressed in this work is the one from NJCLD that remarks that: *"LD refers to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning, or mathematical abilities. These disorders are intrinsic to the individual, presumed to be due to central nervous system dysfunction, and may occur across the life span. Problems of self-regulatory behaviors, social perception, and social interaction may exist with LD but do not by themselves constitute a learning disability. Although LD may occur concomitantly with other handicapping conditions (e.g., sensory impairment, mental retardation, serious emotional disturbance) or with extrinsic influences (e.g., cultural differences, insufficient or inappropriate instruction), they are not the result of those conditions or influences"* (National Joint Committee on Learning Disabilities, 1991).

Nevertheless, the definitions reviewed do not concern about cognitive deficits presented in people with LD. In the past decades, research in the field of LD has focused on the study of cognitive deficits and intervention strategies for detected deficits so as to help students in the learning process. It has been shown that improper operation of cognitive processes interferes in both school and social life of the student (Jiménez, 1999). Moreover, this research focus have implied a challenge in the study of training strategies for cognitive and metacognitive processes that support the student in the learning process, and thus, verify the positive influence of these strategies on the academic performance (Jiménez, 1999; Rojas, 2008).

Students who have LD present common characteristics that can be identified so as to explore specific cognitive deficits and thereafter, provide training support to overcome them. These characteristics describe a heterogeneous population and have been identified mainly in children.

Table 2-1 summarizes some of the most common characteristics of students with LD, identified from related work (Burke & Ryan, 2004; Cousins & Duhl, 1983).

Table 2-1. Summary of common characteristics in people with LD

- They find it difficult to fix goals, prioritize and finish works.
- They find it difficult to organize time; usually, they need more time to finish tasks.
- They find it difficult to concentrate.
- They find it difficult to express themselves.
- They find it difficult to memorize subjects.
- They find it difficult to remember instructions or follow procedures.
- They find it difficult to participate in working groups.
- They find it difficult to process information quickly.
- They find it difficult to capture social signals and keep attention.
- They have rapid changes in mood, apparent immaturity, and lack sensitivity.
- They demand a lot of attention from others.
- They have low self-esteem.
- They have poor academic performance.

2.7.2 LD classification

Currently, there are two systems of classification for disabilities, defined by the World Health Organization (WHO)[26] and the American Psychological Association (APA)[27] respectively. Both systems have their advantages and disadvantages, and their use is associated with different geographic areas: in Europe it is tended to use the classification by WHO, while in the U.S. and Latin America prevails using the classification by APA (Grande, 2009).

The WHO's International Classification of Diseases (Kramer, Sartorius, Jablensky, & Gulbinat, 1979; Sartorius et al., 1993), proposed the 10th revision of the International Classification of Diseases (ICD-10) which is based on a statistical classification of diseases, signs and symptoms, abnormal findings, complaints, social circumstances, and external causes of injury or diseases. In ICD-10 (particularly, in the classification of mental and behavioural disorders: clinical descriptions and diagnostic guidelines) the LD are known as "Specific developmental disorders of scholastic skills" and are classified as follows (World Health Organization, 1993):

- Specific reading disorder.
- Specific spelling disorder.
- Specific disorder of arithmetical skills.
- Mixed disorder of scholastic skills.
- Other developmental disorders of scholastic skills.
- Developmental disorder of scholastic skills, unspecified.

On the other hand, the APA proposed: Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR) (American Psychiatric Association, 2000). In the DSM-IV-TR LD are known as "Learning disorders" and are classfified as follows:

- Reading disorder.
- Mathematics disorder.
- Disorder of written expression.
- Learning disorder, unspecified.

[26] http://www.who.int/en/
[27] http://www.apa.org/

Classificiation made by the WHO and the APA differ in their conception. On the one hand, ICD-10 by WHO is based on the consequences of the disease and its impact on the individual's life, as well as it is more descriptive, while DSM-IV-TR by APA is organized by criteria and it is more based on empirical observation.

Taking into account the ICD-10 and DSM-IV-TR classification systems as well as a literature review conducted for the LD classification (Molina et al., 1998; Padget, 1998; Wong et al., 1996), it was concluded that they have very similar approaches. Thus, four classification of LD are considered:

- *Dyslexia*: refers to specific reading disorders (i.e., difficulties with basic reading skills and reading comprehension).
- *Dysorthographia*: refers to specific spelling disorders (i.e., difficulties with poor performace in spelling).
- *Dysgraphia*: refers to specific disorders of written expression (i.e., difficulties with written expression).
- *Dyscalculia*: refers to specific calculation disorders (i.e., difficulties with calculations and mathematical reasoning).

2.7.3 Influence of educational psychology

The field of psychology has been very influential in the investigation of LD, and in the teaching-learning process in general, providing theories that include new assessment methods and mechanisms for the classification of students so teachers can differentiate students with special needs, and advice about how to generate motivation strategies, improve cognitive abilities, and generate mechanisms for the detection and treatment of LD (Santiuste & González-Pérez, 2005).

Assuming that the *educational psychology* is the area that studies the behavior and performance of people in a learning process, basically defined as a discipline dedicated to the diagnosis, treatment and prevention of LD (Passano, 2000), the analysis of how the educational psychology influences LD is considered in this research work. Some general activities identified from the educational psychology area in which this research is focusing are:

- Selection of students that need support.
- Re-education of students with symptoms of learning failure.
- Diagnosis of LD and the generation of methods and strategies their treatment.
- Rehabilitation of the educational system through their guidance and advice.
- Development of adaptation programs.
- Study of the influence of family, school, environment and psychic structure.

Commonly, based on these activities, an educational psychologist makes a plan indicating all the important information that arises from diagnosis, such as defining the nature and severity of LD, the specific characteristics identifying areas of strength and deficits, the instructional level of the material to be used, the learning and compensatory strategies developed by the students, the attitudes and grade of personal or social adaptation, and others individual needs of the student.

2.7.4 Computer mediated assistance in the teaching-learning process

Different *Assistive Technologies (AT)* are available to support people with different types of special needs such as LD. AT for students with LD are any device, hardware or software, that help avoid, resolve or compensate LD such as dyslexia, dysorthography, dysgraphia, and dyscalculia. The AT do not cure or eliminate these LD but can help students to empower their skills in the learning process. Some identified examples of AT and research projects that use AT to support the types of LD consideren in this research work (i.e., *Dyslexia*, *Dysorthographia*, *Dysgraphia, and Dyscalculia*) are:

- For *dyslexia* there are tools that help to facilitate decoding, reading fluency and comprehension. Some examples are audio books, optical character recognition (OCR), speech synthesizers/screen readers, and videogames. In Rojas (2008) a multimedia interactive 3D videogame for the treatment of dyslexia help to support reading and improve the cognitive processes involved in these students.
- For *dysgraphia/dysorthography* there are tools that help students circumvent the physical task of writing, while others facilitate proper spelling, punctuation, grammar, word usage, and organization. Some examples are abbreviation expanders, alternative keyboards, talking spell checkers, and proofreading programs. In Jones (1994) and Lancaster, Schumaker, and Deshler (2002) is explained that computer-assisted practice reinforces the interest, motivation and safety of students with LD in writing and spelling because they feel more control over their activities. In MacArthur (1999) and Van and Van (1992) some useful applications (software and hardware) for students with LD in writing are presented.
- For *dyscalculia* there are tools that are designed to help people who struggle with computing, organizing, aligning, and copying math problems down on paper. With the help of visual and/or audio support, students can better set up and calculate basic math problems. Some examples are electronic math worksheets, paper-based computer pen, and talking calculators. In Goldman and Hasselbring (1997) and Hasselbring, Going, and Bransford (1988) some automated math programs for students with LD are presented.

In addition, other studies have shown the usefulness of computer-mediated assistance in the teaching-learning processes and tend to increase the motivation of students affected with some LD, personalize their learning process, and improve their learning performace (Ayres, 2002; Barker & Torgesen, 1995; Brünken, Steinbacher, Plass, & Leutner, 2002; Hetzroni & Shrieber, 2004; Macaruso & Walker, 2008; Mayer, Fennell, Farmer, & Campbell, 2004; Rojas, 2008; Taylor et al., 2004; Timoneda, Pérez, Hernández, Baus, & Mayoral, 2005; Wise, Ring, & Olson, 2000).

2.7.5 LMS and LD

Some research studies have confirmed that there are policies that aims to a more inclusive higher education, which promote equality of opportunities (Luna, 2009; Vickerman & Blundell, 2010). Accordingly, some higher educational institutions have implemented strategies to encourage and support the participation of students with disabilities (e.g. dyslexia, dyscalculia, etc.), particularly, there has been an increased focus on studying and implementing strategies for ensuring universal access to the LMS (Hampton & Gosden, 2004).

Currently, some LMS presents characteristics that support students with disabilities. For example, Blackboard, ATutor, and LearnWise include accessibility policies, and may provide accessibility recommendations to its users (Phipps et al., 2002). dotLRN has priority in assisting people with disabilities implementing accessibility mechanisms[28]. LearnWise includes adaptive interfaces and text-to-speech applications (Phipps et al., 2002). Finally IntraLearn offers some specialized tools to support students with specific types of difficulties[29]. Moreover, some research projects that propose the building or extension of an LMS have been focused in incorporating features and functionalities related to LD, namely:

- EU4ALL (European Unified Approach for Accessible Lifelong Learning)[30]. Project intended for university students. It is oriented towards accessible lifelong learning combining three key strategies: using the technology to adapts to diversity, providing support services to student with disabilities, and incorporating accessibility mechanisms to provide services for all. To get this strategies propose the implementation of an open service architecture based on e-learning standards. This Project is developed over dotLRN LMS.
- HADA (tool that supports the treatment of LD in the classroom) (Malet & Mainer, 2010). Project intended for teachers with the aim of helping guiding students with LD. It consists of a collaborative learning platform and a digital library. This project was organized on the Moodle LMS and supports content management, tutorial monitoring, and performance management.
- ABA (Association for Behavior Analysis)[31]. Project intended for teachers to provide education based on the analysis of behavior. Its objectives are to know the principles of an effective methodology in treating LD, to provide theorical and practical knowledge aimed at intervention of LD, and to know and acquire the skills to apply technology in teaching language and social behavior of children with different disorders.
- DysLextest (Development of the elearning system for dyslexia rectification and automatic effectiveness assessment of its utilization)[32]. Project intended for dyslexic children and adults, and teachers. Its aim is to create a web portal containing an LMS where dyslexics can access a series of exercises and tests designed and recommended by specialist therapists. It also provides quality information for the instructors and affected individuals.
- SICOLE (acronym for the Spanish name *Sistema basado en el Conocimiento para la Evaluación de las Dificultades Lectoras en Lengua Española*) (C. S. González, Estevez, Muñoz, Moreno, & Alayon, 2004a). Project intended for dyslexic children. It has a student model built from the profile (variables about the preferences and permanent attributes such as cognitive and chronological age, vision, hearing and laterality) and logs (variables related to the interaction with the system). In

[28] http://dotlrn.org/product/accessibility/
[29] http://www.intralearn.com/
[30] http://www.eu4all-project.eu/
[31] http://www.aba-elearning.com/
[32] http://www.indracompany.com/sostenibilidad-e-innovacion/proyectos-innovacion/

SICOLE the adaptation of the tasks' presentation allows dynamically activities to be adjusted according to the student's learning style.

- Aprender (web for students with LD) (F. García, 2003). Project intended for students, teachers and general public. It proposes the design of accessible resources for all, activities related with the student autonomy and general aspects that can facilitate future learning. Resources are adapted to each teaching unit and have different levels of curricular competence of the student.
- AHS-RW (Adaptive Hypermedia System for Reading and Writing learning) (Ortega, Gea, & Gutiérrez, 2002). It takes into account goals and preferences of students. Define three domains: knowledge, activities and users to implement the adaptations in order to provide appropriately user interfaces, activities, and methods of reading and writing to students.
- COSE (Creation of Study Environments) (Stiles, 2000). It supports students with disabilities (including dyslexics). It supports accessibility characteristics and e-learning specifications.
- AVANTI (Stephanidis et al., 1998). Project intended for general public. It supports individual needs of users through user modeling, content adaptation and individual presentation of web pages. This project considers elderly people and people with SEN (like dyslexia and dysgraphia).

Table 2-2 summarizes some aspects considered in the projects presented above: the type of person to who is intended the project (Actors), LD type targeted (Dyslexia, Dysgraphia, Dysorthography, Dyscalculia), whether the system present or not storage and delivery of educational digital resources led to student with LD, whether the system uses or implements assessment and assistance mechanisms for affected students, and finally whether the system is designed for a course core curriculum with learning purposes (Course-target) or can be used in a LMS as a general tool to support or orient difficulties (General-tool).

Table 2-2. LMS research projects that consider LD

System	Actors			LD				Resources		Assessment		Assistance		System design	
	Student	Teacher	Others	Dysl.	Dysg.	Dysor.	Dysc.	Yes	No	Yes	No	Yes	No	Courses-target	General-tool
EU4ALL	x			x				x			x	x		x	
HADA		x		x	x	x	x		x		x		x		x
ABA		x		x	x	x	x		x		x		x		x
DysLextest	x	x		x				x			x		x		x
SICOLE	x			x				x		x			x		x
Aprender	x	x	x	x	x	x	x	x			x		x		x
AHS-RW	x			x	x	x		x			x	x			x
COSE	x			x	x			x			x	x		x	
AVANTI			x	x	x	x		x			x	x		x	

Here, it is important to note that, none of the systems in Table 2-2 integrate both assessment and assistance of students with learning disabilities, although several of them offer specific learning resources to support these affected students through a LMS in the learning process.

This dissertation focuses on definition of a framework for assessment and assistance of university students who may have dyslexia. This framework is designed taking as conceptual basis the aforementioned systems and it is proposed to be integrated into a LMS. Moreover, the framework is addressed to students, teachers and psychological experts, it let delivering learning resources and technological assistance, and it can be used for learning purposes (Course-target) or as a support tool for students with difficulties. This is further explained in chapters 3, 4, 5, 6 and 7.

Dyslexia was selected because it is the most common LD in education. Moreover, in recent years, there has been a particular concern among researchers and practitioners about reviewing their teaching practices to improve the processes involved in reading and learning and how to assess, intervene and assist affected students during their learning process.

2.8 Dyslexia

Reading is considered the basis of the educational process since most of the knowledge transmitted during academic development relies on the written language. That is why, from the very first years of schooling, learning to read correctly is considered a basic tool for academic development. Furthermore, when we refer to reading as the basis of the educational process, we mean not only in terms of academia but also the importance it has in a general sense. The way it accesses most of the information in the environment is also connected with written language because it is immersed in the so-called information society, where activities (including productive, economic, educational, and cultural ones) are regulated through communication and information. And learning to read correctly is essential for the development of the individual in this society. When students have difficulty acquiring this skill, their academic performance and general personal development are affected. These consequences make it necessary to study the specific reading and writing disabilities also known as dyslexia.

2.8.1 Dyslexia definition

Reviewing some history about dyslexia, and based on the work of Artigas (1999); the first description of a disorder equivalent to dyslexia was made in 1877, the year in which Kussmaul (1877) published the case of a patient who had lost his reading ability despite of preserving his visual sense, intelligence and language. He defined this disorder with the name of *verbal blindness*. Shortly afterwards, Morgan (1896) reported the medical history of a boy of 14, who despite being smart, he had an almost total inability to cope with written language. One of his teachers said, that if this kid had been educated exclusively by oral means, had been one of the brightest students of the school. Since this patient had not acquired any injury, Morgan dignosed him with congenital *verbal blindness*.

Later, Hinshelwood (1900), a surgeon from Glasgow, was interested in the children who could not learn to read. This enabled him to publish the first series of such patients in Lancet. He later published a book about this disability, after having identified new patients. Thus, he could observe that some individuals remained totally incapacitated for reading, despite multiple efforts. Others managed to improve and acquire certain reading skills, but with limitations. For the latter, he proposed the term *congenital dyslexia*, whereas the *verbal blindness* designation should be reserved for severe cases with no chance of improvement.

Thereafter, *dyslexia* has been under constant debate with no end seems to have been reached yet. *Dyslexia* has received so far in this century various definitions. Orton (1928) proposed the name *strephosymbolia* in 1928. The same author in 1937 changed this name to *developmental alexia*. Hallgren (1950) renamed to *constitutional dyslexia*. It was not until 1975 that the World Federation of Neurology first used the term *developmental dyslexia*. The definition provided at that time was: *"A disorder manifested by difficulty in learning to read despite conventional education, adequate intelligence and sociocultural opportunities. It depends primarily of cognitive impairments whose origin often is constitutional."* (Critchley, 1970).

Other definitions for dyslexia have been identified, such as:

- Harris and Hodges (1981) postulated that *dyslexia* is a "medical term for *incomplete alexia*, inability to read, parcial but severe; historically (but less common in its current use). Dyslexia is a rare but definable and diagnosable primary delay in reading with some form of central nervous system dysfunction. It is not attributable to environmental causes or other disabling conditions. "
- Thomson (1992) defines it as "a serious difficulty with the written form of language, that is, independent of any intellectual, cultural and emotional cause. In Dyslexia, individual acquisitions in the area of reading, writing and spelling are well below of the expected level regarding the intelligence and chronological age. It is a cognitive problem that affects language skills associated with the written form, particularly the passage of the written form, particularly by the visual coding step to verbal, short-term memory, perception and sequencing."
- Later in 2002, the DSM-IV-TR of the APA (American Psychiatric Association, 2000), defined it as a discrepancy between learning potential and the performance level of a subject, with no sensory, physical, motor problems or educational deficiencies. Accordingly, the definition provided for *dyslexia* is: "a reading performance (accuracy, speed or comprehension) which lies substantially below the level expected on the basis of the chronological age, IQ and schooling age of the individual".
- In Spain, Román (2008) after conducting an updated concept of dyslexia and rename it as *developmental dyslexia* define it as "an specific and permanent disability to acquire, effectively, the reading skills that allow the subject achieving normally mediated learning by the written support".
- However, the most accepted definition of the term dyslexia was proposed by (Lyon et al., 2003): "*Dyslexia is a specific learning disability that is neurobiological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that often is unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge*".

According to these definitions and particularly in (Lyon et al., 2003), dyslexia is not the result of a single deficit. It would be determined by many factors where each factor gives rise to different types of symptoms. In other words, dyslexia is a LD that may pose a number of difficulties (symptoms) in the various processes involved in reading.

In addition, it is well known that reading and writing skills are closely related; poor readers are also less successful in writing tasks than their peers (Berninger, Nielsen, Abbott, Wijsman, & Raskind, 2008; Berninger, Winn, et al., 2008; Hatcher et al., 2002). Moreover, in accordance with common practice, dyslexia entails not only reading difficulties. It is commonly associated to disorders of writing skills (Høien & Lundberg, 2000; Lindgrén, 2012). In other words, student achievement is determined not only by their reading skills, but also by their performance on tasks that require a written answer.

2.8.2 Dyslexia characteristics

As mentioned before, dyslexia is closely related to other learning disabilities, such as difficulties in writing, namely *dysgraphia* (i.e. difficulties in correctly delineating of letters, in the parallelism of lines, in the size of the letters, in the pressure of writing). Moreover, in later phases of dyslexia also spelling difficulties can be revealed, namely *dysorthography* (i.e. difficulties in the correct use of spelling rules). These characteristics describe common difficulties related to dyslexia. In Table 2-3 some of the characteristics of dyslexia are detailed and in Table 2-4 and Table 2-5 the difficulties presented in writing and spelling related to dyslexia (Baumel, 2008; Davis, 1992a; J. N. García, 1995; Gills, 2007; Grande, 2009; Moore, 2008). Moreover, the guidelines established by the WHO, the APA, the NJCLD, the National Reading Panel (NRP)[33], and the Learning and skills improvement service (LSIS)[34], as well as recent reviews of the characteristics of dyslexia reported by different authors (Beatty & Davis, 2007; Jiménez & Artiles, 2007; Sally E. Shaywitz et al., 2008; Snowling, 2000) support the identified characteristics reported in related literature.

Table 2-3. Summary of common characteristics in people with dyslexia

- They omit and/or confuse letters/phonemes/ syllables/words when reading.
- They have difficulties in recognizing and understanding letters/phonemes/syllables/ words.
- They have to read slowly to avoid confusion.
- They have difficulties with the decoding abilities.
- They find it difficult to read aloud.
- They mispronounce or use the wrong words.
- They have difficulties with security and/or fluent word recognition.
- They find it difficult to acquire new vocabulary and background knowledge.
- They find it difficult to find the right word.
- They have difficulties extracting the main idea of a text in a first reading.
- They have reduced reading experience.
- They find it difficult to concentrate on reading.
- They usually need to go back to the text.

Table 2-4. Summary of common characteristics in people with dysgraphia

- They omit, confuse and/or invert letters/words/numbers when writing (e.g., in dictations).
- They find it difficult to write fluenty and accurately.
- They have difficulties with decoding abilities.
- They find it difficult to organize and finish writing works (e.g., essays)
- They find it difficult to distinguish between nouns, verbs, adjectives and adverbs when writing.
- The handwriting is illegible or difficult to read.
- They frequently mix lowercase and capital letters at random.

[33] http://www.nationalreadingpanel.org/
[34] http://www.excellencegateway.org.uk/page.aspx?o=framework4dyslexia

Table 2-5. Summary of common characteristics in people with dysorthography

• They have difficulties using punctuation. • They have poor spelling. • They need to constantly check their spelling. • They frequently unite and/or separate words improperly. • They mispronounce or use the wrong words.

The characteristics presented in the table above can be basically summarized in the following difficulties (symptoms):

- Difficulty in reading accuracy: accurate recognition of words is not achieved. Many omissions, distortions and replacement of words are presented. An affected individual confuse letters, numbers, words, sequences, or verbal explanations.
- Difficulty in words decofication: printed symbols are not identified. The application of graph-phonemic matching rules that allow reading words is not achieved. An affected individual has poor alphabetical knowledge and phonological recoding.
- Difficulty in reading speed: the silent and oral reading is slow, with many stoppages, repetitions, corrections and blockages.
- Difficulty with vocabulary acquisition: poor experience with printed language that impedes the development of language.
- Difficulty in reading comprehension: understanding of what is read is not achieved.
- Difficulty on reading concentration: an affected individual has problems to concentrate when reading or writing.
- Difficulty in writing accuracy: an affected individual has an inaccurate copying, with substitutions, omissions or reversal of words.
- Difficulty in writing production: converting ideas into words is difficult. It is related to the construction of grammatical structures that best express a message, to find the right words, to give a meaning, and with movements to represent words.
- Difficulty in getting a correct orthography: an affected individual has difficulty in using punctuation as well as the spelling is poor.

Furthermore, it is emphasized that dyslexic individuals tend to read in a very literal level because they have difficulties to quickly process the information, and many have not had experience with high levels of critical thinking skills such as analysis and synthesis. Some others have trouble summarizing and phrasing (Gills, 2007).

2.8.3 Associated difficulties

Apart from the relationship that dyslexia has with difficulties in writing and orthography, dyslexia is often also associated to other difficulties, for instance, difficulties with memory, attention, pronunciation, speech, mathematics, spatial organization, and automation (Baumel, 2008; Beacham, Szumko, & Alty, 2003; Beatty & Davis, 2007; Davis, 1992b; Gills, 2007; Jiménez & Artiles, 2007; Jiménez, 1999; Marken, 2009; Sally E. Shaywitz et al., 2008; Snowling, 2000; Vinegrad, 1994; Wesson, 2005). Next, a description with associated difficulties is presented:

- Difficulties with memory: problems with immediate memory can be presented. An affected individual may has problems to remember what she/he just read as well as to recognize previously learned words; bad memory for sequences and instructions can be presented, and to facts and information that has not experienced, difficulty to remember names, phone numbers and addresses.
- Difficulties with attention: it seems that daydream often; gets lost easily or loses sense of time. Difficulty to pay attention. She/he seems to be hyperactive or dreamer.
- Difficulties with pronunciation: difficulty when pronouncing words by means of reversing them or replacing parts of words. Affected individuals have a greater impact on the difficulty of pronunciation of new, long words or those containing combinations of letters that leads to reading difficulties.
- Difficulties in speech: difficulty putting thoughts into words. Normally, affected individuals speak in halting phrases; leave incomplete sentences, stutter when stressed; mispronounce long words, or transpose phrases, words and syllables when speaking. They have trouble giving their thoughts in an organized manner.
- Difficulties with mathematics: affected individuals depend on finger counting and other tricks for mathematics: know answers, but can not put the procedure on paper. Can count, but has difficulty counting objects and dealing with money. Can do arithmetic, but struggle written problems; struggle with algebra or advanced mathematics.
- Difficulties with spatial organization: affected individuals can be ambidextrous, and often confuses left / right, up / down. Struggle telling time, managing time, learning sequenced information or tasks, or being on time. Directional confusion is presented; they are easily lost and have trouble using maps or find their way to a new place. A poor sense of time, mixing dates and missing appointments.
- Difficulties with automation: difficulty to achieve automaticity when they have to do more than one thing at a time, such as listening and writing at the same time, taking notes, taking messages, and copy on the board. Problems with the mathematical procedures or sequences of numbers or letters and difficulty using dictionaries, encyclopedias and directories.

In addition, other external associated aspects are considered for the characterization of the difficulties of dyslexia such as medical and family history, school life, reading and writing habits as well as affective and motivational aspects that reveals when being affected with dyslexia (Decker, Vogler, & Defries, 1989; Giménez de la Peña, Buiza, Luque, & López, 2010; Goldberg, Higgins, Raskind, & Herman, 2003; González-Pienda et al., 2000; Lefly & Pennington, 2000; Stanovich, 1986; Westwood, 2004).

2.8.4 Prevalence in university students

Until recently, LD as dyslexia had been studied very little at the university level (Gregg, 2007; Jiménez et al., 2004; Sparks & Lovett, 2010). However, nowdays, there has been particular concern among researchers and practitioners with identifying the remaining difficulties shown by adults with dyslexia, and developing intervention programs to reduce their difficulties (Goswami, 2010; Guzmán et al., 2004; Luque et al., 2011; Metsala, 1999; Nicolson & Fawcett, 1990; Sally E. Shaywitz, 2005; Snowling, 2000). In addition, it is a topic of interest because of the high prevalence found in this population. According to the British Dyslexia Association, it is estimated that between 10% and 15% of the world population has some LD, and the percentage of dyslexic people is around 8% (Jameson, 2009). According to the European Dyslexia Association, the estimation of European citizens with dyslexia are between 4% and 10% (Kalmár, 2011). In Spain, the Dyslexia Association of Jaen has estimated a prevalence of dyslexia of between 5% and 15% among the general Spanish population, and between 6% and 8% among university students, although an exact percentage is unknown and it is believed that this percentage may increase in coming years (Bassi, 2010). Considering this population of university students with LD (10-15%) support services and resources should be increased in the university context. Moreover, 80% of college students with a LD claim that their academic performance is severely affected by their difficulties (Ingesson, 2007), which confirms the importance of considering services and resources for these students. Thus, services for these students must be increased, and resources that treat the specific deficiencies of the students must be created to improve their academic performance so that they can advance at the same pace as their peers. Moreover, these services and resources may motivate otherwise reluctant students to register in different university programs. Many of them do not register because of their LD, which makes them lose their self-esteem and feel intimidated and unable to continue beyond high school (Ingesson, 2007).

In Spain, the Organic Law of Education (LOE) (adopted in May 3, 2006) recognizes *dyslexia* as a Learning Disability independently from other special educational needs. The LOE states that: "... *corresponds to the education authorities ensure the necessary resources that students who need an educational different from the ordinary, due to specific learning disabilities, ..., can achieve the maximum development of their personal skills and, in any case, the objectives established general for all students.*" However, despite the undoubted breakthrough that this law led to students who have these conditions, the scope was limited to compulsory education levels (primary and secondary) and therefore be exempt from its application not mandatory in higher levels such as the university level.

Both the definition of dyslexia and empirical research on this issue make it clear that this disability is not specific to children but can persist into adulthood (Callens et al., 2012; Hatcher et al., 2002; Swanson & Hsieh, 2009). For instance, *dyslexia* definition proposed by (Lyon et al., 2003) (see Section 2.8.1), is characterized not by age but the presence of difficulties in the recognition of words mainly with a deficit in the phonological component of language (Ben-Dror, Pollatsek, & Scarpati, 1991; Bruck, 1990, 1992, 1993a; Jiménez & Hernández-valle, 2000). The recognition of words, and all cognitive processes related to it and associated with the presence of dyslexia are crucial in the acquisition and development of reading in children and adults. These cognitive processes will be explained in Section 2.8.6.

2.8.5 Compensatory strategies

Despite their difficulties and the still underperforming in reading-related tasks, many dyslexic students could develop compensatory strategies to help them succeed in their studies (Firth et al., 2008; Lefly & Pennington, 1991; Mellard et al., 2010; Niemi, 1998; Ransby & Swanson, 2003) and get into university (Callens et al., 2012; Hatcher et al., 2002). For instance, in Firth et al. (2008) a study on the coping strategies and strategy-based feedback used by students is presented. This study discuss some coping skills such as positive thinking, assertion, goal setting, and problem solving, as well as seeking support from teachers, so that they can provide them appropiate resources. Scanlon et al. (1998) found in some of their studies, the need to include learning styles, characteristics of students, effective tutoring strategies and lesson planning, materials/resources, and cultural differences; as well as include training sessions, tutor manual, private consultation, workshops, and self-study. Coffield, Moseley, Hall, & Ecclestone (2004) also describe the importance of including the learning styles in order to help students with LD to identify compensatory strategies they could use. They also provide an extensive list of leaning styles tools and theories. More specifically, Lefly and Pennington (1991) describe strategies to improve spelling. Mellard et al. (2010) describe strategies to improve reading comprehension. Mishoe (1994) found differences between the preferred learning styles for males and females which could be considered. On the other hand, Ransby & Swanson (2003) pose that students who know their particular difficulties since childhood can develop more compensatory strategies than those who do not know it until adulthood. He concluded that identified dyslexic students (i.e., diagnosed) can do better certain tasks than those who have not been identified.

Identifying compensatory strategies promotes the independence of level of LD (Hellendoorn & Ruijssenaars, 2000; Núñez et al., 2005a; Raskind, Goldberg, Higgins, & Herman, 1999; Sideridis, Mouzaki, Simos, & Protopapas, 2006). Students who are or become aware of their particular difficulties, and are creative to find alternative learning strategies to cope with them (i.e., focus on their learning preferences and / or learning styles), manage to take control of the challenges imposed by these difficulties (Goldberg et al., 2003; Raskind et al., 1999; Reiff, Gerber, & Ginsberg, 1994).

However, many students are at risk of passivity in the face of difficulty, which manifests as learned helplessness (Bender, 1987; Borkowski, J., Weyhing, R., & Carr, 1988; Núñez et al., 2005b; Sideridis et al., 2006), which leads students to avoid enrolling in university programs, or delays or fails obtaining undergraduate degrees by those who are enrolled.

2.8.6 Cognitive processes involved

The complexity of the reading activity, often goes unnoticed to the skilled reader. The skilled reader has a subjective impression of which to read, and understanding a word is an entirely automatic activity. In addition, the process of understanding a word, either auditory or visualy, is extremely fast and can give the impression that the process is simple and less complex. Moreover, he/she thinks that recognizing a word, is to establish a simple association between the results of sensory analysis of the stimulus and a lexical representation in the memory. However, psycholinguistic research has revealed that the nature of this connection can not be reduced to mere associative mechanisms but involves negligible complexity. Reading is an activity that involves operating with abstract segments or phonemes that make no sense, complicating this task and making it difficult and arduous. In turn, the reader must assign a syntactic value to words, to construct the meaning of sentences and phrases, must develop the overall meaning of the text, and even to make a series of inferences based on his/her own knowledge (De Vega, Carreiras, Gutiérrez, & Alonso, 1990). The immediate consequence of this complexity is that reading requires an explicit and systematic instruction. However, this statement does not guarantee success in all cases and, consequently, a large proportion of students do not get to acquire the appropriate expertise to use this skill as a tool for learning.

Consistent with the contributions of cognitive psychology in recent years, reading is conceptualized as a complex cognitive process, consisting of a multitude of operations that are not observable to the reader eye. They are made, as mentioned above, at high speed to be automated. When reading different cognitive processes at different levels are performed, ranging from visual perception of letters to obtain the overall meaning of the text.

De Vega et al., (1990) consider reading as a multiple activity in which "*our cognitive system identifies letters, performs a transforming letters into sounds, builds a phonological representation of the word, go to the multiple meanings to this word, select an appropriate meaning to the context, assign a syntactic value to each word, constructs the meaning of the phrase, integrates the meaning of the sentences to develop the overall meaning of the text, make inferences based on world knowledge, etc. (...). The entire reading process involves the construction of the overall meaning of the text.* "

Therefore, when attempting to address the processes involved in reading, there are many terms used: word recognition, lexical access, word identification, word perception, comprehension of words, etc. (Cuetos & Valle, 1988; Santiuste & González-Pérez, 2005), but certainly, the most common terms to refer to these processes are the first two: *word recognition* and *lexical access*.

When expert readers face with written words, firstly, a visual-orthographic analyzer collects, analyzes and identifies the physical features of the graphics stimuli. This information goes to a sensorial memory called "iconic memory" and then immediately goes to the "short-term memory," in which recognition operations of letters and visual patterns of words are conducted. This first stage is called *word recognition* (i.e. *phonological* and *orthographic processing*). Secondly, words are associated with the concepts they represent, which are stored in a "mental lexicon" in the long-term memory (phonological, orthographic and semantic inventory of all known words). The visual information is used to identify the word as belonging to the language, once it has been identified, the subject access to information associated with it, mainly to its meaning. This second stage is called *lexical access* (Forster, 1976; Marslen-Wilson, 1987; Swinney, 1979).

More specifically, *phonological processing* refers to the process that the reader performs prior to *word recognition*. To translate a word written in its phonological form prior to *lexical access*, there must be a set of rules that convert the grapheme(s) in its corresponding phonem(s). The complexity of these transformation rules depends on the language, particularly, on the direct or simple that an orthographic system represents its phonology (declared as orthographic transparency). However, despite the evidence for the role of this type of processing (Perfetti, C. A., Zhang, S., Berent, 1992), some related works have questioned that it represents a unique way of *lexical access* (Frederiksen & Kroll, 1976). In this sense, different models have been defined such as: the dual-route (Coltheart & Rastle, 1994), which proposes the existence of an indirect pathway mediated by phonology (*phonological processing*) and a direct route from orthography (*orthographic processing*). Research on the influence of *phonological* and *orthographic processing* in reading, have shown that in visual word recognition exists both phonological and orthographic encoding, acting independently and at different times (Grainger & Ferrand, 1996). Thus, there is a strong association between *phonological processing* and reading performance, with possible finding of deficits in people with dyslexia (Booth, Perfetti, MacWhinney, & Hunt, 2000). Moreover, given that *phonological processing* would be a pre-processing step prior to *orthographic processing* (Waters, Seindenberg, & Bruck, 1984) this type of processing could be similarly deficient presented in people with dyslexia.

Furthermore, there are other cognitive processes, which their deficits are associated to the presence of dyslexia, and therefore, they are equally relevant to the identification of dyslexia. These processes are: *processing speed*, *working memory* and *semantic processing*. Regarding the *processing speed* it has been stated that slowness in processing, influences, by means of a delay, letter identification, compromising the speed and activation of those letters and preventing to capture the patterns that occur in written language. Thus, some studies have shown that there is evidence that in dyslexia can be presented associated deficits in processing speed, i.e. in the processes that underlie rapid recognition and retrieval of visually-presented linguistic stimuli (Fawcett & Nicolson, 1994; Näslund & Schneider, 1991; Van den Bos, 1998; Heinz Wimmer, 1993; Yap & Van der Leij, 1993). Regarding, the *working memory* can be defined as an ability to maintain and manipulate necessary information in the short term to generate actions close in time, for this reason it has been considered an important variable in learning to read (R. Bull & Scerif, 2001). Several studies have found deficits in verbal *working memory* in children with dyslexia (Felton, R.H., Wood, F.B., Brown, L.S., Campbell, S.K., Harter, 1987; Siegel & Heaven, 1986; Siegel & Ryan, 1989). Regarding *semantic processing* consists in extracting the meaning of sentences and integrates it into memory. Integration in memory is important as long as the process of understanding does not end until new information is added to one which the reader already possesses (Schank, 1982). Some authors suggest that poor readers have difficulty in processing phonological information and this in turn affects other processing modules such as the semantic (Bar-Shalom, Crain, & Shankweiler, 1993; Smith, S.D., Macaruso, P., W.J., Shankweiler, D., Crain, 1989).

Table 2-6 summarizes the description of each aforemenditoned cognitive processes involved in reading, which may be altered in people with dyslexia.

Table 2-6. Summary of cognitive processes involved in reading

Cognitive process	Description
Phonological processing	This process refers to the ability to separate the units into which speech can be divided: the phonemes or sounds that make up the words. This is a major deficit in dyslexia and is characterized by difficulty in acquiring, consolidating, and automating sounds of the words (Jiménez, 1997).
Orthographic processing	This process involves recognizing the word as an orthographic pattern and retrieving its pronunciation from memory (via the visual route). Although research in this process has received less attention than phonological processing (Díaz, 2007), it is important to note that people with dyslexia present a deficit in orthographic processing (Farmer & Klein, 1995), probably due to a deficit in phonological processing (Bruck, 1993a; Share & Stanovich, 1995).
Lexical access	This is the process involved in obtaining the meaning of written words. This can occur over two routes (Coltheart & Rastle, 1994): one that directly connects graphic signs with meaning (visual route) and another that transforms the graphic signs into their corresponding sounds and uses those sounds to access the meaning (phonological route). This process is essential for proper reading performance and its impairment is considered a major deficit in dyslexia (Jiménez & Hernández-valle, 2000).
Processing speed	This process refers to the speed in which stimuli are processed. Slowness in naming familiar visual stimuli may be related to dyslexia (Fawcett & Nicolson, 1994; H. Wimmer, Mayringer, & Landerl, 2000). When a person reads a series of processes

Cognitive process	Description
	similar to those carried out in tasks measuring processing speed (attention to the stimulus, visual processes, access and retrieval of phonological labels, activation and integration of semantic information, etc.) are required.
Working memory	This is the ability to temporarily retain information in memory, work with it or operate on it, and produce a result. Working memory is important in reading because readers have to decode and recognize words as they remember the meaning of what they have read. It has been suggested that the underlying deficit in dyslexia is in working memory and that that can be attributed to difficulties accessing or using phonological structures (Bar-Shalom et al., 1993).
Semantic processing	This process refers to understanding and interpreting written information. This processing involves the extraction of meaning from text and the integration of information in memory. This process involves readers' background knowledge about what they are reading (a text), which will facilitate a mental representation of the entities evoked by the text (Fayol, 1995).

All these processes are essential for reading comprehension to be successful, and not all students perform them properly, and as a consequence, there are individual differences and hence, learning difficulties that may have a different origin (i.e. different cognitive processes that can be affected) in each case.

2.8.7 Assistance through technology

As mentioned before, dyslexia is a common LD in university students and requires a special attention by experts (e.g., educational psychologists) and teachers in order to provide suitable learning materials (e.g., activities, resources, feedback, etc.) and training activities (e.g., exersices, games, etc.) that support and benefit assistance during the learning process. Thereby, there is notable challenge with regards to using technology that support students with dyslexia, and thus, facilitate the learning process and assistance of affected students by supporting materials and activities that are not necessarily provided during school hours due to busy learning schedule to be followed.

In the past years, several studies that involve technologies have been applied to children: detecting population of children with dyslexia, assessing their cognitive processes to determine specific deficits and creating assistance programs to improve their learning efficiency to read and write (Guzmán et al., 2004; Luque et al., 2011; Nicolson & Fawcett, 1990). However, as mentioned before, research in LD has shown that the dyslexia problem can persist into adulthood. Thus, a new challenge is the use of technologies with adults.

Furthermore, other studies have shown that detection, assessment and assistance supported by technologies (i.e., using web-based software) tend to increase affected students' motivation and personalize their learning process (Barker & Torgesen, 1995; Rojas, 2008; Wise et al., 2000). Technologies also help these students progress in skills development and enhance their learning performance (Rojas, 2008; Taylor et al., 2004). Additionally, the benefits of using assistive technology (e.g. speech recognition systems, screen readers, and talking spell checkers) are considered in compensatory strategies for these affected students (Hetzroni & Shrieber, 2004; MacArthur, 1999). Finally, technology encourages a new challenge: to promote student reflection on their learning (skills, difficulties, preferences, misconceptions, etc.) (S. Bull, Mcevoy, & Reid, 2003; Collins & Brown, 1988; White, Shimoda, & Hall, 1999). However, this challenge has not been undertaken in university students with dyslexia and/or reading difficulties (Goldberg et al., 2003; Raskind et al., 1999).

Further sections expose the methods and tools that enable the detection of difficulties related to reading and compensatory strategies, as well as the assessment of cognitive processes and assistance of university students with dyslexia and/or affected with some reading difficulties.

2.9 Detection, Assessment and Assistance to Dyslexia

In Spain research studies about LD, and particularly dyslexia, have focused mainly on primary school and few on secondary school (Bassi, 2010; Giménez de la Peña et al., 2010; D. González et al., 2010). Little work has been done at the university level (Gregg, 2007; Jiménez et al., 2004; Sparks & Lovett, 2010). This lack of studies on university level may reveal that the intervention initiated in primary or secondary school does not continue into university. That is, there is no advice or support given after secondary school, and older dyslexic students have to cope with their reading difficulties on their own, affecting the development of professional skills. Moreover, if the student's difficulties have not been identified in primary or secondary school, they are not likely to be detected later on. As a result, students might fail, or even drop out (Ingesson, 2007), because they lose their self-esteem, feel intimidated, and are unable to continue beyond secondary school. Thereby, there is a research challenge to determine the compensatory strategies that university students may develop and the cognitive processes that they have altered, so as to provide them with personalized assistance.

Thus, it is necessary to study methods and tools that enable the detection of difficulties related to reading and compensatory strategies, as well as the assessment of cognitive processes and assistance of university students with dyslexia and/or affected with some reading difficulties.

2.9.1 Detection of difficulties related to reading

As mentioned in Section 2.8.5, despite their difficulties, many dyslexic students (diagnosed or not) could develop compensatory strategies to help them succeed in their studies, and get into university. Furthermore, in Spain, university students are not questioned about their LD when they enter into university. Accordingly, there are a growing number of dyslexic students in higher education that may not have been detected when they started their studies at university. As a consequence, higher education institutions are in clear need of specific resources to detect students with or without a previous diagnosis of dyslexia that still show reading difficulties (i.e., particular reading difficulties or dyslexia symptoms), and identify which reading skills this population lacks in order to provide advice and support to them. Accordingly, research has indicated that self-report questionnaires could be a suitable tool to achieve these two goals.

Self-report questionnaires have aroused interest because they have been proven to be valid and reliable tools for recalling information about personal history and current difficulties (Gilger, Geary, & Eisele, 1991; Gilger, 1992; Lefly & Pennington, 2000). Although it could be argued that the answers might be too subjective, the individuals that describe themselves as having reading difficulties tend also to obtain lower scores on specific tests. The high correlations found in many studies have shown that adults with a history of reading difficulties could provide a precise description of their limited abilities. For example, in an early study about young children's risk of developing dyslexia, Decker, Vogler, and Defries (1989) found that parents who reported having had problems in learning to read obtained lower scores on reading tests. Gilger (1992) compared the antecedents of 1118 children and adults collected by questionnaire and interview with the results of several tests. Despite some individual differences, a high correlation was found between self-evaluated reading skills and the scores obtained with the tests. In another study designed to explore self-report questionnaires' suitability for estimating dyslexia in adults, after evaluating 79 adults, Schulte-Körne, Deimel, and Remschmidt (1997) found 88% coincidence between psychometric measures and the self-report evaluation. Similar results were obtained by Remschmidt, Hennighausen, Schulte-Körne, Deimel, and Warnke (1999). Also, Lefly and Pennington (2000) found that the participants' answers to the questionnaire correlated significantly with their performance on reading tasks. These results were interpreted as proof that self-report questionnaires are reliable tools, although their predictions should be validated by a thorough exploration of the participants' abilities. Likewise, Wolff and Lundberg (2003), in a study aimed at designing a battery for screening adults with dyslexia, found that the self-report questionnaire discriminated between normal and poor readers as efficiently as orthography or spoonerism tasks. They concluded that the dyslexics' awareness of their own difficulties makes them reliable respondents.

Furthermore, self-report questionnaires have been successfully used with other tools as criteria for selecting the participants of several studies of reading development and difficulties (Birch & Chase, 2004; Fink, 1998; Hatcher et al., 2002; Lyytinen et al., 2006; Natale et al., 2008; Pennala et al., 2010; Pereira-Laird, Deane, & Bunnell, 1999; Ramus et al., 2003; R. Reid, Bruce, Allstaff, & McLernon, 2006; Snowling, Adams, Bowyer-Crane, & Tobin, 2000; Torppa, Lyytinen, Erskine, Eklund, & Lyytinen, 2010).

The findings of these studies provide evidence in support of self-reports as highly predictive tools that can reveal dyslexic high performers, who may not have a previous diagnosis, but nevertheless exhibit subjective symptoms implying dyslexia. Although unable to provide a diagnosis, self-reports are easy and quick-to-use tools to recognize students with limited reading abilities, and the difficulties exhibited by this population. These attributes make them handy tools to assign students with dyslexic symptoms into study groups for further in-depth assessment, and to provide specialized advice and feedback to overcome their difficulties.

2.9.2 Detection of compensatory strategies

As mentioned before in Section 2.8.5, development of compensatory strategies helps students with reading difficulties to succeed in their studies, as well as identify these strategies helps promoting the independence on these students to perform their learning activities.

In this sense, several studies have demonstrated the relevance of detecting the learning styles of these students can help them to identify and develop the most effective compensatory strategies they could use to learn (Coffield et al., 2004; Mortimore, 2008; G. Reid, 2001; Rodríguez, 2004; Scanlon et al., 1998).

Basically, the importance of detecting the learning styles is to identify the strengths and preferences in learning that have allowed affected students advance in their studies. Thus, some issues raised for studying the learning styles of students with reading difficulties are: How these students learn? How can these students improve their performance? and How to enhance their learning?. Moreover, many of these students have acknowledged that their learning styles have helped them: to understand the ways in which they learn, to understand their strengths and their weaknesses, and to develop appropriate strategies (Cooper, 2006; Sumner, 2006). Additionally, identifying the learning styles of each student contributes to enhance the quality of learning process (Felder, 1989, 1990; Montgomery, 1995; Rosati, 1988, 1996, 1999; O. C. Santos & Boticario, 2009), hence teachers and experts can offer adapted materials and activities to the learning preferences of each individual.

2.9.2.1 Learning styles

Learning styles refer to the procedures, methods or strategies used by students to select, process and work with information (Keefe, 1979). People perceive and acquire knowledge in different ways, they have their own methods or strategies to learn, and think and act differently. This means that each individual responds to various situations and learning environments, according to their particular learning preferences or learning style.

Thus, if students identify their learning styles, they will become more motivated to learn by knowing more about their own strengths and weaknesses as students (C. S. González, 2001). In addition, teachers and experts can respond to individuals' strengths and weaknesses, aiming to raise the achievements in classrooms.

There is not a single definition for learning styles. For instance, Honey & Mumford (1986), defined learning styles as "*a description of the attitudes and behaviours which determine an individual's preferred way of learning*". Felder (1996) defined learning styles as "*characteristic strengths and preferences in the ways they (students) take in and process information*". James and Gardner (1995) defined learning styles more precisely by saying that learning style is the "*complex manner in which, and conditions under which, learners most efficiently and most effectively perceive, process, store, and recall what they are attempting to learn*".

Moreover, there are different approaches to classify the learning styles and several tools proposed by researchers so as to detect the learning styles of students (regarding the classification approach) (Coffield et al., 2004; Curry, 1987; Graf, 2007; Mortimore, 2008; Rodríguez, 2004; Vélez, 2009). In next section some of these proposals are presented.

2.9.2.2 Tools for detecting learning styles

As mentioned before, there are many classification proposals for learning styles and several tools to detect them. In the next list some of these proposals and tools used to detect them are presented:

- Allinson and Hayes' Cognitive Style Index (Allinson & Hayes, 1996).
- Apter's Motivational Style Profile (Apter, 2001).
- Dunn and Dunn's model (R. Dunn, Dunn, & Price, 1985).
- Entwistle's Approaches and Study Skills Inventory for Students (Entwistle, McCune, & Walker, 2001).

- Felder-Silverman's Index of Learning Styles (Felder & Silverman, 2002).
- Field-Dependent and Field Independent Cognitive Styles (Witkin & Goodenough, 1981).
- Grasha-Riechmann' model (Grasha & Riechmann, 1974).
- Gregorc's Mind Styles Model and Style Delineator (Gregorc, 1985).
- Herrmann's Brain Dominance Instrument (Herrmann, 1989).
- Honey and Mumford's Learning Styles Questionnaire (Honey & Mumford, 2006).
- Jackson's Learning Styles Profiler (Jackson, 2002).
- Kolb's Learning Style Inventory (Kolb, 1984).
- Myers-Briggs Type Indicator (Myers & McCaulley, 1985).
- Sternberg's Thinking Styles Inventory (Sternberg, 1985).
- Vark model (Fleming & Mills, 1992).

Aditionally, some of the listed tools have been implemented and validated in different e-learning systems, aiming to detect, store and clasify the students according to their learning styles, and provide them with adapted educational materials tailored to their individual learning preferences. Table 2-7 summarices the learning systems in which tools have been implemented (Mejia, 2009).

Table 2-7. Summary of learning styles' tools implemented in e-learning systems

e-Learning system	Learning styles' tool implemented
ABITS (Capuano, Marsella, & Salerno, 2000)	Felder-Silverman's Index of Learning Styles (Felder & Silverman, 2002)
CS-383 (Carver, Howard, & Lane, 1999)	
LSAS (Bajraktarevic, Hall, & Fullick, 2003)	
MAS PLANG(Peña, 2004)	
MOODLE (Graf, 2007)	
SPORAS (Schehing, Carrasco, Guerra, & Parra, 2005)	
TANGOW (Paredes & Rodriguez, 2006)	
WHURLE-HM (E. Brown et al., 2006)	
AHA! (Bra & Stash, 2002)	Honey and Mumford's Learning Styles Questionnaire (Honey & Mumford, 2006).
INSPIRE (Grigoriadou, Papanikolaou, Kornilakis, & Magoulas, 2001)	
AES-CS (Triantafillou, Pomportsis, & Georgiadou, 2002)	Field-Dependent and Field Independent Cognitive Styles (Witkin & Goodenough, 1981)
iWEAVER (Wolf, 2002)	Dunn and Dunn's model (R. Dunn et al., 1985)
MOT (Stash, Cristea, & De Bra, 2004) [STA2004]	Kolb's Learning Style Inventory (Kolb, 1984).

2.9.3 Assessment of cognitive processes

After symptoms present in dyslexia and compensation strategies used to overcome these symptoms are detected (see Section 2.9 and 2.9.2 respectively), psychometric tests are conducted so as to: confirm the diagnosis and define the cognitive profile of students (related to cognitive processes involved in reading, which can affect the learning process).

As explained in Section 2.8.6, during reading a set of stages are performed without the person being aware of them and which take place while the eye moves by words. These stages are accompanied by operations performed by the cognitive processes (that have been developed) related to reading. For example: *phonological* and *orthographic processing* are responsible for understanding and applying the rules of grapheme-phoneme correspondence (Rack, J. P., Snowling, M. J., Olson, 1992); the *working memory* is responsible for both processing requests and storage (Baddeley, 1981); the *processing speed* which refers to the processes underlying the rapid recognition and retrieval of linguistic stimuli presented visually (Fawcett & Nicolson, 1994); and the *semantic processing* that is a necessary component to access the meaning of written material.

Kaufman (2000) states that if it is suspected the existence of dyslexia, it is important to have an assessment of cognitive processes to better understand the problem. The results of such tests will determine whether an individual is eligible for appropriate assistance. The assessment provides a basis on which to make educational recommendations and to determine the basis on which to establish psychology intervention programs. Figure 2-5 summarizes an assessment process for students so as to determine possible presentation of dyslexia (E. García, 2004).

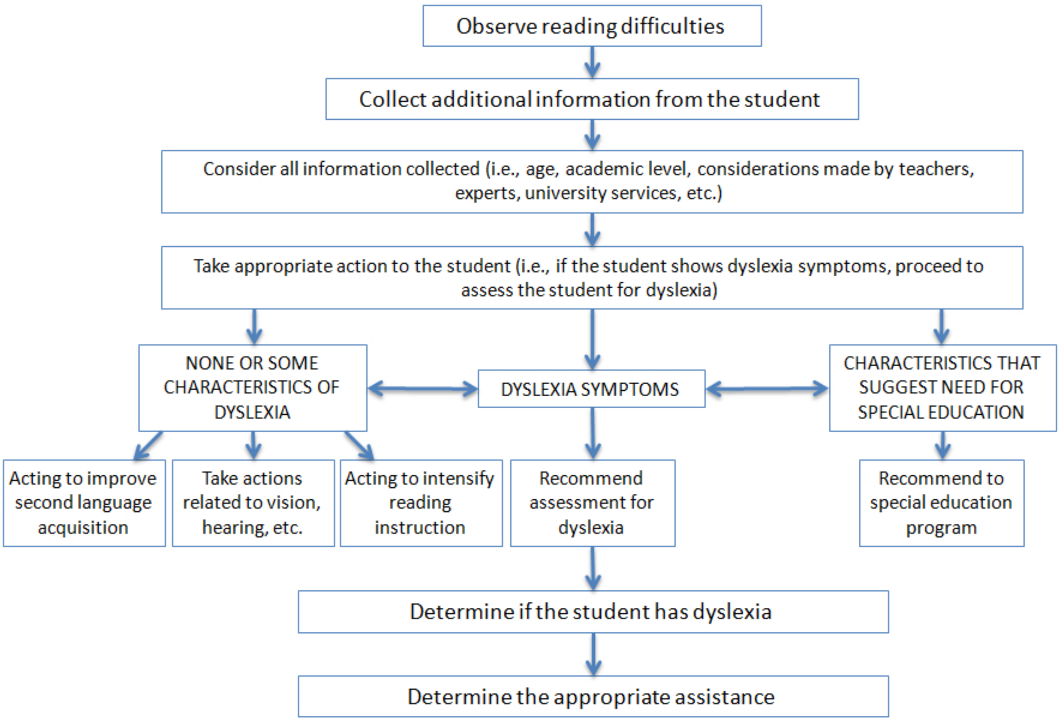


Figure 2-5. Process evaluation to determine if students have dyslexia. Extracted from García (2004)

Consequently, the assessment should aim to discover meaningful information from the possible affected student by identifying the cognitive processes related to reading that are deficient. Therefore, the assessment consists of tests – also referred to as instruments, batteries or tasks – that access and retrieves information about the assessed cognitive processes (i.e., *phonological* and *orthographic processing*, *working memory*, *lexical access*, *processing speed*, *semantic processing*).

2.9.3.1 *Assessment tests*

Different assessment tests (also known as "batteries") have been proposed to identify LD, and particulary dyslexia. Some of the tests are available for sale or are in the public domain, and are not connected with a particular core curriculum. The tables presented below (see Table 2-8 to Table 2-12) shows an overview of existing tests identified from related research works. Assessment tests have been categorized in groups for a greater understanding of their scope (Santiuste & González-Pérez, 2005), namely: intelligence tests, general and specific aptitude tests, achievement tests, personality tests, and reading and writing tests.

Information of identified tests and showed in next tables consists of: abbreviation and name of the test with the original author and creation year, the age (in years) of the people with whom it can be used, the administration format (individual, collective or both), the type of test (verbal, non-verbal, or both), and finally whether or not the test has been oriented to be filled through computer (automated).

- **Intelligence Tests** (see Table 2-8). These tests try to measure people's potential ability or learning capacity. These tests measure a person's intellectual capacity (or IQ) using different tasks focusing on, for example, cognitive ability, perceptual ability, comprehension skills, ability to abstract, mathematical ability, verbal and mathematical reasoning, vocabulary, memory, speed processing, and visual and auditory processing. The importance of intelligence tests as a tool for LD detection is in the discrepancy between the value obtained from the IQ (an average level for students with LD) and academic achievement (abnormal or deficient level for students with LD) (Santiuste & González-Pérez, 2005; Sparks & Lovett, 2010). Several of the tasks that make up the intelligence tests are used in schools and colleges to identify different types of LD and many of these tests are fairly complete tools that can provide specific details about students' difficulties in reading, writing, math or language.

Table 2-8. Intelligence tests

Abbreviation	Name	Age	Application	Test type	Automated
RAVEN (Raven, 1936)	Raven's Progressive Matrices	6-65	Individual/ Collective	Non-verbal	Y
D-48 (Anstey, 1990)	Dominoes Test	10-65	Collective	Non-verbal	Y
WJ-R (Richard W. Woodcock, 1990)	Woodcock-Johnson Psycho-Educational Battery	5-95	Individual/ Collective	Verbal/ Non-verbal	Y
FACTOR "G" (Cattell & Cattell, 1994)	General Intelligence Factor, test of scale 1, 2, 3	4-15+	Individual	Non-verbal	Y
WAIS-III (D. Wechsler, 1997)	Wechsler Adult Intelligence Scale	4-94	Individual	Verbal/ Non-verbal	Y
KAIT (A. S. Kaufman & Kaufman, 1993)	Kaufman Adolescent and Adult Intelligence Test	11-85	Individual	Verbal	N/A
IGF (Yuste, 2001)	General Factorial Intelligence test	7-19+	Individual	Verbal/ Non-verbal	Y

- **General and Specific Aptitude Tests** (see Table 2-9). These tests as intelligence tests, can measure intellectual capacity. However, they can also evaluate important learning skills and basic aptitudes (such as verbal, numerical, spatial, reasoning, and memory). These include indicators to measure expression capability, imaginative capability, information processing capability, reasoning and comprehension abilities, cognitive abilities, spelling, memory, and verbal fluency. These tests are all made up of different tasks (e.g., vocabulary, spelling, or arithmetic tests) which can be used together or individually to detect the possible existence of an LD.

Table 2-9. General and specific aptitude tests

Abbreviation	Name	Age	Application	Test type	Automated
PMA (Cordero, 1984)	Primary Mental Abilities	10+	Collective	Verbal	Y
DAS (Elliot, 1990)	Differential Ability Scales	2-18	Collective	Verbal	N
TEA (Thurstone & Thurstone, 1994)	Test of Education Ability	8-18	Collective	Verbal	Y
TOMAL (Reynolds & Bigler, 1994)	Test of Memory and Learning	5-19	Individual	Verbal/ Non-verbal	Y
GMA (Blinkhorn, 1999)	Graduate and Managerial Assessment	18+	Collective	Verbal	Y
DAT-5 (Bennett, Seashore, & Wesman, 2000)	Differential Aptitude Test	5-18+	Collective	Verbal/ Non-verbal	Y
EFAI (Santamaría, Arribas, Pereña, & Seisdedos, 2005)	Factorial Assessment of Intellectual Aptitudes	8-18+	Collective	Verbal	Y

- **Achievement Tests** (see Table 2-10). These tests measure a student's achievement in realizing a task. They can also measure failures that limit the effectiveness of learning. Tests are used to measure the acquisition, encoding, retrieval and improvement of knowledge, to assess cognitive strategies, and to examine environmental issues, study plans, the use of materials and the assimilation of content. Achievement tests are very useful for diagnosing LD, because they analyze the students' academic performance in achieving the proposed objectives in a corresponding curriculum by their age and grade. They measure different academic aspects using a variety of subtests such as reading fluency, passage comprehension, writing fluency, picture vocabulary, and sound awareness tests.

Table 2-10. Achievement tests

Abbreviation	Name	Age	Application	Test type	Automated
ACRA (J. M. Román & Gallego, 1994)	Abridged ACRA Scale of Learning Strategies	12-16	Individual/ Collective	Verbal	N
IHE (Pozzar, 1989)	Inventory of Study Habits	12+	Collective	Verbal/ Nonverbal	Y
EPA-2 (Fernández, 2000)	Learning Potential Assessment	5+	Collective	Non-verbal	N
WJ III ((R. W. Woodcock, McGrew, & Mather, 2001)	Woodcock-Johnson Test of Achievement	2-90+	Individual/ Collective	Verbal/ Non-verbal	N/A
WIAT II (David Wechsler, 2001)	Wechsler Individual Achievement Test	4-85	Individual	Verbal	N/A

- **Personality Tests** (see Table 2-11). These tests can accurately identify the main characteristics of a person's behavior, and thus determine learning strengths and weaknesses. These tests measure aspects of personality such as leadership and social skills, attention problems, hyperactivity, ability to work in a team, and self-assuredness. For LD detection and the definition of possible causes and treatments it is important to measure the emotional, motivational and personality aspects of students as well as their metacognitive processes. Moreover, it is necessary to identify the existence of serious imbalances that are exclusive to the LD, like neurosis, striking alterations of behavior, and others.

Table 2-11. Personality tests

Abbreviation	Name	Age	Application	Test type	Automated
BASC (Reynolds & Kamphaus, 1992)	Behavioral Assessment System for Children and Teenagers	3-18	Individual/ Collective	Verbal/ Non-verbal	Y
16PF-APQ (Birkett-Cattell, 1989)	Adolescent Personality Questionnaire	12-20	Individual/ Collective	Verbal/ Non-verbal	Y
BIP (Hossiep & Parchen, 2006)	Bochum Inventory of Personality and Competencies	18+	Collective	Verbal/ Non-verbal	N
MIPS (Millon, 2003)	Millon Inventory of Personality Style	18+	Individual/ Collective	Verbal/ Non-verbal	Y

- **Reading and Writing Tests** (see Table 2-12). These tests identify people with specific disorders in either of these two skills: reading and writing. They analyze specific problems in areas that include reading and writing ability, reading comprehension, speaking, verbal and written reasoning, and vocabulary. They can also be used to find the causes of reading-writing difficulties and identify whether the problem is related to a lexical or phonological route, i.e., students cannot visually connect the spelled form of a word with its meaning or they cannot comprehend the meaning through the sound of a word. Other tests for detecting LD in reading and writing are: Reading Comprehension Test (Lázaro, 1996), Halstead-Reitan Neuropsychological Test Battery (Reitan & Wolfson, 2004), Communicative Abilities in Daily Living (CADL-2) (Holland, Frattali, & Fromm, 1999), Test for examining for aphasia (Ducarne de Ribaucourt, 1977), Examining For Aphasia (EFA-3) (Eisenson, 1954), Exploration and Differential Diagnosis in Aphasia (Borregón, 2000), Silent Reading (Fernandez, 1991), EVOCA (Suárez, A., Seisdedos, N. y Meara, 1998), TALE (Toro, Cervera, & Urío, 2002), and Reading Comprehension Evaluation (ECL-2) (De la Cruz, 1999).

Table 2-12. Reading and writing tests

Abbreviation	Instrument name	Age	Application	Test type	Automated
BDAE-3 (Goodglass & Kaplan, 1976)	Boston Diagnostic Aphasia Examination	18+	Individual	Verbal	Y
PIENB (Peña-Casanova, 1991)	Barcelona Test	20+	Individual	Verbal	N/A
Nelson-Denny (J. I. Brown, Fishco, & Hanna, 1993)	Nelson-Denny Reading Test	9-18+	Collective	Verbal	Y
WRAT-3 (Wilkinson, 1993)	Wide Range Achievement Test - Third Edition	5-75	Individual/ Collective	Verbal	N/A
RA+PD (Riart, 1994)	Verbal reasoning test and development program	8-18	Collective	Verbal	N/A
PROLEC-SE (Ramos & Cuetos, 1997)	Assessment of reading processes	10-16	Individual/ Collective	Verbal	Y
UGA (Gregg, 1998)	UGA Phonological / Orthographic Battery	14+	Individual	Verbal	Y
PROESC (Cuetos, 2002)	Battery of writing process assessment	8-15	Individual/ Collective	Verbal	N
SICOLE (Jiménez et al., 2002)	Assessment system for the diagnosis of reading disabilities in the Spanish language	7-12	Individual	Verbal	Y
BAIRES (Cortada de Kohan, 2003)	Verbal Aptitude Test	15+	Individual/ Collective	Verbal	Y
WMLS-R (Alvarado, Ruef, & Schrank, 2005)	Bilingual Verbal Ability Tests	5-90	Individual	Verbal/ Non-verbal	N/A

Abbreviation	Instrument name	Age	Application	Test type	Automated
DN-CAS (Tellado, Alfonso, & Deaño, 2007)	Cognitive Assessment System	5-17	Individual	Verbal/ Non-verbal	N
PPVT-4 (L. M. Dunn & Dunn, 2007)	Peabody Picture Vocabulary Test	2-90	Individual	Verbal	Y

Analyzing in detail the different presented tests proposed for identifying LD, and particularly those to identify dyslexia, it was observed that the assessment process, provided by some of the tests previously presented from Table 2-8 to Table 2-12, is oriented to the definition of a common set of tasks related to Reading (comprehension, vocabulary, listening, memory and fluency) and Writing (spelling, grammar, dictation and fluency) skills. Consistently with the focus of this research work, next in Table 2-13 a summary of specific types of tasks, regarding reading and writing skills for the identification of dyslexia is presented.

Table 2-13. Summary of specific tasks to identify dyslexia provided by tests

Instrument	Reading					Writing			
	Comprehension	Vocabulary	Listening	Memory	Fluency	Spelling	Grammar	Dictation	Fluency
WJ-R	x	x	x	x			x	x	
WAIS-III	x	x	x	x					
KAIT	x		x	x					
PMA	x	x					x		
EAS						x			
TOMAL				x					
DAT-5	x					x			
EFAI				x			x		
WJ-III	x	x	x	x	x	x			x
WAIT-II	x		x			x	x		
BDAE-3	x	x							
PIENB	x				x			x	x
Nelson-Denny	x	x			x				
WRAT-3	x	x			x	x			
RA+PD	x								
PROLEC-SE	x	x							
BAIRES		x							
WMLS-R	x	x	x	x	x	x		x	x
PPVT-4	x	x			x	x	x		
UGA			x	x		x			x
DN-CAS	x		x	x	x				
SICOLE	x		x	x	x	x	x		

From Table 2-13, only DN-CAS and SICOLE tests which are targeted to children and the UGA targeted to adults offer specific tasks aiming to assess some of the processes mentioned above (see Section 2.8.6). However, there is not yet a tool that evaluates all cognitive processes related to reading in adults and particularly in university students (e.g., *phonological processing, orthographic processing, lexical access, processing speed, working memory, and semantic processing*).

2.9.3.2 *Criteria for diagnosing dyslexia*

For the diagnosis of an LD such as dyslexia, one widely used criterion is the *discrepancy*, i.e., since in the LD there are associated failures that affect academic performance but the intellectual capacity remains, discrepancy consist in considering the contrast between the IQ and the student's academic performance. This criterion was defined by both the APA in the DSM-IV-TR, and the WHO in the ICD-10. Both APA and WHO states that there is not a diagnosis of LD when an IQ below 75 is presented (value of IQ stablished for the diagnosis of mental retardation).

However, *discrepancy* has not been exempted from criticism. On the one side, the methods to find the *discrepancy* have been criticized since different methods could produce different results, and therefore, there will be the need to estimate what are the most appropriate methods (D'Angiulli & Siegel, 2004; Forness, Sinclair, & Guthrie, 1983; Siegel & Smythe, 2006). On the other hand, the concept of *discrepancy* has been has criticized. Specifically, the work in Siegel (1989) analyzes and criticizes the assumptions on which *discrepancy* criterion is based on. These assumptions are: (1) IQ tests measure intelligence, (2) intelligence and performance are independent and the presence of LD not affect IQ scores, (3) the IQ predicts academic performance (i.e., students with low IQ should be poor readers and students with high IQ score should be good readers), and (4) students with LD of different IQ levels are qualitatively different (i.e., students with LD and low IQ are different from students with LD and high IQ).

With regards to the assumption (1), Siegel (1989) explains that the most commonly used IQ tests do not measure intelligence, understood as reasoning and problem solving skills. For the assumption (2), Siegel claims that there is no independence between performance and IQ, since poor readers have deficits in many skills that IQ tests measure. Sometimes a low IQ is a result of a LD in reading. With regard to the assumption (3), Siegel argues that we can find students with low IQ and capable of decoding (hyperlexics) and students with high IQ and reading problems. Finally, the assumption (4) would be compromised because Siegel provides empirical evidence to demonstrate that students with LD and low IQ are not qualitatively different than students with LD and high IQ. From these reviews, Siegel concludes that the concept of *discrepancy* is not necessary to diagnose an LD.

However, Siegel (1999) suggests a number of guidelines to follow to identify the LD. Siegel proposes that a systematic assessment of LD using standardized tests should be made. In the case of reading, such tests must contain words reading, pseudowords reading, reading comprehension, and dictation of words, among others. In these tests the student must obtain a score below the percentile 25 to present a reading difficulty. In this sense, several studies have found that this score can differentiate individuals with LD from those with low academic performance by other causes (Fletcher, 1985; D. González et al., 2010; Jiménez & García, 2007; S. E Shaywitz, Shaywitz, Fletcher, & Escobar, 1990; Siegel & Ryan, 1988).

Thus, following these concepts previously mentioned and putting them into practice, according to Jiménez & Artiles (2007), students present dyslexia when show the next indicators:

- Poor performance on standardized reading tests (percentile < 25 in reading pseudowords and percentile ≥ 75 in time of reading words or pseudowords);
- Poor academic performance in reading (e.g., accuracy, speed, or comprehension) and problems associated with writing (e.g., orthography or spelling) and normal performance in other curriculum areas where the reading activity is not as relevant (e.g., mathematics)
- IQ score ≥ 75 in order to exclude intellectual deficit (Siegel & Ryan, 1989).
- After the above criteria are verified, a percentil below 50 on standardized tests of reading comprehension must be presented.

Consistently, a review from the literature (Díaz, 2007; E. García, 2004; Jiménez & García, 2007; Rodrigo et al., 2004; Rojas, 2008) suggests that to measure the performance in reading and reading comprehension, is necessary to conduct standardized tests to assess cognitive processes related to reading (e.g., *phonological processing, orthographic processing, lexical access, processing speed, working memory,* and *semantic processing*).

2.9.4 Assistance to dyslexia in university students

Assistance to dyslexia is an issue that has concerned researchers and practitioners in the recent years and is known for being especially practical. Hence, the fact that an important related line of research to this work has been based on describing the psychological characteristics of affected students in the university context instead of investigating the effectiveness of psychology interventions that are applied (Pressley & Forrest-Pressley, 1992).

Here, it is worth noting that from the area of psychology, the term used to refer to the assistance or support to affected students with dyslexia is "interventional psychology". Basically, the term refers to the orientation in the teaching-learning processes and focuses on the inclusion of learning techniques and strategies, as well as in the development of metacognitive and motivational strategies.

There are several theoretical perspectives that have served as guidelines to carry out the intervention in dyslexia. One example is the theoretical perspective focused on cognitive and metacognitive strategies in which teaching is characterized by training in cognitive processes based on the observations of the execution and of problem solving by effective learners (Rojas, 2008).

According to Moore (2008) children can benefit more from pedagogical intervention, while adolescents and adults from adaptations to educational materials or assistance, tailored to their preferences (strengths).

Studies done on university students with LD have revealed that (1) awareness of their weaknesses, and then some of their strengths, as well as (2) ability to make decisions and self-regulate their learning, are powerful predictors for their academic success (Goldberg et al., 2003; Raskind et al., 1999; Reiff et al., 1994; Werner, 1993).

Accordingly, as mentioned in Section 2.4, opening the user model to the students has been a successful strategy to promote awareness-raising, which leads to reflection on learning, and its facilitate self-regulation, thereby the learning process is supported (S. Bull & Kay, 2008, 2010; Hsiao et al., 2010; Mitrovic & Martin, 2007).

In this sense, one of the emerging visualization techniques of the learner model and potential impact on TeL are LA (Campbell & Oblinger, 2007; Ferguson, 2012; Siemens et al., 2011; Vatrapu et al., 2011; Verbert et al., 2011). Basically, these analytics are visual representations of aggregated data about students, for purposes of understanding their activity and performance in a fairly intuitive format, thus achieving the optimization of learning. Additionally, these analytics are quite related to educational data mining, focusing on the detection of patterns that allow the creation and delivery of personalized recommendations for resources, activities, people, etc. (Duval, 2011), which may contribute to the self-regulation.

2.9.4.1 Approaches for learning analytics production

LA solutions allow opening the learner model for understanding the performance and activity in an e-learning process. Considering the fact that such solutions can be extended to teachers and even experts (e.g., educational psychologists) in such contexts, this type of visualizations can also be delivered to different perspectives (e.g., students, teachers, or experts) and social planes (e.g., student, class, or group).

In TeL, a perspective defines the set of available learning analytics functions for a role (i.e., student, teacher, etc.) whereas a social plane determines the monitored and analyzed population related with an activity or outcome (i.e., a single student, a classroom, a group, etc.). Thus, an teacher can request a particular learning analytic, such as the performance in a task, either for a single student or for the whole classroom.

Some research works have attempted to monitor students' activities so as to provide LA from different perspectives (Florian et al., 2011; Sten Govaerts, Verbert, & Duval, 2011; Schmitz et al., 2009; Zhang et al., 2007). For example, in (Zhang et al., 2007) a log analysis tool enabled in Moodle, called Moodog, to track and visualize students' learning activity was implemented. This tool provides teachers with insights about how students interact with resources, and allow students to easily compare their progress to others in the class. Schmitz et al. (2009) presented CAMera, a tool that visualizes student activities and simple metrics of events, e.g. mouse clicks. This tool collects usage metadata from diverse application programs and makes them accessible to the student for recapitulating her learning activities. Govaerts et al. (2011) proposed SAM (Student Activity Meter), a tool that visualizes student activities, such as time spent on learning activities and resources used, within a LMS like Moodle for perspectives of students and teachers. Florian et al. (2011) proposed a technical framework to build Activity-based learner models based on existing data in the Moodle in order to provide evidence for competence assessment. This requires the consideration of the social planes and perspectives for accessing Moodle's tracking data.

All these works seek through LA help students to increase their awareness and to support self-regulation in their learning process, as well as help teachers to monitor the students' progress.

In the case of the dyslexia, there are not existing works that use LA solutions to provide students with visualizations about their learner model to support them with their reading difficulties, as well as to provide teachers with insights about the students' reading difficulties in order to understand and reflect about the strategies they can use with their students. Thus, a challenge that could be studied to assist students with reading difficulties is to promote awareness of their weaknesses and strengths, as well as self-regulation of their learning through LA solutions (Mejia, Bull, et al., 2012).

2.9.4.2 Recommendations

As mentioned before (see Section 2.9.4), the ability to make decisions and self-regulate the learning are powerful predictors for the academic success of students with LD (Goldberg et al., 2003; Raskind et al., 1999; Reiff et al., 1994; Werner, 1993). On the other hand, among the activities identified from the educational psychology area to support students with LD is giving hints, feedback, scaffold guidance and/or advice as well as generate methods and strategies for their treatment (Passano, 2000; Santiuste & González-Pérez, 2005).

In this sense, the provision of recommendations of learning activities by expert psychologists could help affected students to facilitate and develop self-regulation that will allow the independence of their difficulties (Hellendoorn & Ruijssenaars, 2000; Nunez et al., 2005; Raskind et al, 1999; Sideridis, Mouzaki, Simos, & Protopapas, 2006). Thus, a channel of communication between expert psycologists and students affected could be established with the objective to support reading difficulties presented.

2.10 Summary

This chapter presented the state of the art related to this dissertation. Firstly, this chapter discusses some theoretical background on e-Learning such as the concepts of *Learning Management Systems (LMS)* which are systems that manage students and learning resources (like images, animations, videos, etc.), providing tools to develop learning activities of a course as collaboration tools, monitoring of students, evaluation systems, etc., *Adaptive Hypermedia Systems (AHS)* which are systems that are able to provide students with adaptive and personalized experiences based on processing information from a *Learner Model*. This model describes the student characteristics (like knowledge, interests, preferences, etc.) and it is used to achieve *Adaptations* of different aspects of AHS (like contents, resources, activities, etc.) to the students. It was highlighted that there exist a prominent research tend in *Technology-enhanced Learning (TeL)* to focus in the integration of AHS aspects with LMS, so as to ensure that LMS are able to provide an adequate adaptive and personalizing learning. Furthermore, considering adaptivity, personalization, and even accessibility capabilities, it was concluded that only Moodle, dotLRN and ATutor are the most capable LMS to support these aspects.

Then, within an e-learning process, it also was discusses the concepts of *Open Learner Model (OLM)* and *Learning Analytics (LA)* in order to increase awareness of the students about their learner model and to support reflection and self-regulation of their learning process. OLM focus on opening the learner model to students and provide information about their knowledge, interests, preferences, etc. while LA focus on the detection of student key-activity and key-performance indicators based on statistical and data mining techniques, which are reflected in his/her learner model, and could provide recommendations for learning activities, resources, training, people, etc. Thus, a way of opening the learner model could be using LA techniques.

Secondly, this chapter discusses the concepts of *e-Learning for All* and *Inclusion*, since this dissertation considers the inclusion of university students with *Learning Disabilities*

(LD) in an e-learning process. Thus, the chapter discusses the interest among researchers for people in need, as well as the participation of the European Commission by promoting projects such as IRIS, TATE, BenToWeb, MICOLE, SEN-IST-NET, ALPE, EU4ALL, ALTER-NATIVA, and ALTERNATIVE-eACCESS with the purpose to aim both education and labor inclusion and promote the independence of people in need, creating training activities, web portals, methodologies, accessibility guidelines and assistive technologies. However, although new regulations and the generation of projects have enabled support for "inclusive practices", there is still the challenge to put in practice day to day these principles within the educational institutions. In this sense, education supported by technology and more specifically in LMS could be of relevant help to facilitate the road towards a real "inclusion".

Author of this dissertation studies the concepts of LD, their classification and the influence of educational psychology on them. Based on these studies some relevant statements about LD were identified and are considered by author:

- LD are difficulties in listening, speaking, reading, writing, and even in mathematical calculation abilities.
- LD are not problems of any of this types: sensory, physical, intellectual, attention, behavior, social interaction, mental retardation, emotional, socio-cultural deficiencies and higher intellectual skills.
- LD generally emerge in childhood and are detected at school age, but can be generated later by factors such as educational, social, and emotional.
- LD may affect people throughout their entire lives. For this reason, LD can be categorized in: children with LD, adolescents with LD and adults with LD.
- Finally, four classes of LD are considered: dislexia, dysorthographia, dysgraphia and dyscalculia.

Futhermore, analysis of the state of the art in using computers to assist students who presents some type of LD was made, also, in this analysis the potential benefits of technology that support the needs of these students was disscussed. Some available assistive technologies and projects related to LMS that consider features of these students were found.

Thirdly, as mentioned before, this work is focused on university students with dyslexia (i.e., students who present difficulties with basic reading skills and reading comprehension), a population that has been studied very little. University students with this type of disability may experience difficulties during their academic careers, since reading is the basis of most, if not all, formal educational processes and has significant importance in many learning domains. Thus, this chapter discusses the different definitions given for dyslexia and the most accepted, the common difficulties presented in students with dyslexia (i.e., their symptoms) as well as its closely related to difficulties in writing and spelling. A literature review shows that poor readers are also less successful in writing tasks than their peers. Moreover, in accordance with common practice, dyslexia entails not only reading difficulties. It is commonly associated to disorders of writing and spelling skills.

Additionally, it also discusses difficulties of these students in associated areas such as speech, working memory, attention, and spatial organization, compensatory strategies developed to help them succeed in their studies and get into university, and cognitive processes involved in reading that can be altered in them. At this point, it was discovered that the cognitive processes that can be altered and it necessary to study are: phonological awareness, orthographic processing, lexical access, processing speed, working memory, and semantic processing. Furthermore, it was highlighted that technologies help these students progress in skills development and enhance their learning performance, consequently, there is notable challenge with regards to using technology that support these students, and thus, facilitate their learning process and assistance by supporting materials and activities that are not necessarily provided during school hours due to busy learning schedule to be followed.

Finally, this chapter discusses methods and tools that enable the detection of difficulties related to reading and compensatory strategies, as well as the assessment of cognitive processes and assistance of university students with dyslexia and/or affected with some reading difficulties. It was highlighted the usefulness of self-report questionnaires for detecting affected students, the relevance of detecting the learning styles of these students in order to help them to identify and develop the most effective compensatory strategies they could use to learn, and the usefulness of batteries for assessing the cognitive processes that they may have altered. At this point, since “assessment” it is important to this research work for defining a software tool, it was also relevant to identify whether the studied batteries have been partially or completed automated and oriented to be filled by students through computers. It was also argued that only DN-CAS and SICOLE batteries which are targeted to children and the UGA targeted to adults offer specific tasks aiming to assess some of the processes mentioned above. However, there is not yet a tool that evaluates all cognitive processes related to reading in Spanish-speaking university students.

Regarding the assistance, it was argued that the students' awareness of their weaknesses and strengths, as well as ability to make decisions and self-regulate their learning, are powerful predictors for their academic success. Thus, OLM, LA and specialized recommendation are presented as tools to increase awareness and support self-regulation of the students during their learning process, as well as help teachers to monitor the students’ progress and advice to support such self-regulation processes of the students.

CHAPTER 3

THESIS PROPOSAL: FRAMEWORK FOR DETECTION, ASSESSMENT AND ASSISTANCE OF UNIVERSITY STUDENTS WITH DYSLEXIA AND/OR READING DIFFICULTIES

In order to provide a solution that overcomes the main objective of this dissertation, namely: "***including students with dyslexia and/or reading difficulties in an e-learning process, so as to define methods and tools to detect, assess and assist them in overcoming their difficulties during their higher education***", in this chapter is presented the main proposal which consist of a *framework for detection, assessment and assistance of university students with dyslexia and/or reading difficulties.* In order to achieve this, some specific proposals were defined as follows:

- Definition of a ***learner model*** based on preliminary studies about dyslexia and reading difficulties.
- The development of a set of software tools to collect and store data into the *learner model* so as to detect and assess the profile of each student.
- The definition of ***adaptive components*** that provides personalized assistance to each student's profile through data visualization techniques and recommendations.
- Integration of the learner model, implemented software tools and adaptive components with a LMS so as to support affected students in an e-learning process.

Thus, this chapter provides a complete picture of the main proposal and goes through further descriptions of each specific proposal.

This chapter is structured as follows: Section 3.1 shows a brief introduction and the objectives concerning to the work presented in this dissertation. Section 3.2 explains the framework components proposed, and Section 3.3 explains the learner model and the four submodels comprime demographics, reading profile, learning styles, and cognitive traits. Section 3.4 presents the adaptation processes defined and the two adaptation engines: learning analytics and recommendations. Section 3.5 describes the integration with a LMS. This chapter ends in Section 3.6 with a summary of the chapter.

3.1 Introduction

There is abundant evidence that dyslexia does not disappear with age or training (Callens et al., 2012; Hatcher et al., 2002; Swanson & Hsieh, 2009). On the contrary, despite their effort, when compared to their peers, affected students still show significant difficulties in reading tasks (Eden et al., 2004; Hatcher et al., 2002; Lyon et al., 2003; Miller-Shaul, 2005; Ramus et al., 2003; Sally E. Shaywitz et al., 2008). However, many dyslexic students can develop compensatory strategies to help them succeed in their studies (Firth et al., 2008; Mellard et al., 2010; Ransby & Swanson, 2003) and get into university (Callens et al., 2012; Hatcher et al., 2002). For instance, according to the British Dyslexia Association, it is estimated that between 10% and 15% of the world population has some LD, and the percentage of dyslexic people is around 8% (Jameson, 2009). According to the European Dyslexia Association, the estimation of European citizens with dyslexia is between 4% and 10% (Kalmár, 2011). In Spain, the Dyslexia Association of Jaen has estimated a prevalence of dyslexia of between 5% and 15% among the general Spanish population, and between 6% and 8% among university students (Bassi, 2010).

Surprisingly, not all students whose performance is affected were diagnosed by dyslexia and/or assisted before starting their studies at university; therefore, there are many students with symptoms or reading difficulties who have not been diagnosed with an official psychoassessment procedure. Consequently, a considerable number of students enter university without having the expected reading skills, and would require support to cope with high reading demands.

Thus, higher educational institutions are in clear need of specific resources to identify students with or without a previous diagnosis of dyslexia that still show reading difficulties, and to provide assistance to them. In this sense, this dissertation addresses such need and contributes in the development of an "e-Learning for All" and aims to provide a solution to the university context, in which dyslexia have not been deeply studied yet (see Section 2.8.4 for further details).

Thereby, in this dissertation a ***Framework for Detection, Assessment and Assistance of University Students with Dyslexia and/or Reading Difficulties*** that can be integrated into a LMS was defined as the main proposal (Mejia & Fabregat, 2012) and a set of specific proposals, to achieve it were defined as follows:

(i). A learner model based on information related to dyslexia in students. This model stores information about the characteristics of affected students with dyslexia and those who present particular reading difficulties.

(ii). A set of adaptation processes and software tools to detect, assess and assist dyslexia in students. More precisely, adaptation engines that receive information and provide adaptation results through software tools. The tools let collect and store (detect and assess) students' data into the defined learner model, and provide personalized data visualizations and recommendations (assistance) to these students.

(iii). Integration of proposals (i) and (ii) into an LMS so as to achieve interoperability of the defined learner model and adaptation engines in an e-learning process.

Regarding proposal **(i)**, considerable preparation on psychologic topics related to dyslexia and reading difficulties in education was required (first details and results of this preparation was presented through the theoretical background in Chapter 2 from Sections 2.8 and 2.9). Moreover, this preparation involved a set of preliminary studies to determine the characteristics of affected students with dyslexia and those who present reading difficulties, as well as a set of studies to understand how these students can be treated and how technologies can enhance their learning process.

For the basis of the specific proposals **(ii)**, methodological approaches related to detecting, assessing and assisting affected individuals, which have been used with children, were proposed and adapted for university students. With this approaches in mind and applied to the e-learning process it is aimed to give a solution to the first defined objective (OB.1.), namely "***defining a framework for detection, assessment and assistance of university students with dyslexia and/or reading difficulties that can be integrated into a LMS***". Consistently, three phases are considered to achieve this objective: (1) **Detection** of university population with dyslexia and/or reading difficulties, (2) **Assessment** of their cognitive processes to determine specific deficits and (3) creating adaptive **Assistance** to individual needs so as to improve their personal learning efficiency in reading (Guzmán et al., 2004; Luque et al., 2011; Nicolson & Fawcett, 1990). These three phases are described as follows:

1. **Detection**. There are three parallel ways in which the detection could be made:
    - **Detection of demographics**: detect personal details of the affected students. This information is important because it provides general knowledge about each student at a given moment in time, like age, gender, and academic level, etc. In this work a tool, based on web-forms, to capture these personal details is proposed.
    - **Detection of reading profile**: detect individual reading profiles and identify related weaknesses (difficulties) of the affected students. In this sense, findings reported provided reasonable evidence in support of the self-report questionnaire as a highly predictive tool to detect or contact with students with LD (Lefly & Pennington, 2000; Wolff & Lundberg, 2003). In this work a tool is proposed based on the work of (Giménez de la Peña et al., 2010) who designed a self-report questionnaire that is hand-filled by students at the University of Malaga (Spain), making it possible to detect students previously diagnosed with dyslexia and/or reading difficulties among this population.
    - **Detection of learning styles**, detect strengths/preferences (i.e., learning styles) of the affected students. Several studies have demonstrated the relevance of detecting the learning styles of affected students to identify the most effective learning strategies they could use to learn (Mortimore, 2008; G. Reid, 2001; Rodríguez, 2004). Many students with dyslexia have acknowledged that awareness of their learning styles have helped them to understand the ways in which they learn, to understand their strengths and their weaknesses, and to develop appropriate strategies (Cooper, 2006; Sumner, 2006). There are several models to detect the learning styles (Coffield et al., 2004; Mortimore, 2008; Rodríguez, 2004), nevertheless, in this work is adopted the revised version of the Felder-Silverman model

(Felder & Soloman, 2008) mainly for: it has been tested with dyslexic students (Beacham et al., 2003), it is easy to administer and takes short time, it has been tested in digital contexts, and it has been validated with university students.

The first two ways (i.e., demographics and reading profile) address a solution to the second objective (OB.2.) of this dissertation, namely "***analyzing and developing methods and tools for the detection of university students with dyslexia and/or reading difficulties***". The latter way (i.e., learning styles) aims to give a solution to third objective (OB.3.) of this dissertation, namely "***analyzing and adopting methods and tools for the detection of learning style of university students with dyslexia and/or reading difficulties***". Chapter 4 describes and explains the work developed regarding the **Detection** phase.

2. **Assessment**. After the detection phase, it is necessary to assess the cognitive processes (i.e., *Phonological processing, Orthographic processing, Lexical access, Processing speed, Working memory, Semantic processing,* further details are described in Section 2.8.6) that can be altered in students and determining their cognitive deficits, even whether or not they have dyslexia (Bruck, 1993b; Felton, Naylor, & Wood, 1990; Lachmann & Van Leeuwen, 2008). Therefore, several tools (tests or batteries) to identify dyslexia-related cognitive deficits were analyzed and reported in previous research work (this analysis is presented in Chapter 2) (Mejia et al., 2010). The findings revealed that in the Spanish language there are not existing tools for the assessment of the cognitive processes in Spanish-speaking adult dyslexic population. However, it is highlighted the work reported in Díaz (2007) who conducted a research that consisted in the adaptation of an English assessment battery to Spanish language to assess *phonological* and *orthographic processes*. In this work an assessment battery is proposed based on the work of Díaz (2007) and it is extended so as to implement the assessing process of other cognitive processes: l*exical access, processing speed, working memory* and *semantic processing.*

   This phase aims to give a solution to the fourth objective (OB.4.) of this dissertation, namely "***analizing cognitive processes associated with reading that can be altered in university students with dyslexia and/or reading difficulties in order to develop methods and tools needed to determine which specific processes are failing***". Chapter 5 describes and explains the work developed regarding the **Assesement** phase.

3. **Assistance**. Detection of demographics, reading profile and learning styles, as well as assessment of cognitive deficits are necessary for generating of appropriate assistance to help students to overcome these shortcomings and support their cognitive performance (Díaz, 2007; Rojas, 2008). Previous works related with assistance in Spanish spoken universities and support for the treatment of these difficulties and cognitive deficits in this population has not been found. However, other related work that focus on university students have revealed that (1) awareness of their strengths and weaknesses, (2) reflection on their learning process, as well as (3) the ability to make decisions and self-regulate their learning, are powerful predictors for their academic success

(Goldberg et al., 2003; Raskind et al., 1999; Reiff et al., 1994; Werner, 1993). In this work, it is proposed and attempted to provide adaptive assistance to affected students after detection and assessment processes have been evaluated. This adaptive assisstance consists of providing a learning analytics' dashboard of their detection and assessment results based on data visualization techniques, as well as to provide recommendations with regards to the personal identified difficulties.

This phase aims to give a solution to the fifth objective (OB.5.) of this dissertation, namely "***analyzing and developing adaptation methods and tools that can be used to assist university students with dyslexia and/or reading difficulties***". Chapter 6 describes and explains the work developed regarding the **Assistance** phase.

Accordingly, results obtained from phases **Detection** and **Assessment** will feed the proposed *learner model* [i.e., proposal **(i)**]. More precisely, this model is designed and implemented by defining variables related to information captured in the detection and assessment phases, i.e., related to demographics, reading profile, learning styles, and cognitive traits. As mentioned in both phases, in order to capture information from the students and store into the learner model, tools such as forms to capture students' demographics (Mejia et al., 2010), questionnaires to detect reading difficulties and learning styles (Mejia, Clara, et al., 2011; Mejia, Giménez de la Peña, et al., 2012, 2013), and a battery to assess the cognitive processes involved in reading (Díaz et al., 2013; Mejia, Díaz, et al., 2011; Mejia, Díaz, Jiménez, et al., 2012) were proposed (this is further presented in Chapter 4 and Chapter 5).

Thereafter, the variables of the *learner model* are used by an adaptive component so as to deliver personalized assistance through learning analytics and specialized recommendations (made it during the **Assistance** phase) aiming to create awareness, promote reflection and facilitate self-regulation during the learning process. To provide the adaptation effects a learning analytics' dashboard (data visualization technique) and a first scope of a recommender system were proposed (Mejia, Bull, et al., 2012; Mejia, Díaz, Florian, et al., 2012; Mejia, Florian, et al., 2013). This is further presented in Chapter 6.

Finally, regarding proposal **(iii)**, in order to integrate the results of the proposals **(i), (ii)** into a LMS, an architecture based on web services is proposed so as to achieve interoperability of the defined learner model and adaptation engines in an e-learning process. With this integration, besides the proposal tools can be used independently from an LMS, it enables working within a specific LMS. This proposal attempts to provide a solution to the sixth objective (OB.6.) of this dissertation, namely "***integrating the tools developed for the detection, assessment and assistance of university students with dyslexia and/or reading difficulties with a LMS***". Chapter 7 describes and explains the work developed to achieve this objective and give details of a first implementation approach.

3.2 Framework's Components

In this dissertation the *Framework for Detection, Assessment and Assistance of University Students with Dyslexia and/or Reading Difficulties* that can be integrated into a LMS was defined as the main proposal. This framework aims to provide detection, assessment and assistance to affected students with dyslexia and/or reading difficulties. It considers a model of the profile of students with dyslexia and/or reading difficulties, namely Learner model, and two adaptation engines, namely Learning Analytics engine and Recommendations engine. It includes multimodal interaction mechanisms, such as visual, auditory and speech communicative channels to achieve personalized interaction with detection and asssessment tools and increase students' motivation and performance. It is proposed to be integrated into a LMS and, to this end, the architecture of its components is supported by web services.

Figure 3-1, depicts the components of the framework: (a) a ***Software toolkit*** that consists of a set of external web-based tools, namely: a set of Forms to capture student demographics, ADDA (acronym for Spanish name Autocuestionario de Detección de Dislexia en Adultos), ADEA (acronym for Spanish name Autocuestionario de Detección del Estilo de Aprendizaje), BEDA (acronym for the Spanish name Batería de Evaluación de Dislexia en Adultos), PADA (acronym for the Spanish name Panel de Analíticas de Aprendizaje de Dislexia en Adultos), and RADA (acronym for the Spanish name Recomendador de Actividades para la Dislexia en Adultos), for the detection, assessment and assistance of students with dyslexia and/or reading difficulties, (b) a ***Learner model*** that includes information of students regarding the Demographics, Reading profile, Learning styles, and Cognitive traits, (c) Two ***Adaptation engines*** that processes individual information so as to deliver personalized assistance through learning analytics and recommendations, (d) an ***LMS*** that enables students to visualize and interact with the tools of the S*oftware toolkit* (e) ***Web services*** to achieve access and communication by the LMS with the tools of the *Software toolkit*'s, and (f) ***Multimodal interaction mechanisms*** for students so as input and output of information can be made through different modals, such as visual (e.g. a display, keyboard, and mouse), auditory (e.g. speech recognition for input, speech recorded audio for output), among others.

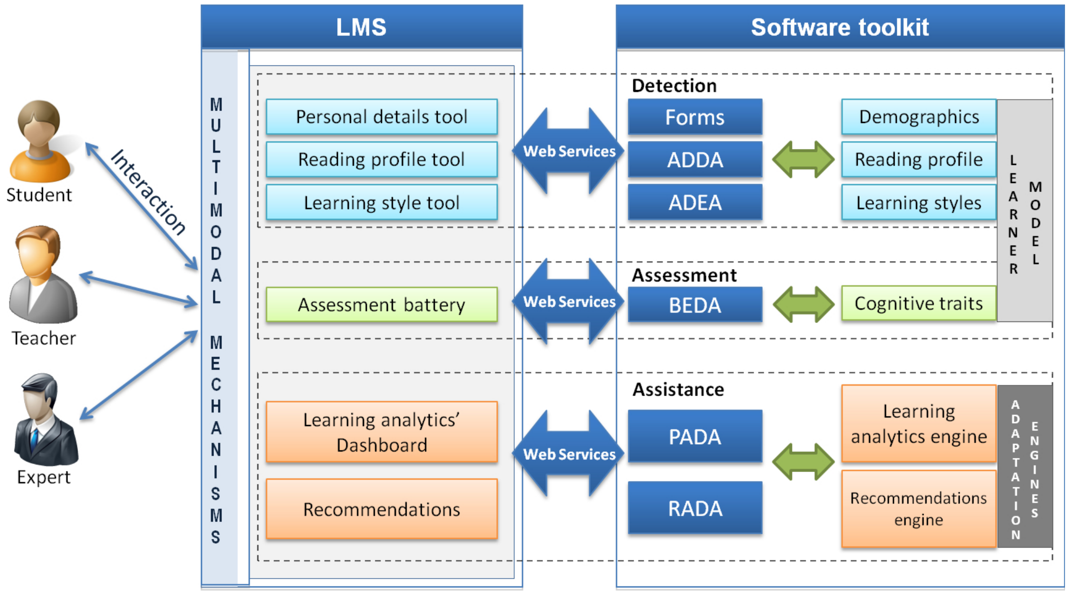


Figure 3-1. Framework's components

a) **Software toolkit.** For *Detection*, three web-based tools were defined and developed: web-based Forms to capture the students' demographics, ADDA to detect their reading profile, and ADEA to detect their learning style (Mejia, Clara, et al., 2011; Mejia et al., 2010; Mejia, Giménez de la Peña, et al., 2012, 2013; Mejia, 2009). These tools are further presented in Chapter 4. For *Assessment,* BEDA, a battery that assesses students' cognitive processes so as to identify their cognitive deficits and to determine whether or not the student has dyslexia was defined and developed (Díaz et al., 2013; Mejia, Díaz, et al., 2011; Mejia, Díaz, Jiménez, et al., 2012). This tool is further presented in Chapter 5. For *Assistance*, two tools were defined and developed: PADA to visualize graphically and textually the results (as a learning analytics' dashboard) of the detection and assessment results (i.e., information of the *Learner model*), and RADA to provide personalized advices (as recommendations) provided by experts that could help the students to overcome their difficulties and improve their academic outputs (Mejia, Bull, et al., 2012; Mejia, Díaz, Florian, et al., 2012; Mejia, Florian, et al., 2013). These tools are further presented in Chapter 6.

b) **Learner Model.** This model comprises four submodels: 1) the demographics submodel which considers variables related to students' personal details such as their educational level, age and gender, among other information; 2) the reading profile submodel which considers information about their school life, personal and family history of learning difficulties (diagnosis and treatment), associated difficulties, and reading and writing habits; 3) the learning styles submodel which is used to include the students' learning preferences (seeing or hearing, reflecting or acting, reasoning logically or intuitively, analyzing or visualizing); and 4) the cognitive traits submodel which describes characteristics of the students that are gathered by assessing the cognitive processes involved in reading (*phonological processing, orthographic processing, lexical access, processing speed, working memory, and semantic processing*) (Mejia, Díaz, et al., 2011; Mejia et al., 2010; Mejia & Fabregat, 2010). Information of submodels (1), (2) and (3) are considered in Chapter 4 and Chapter 6, and information of submodel (4) is considered in Chapter 5 and Chapter 6.

c) **Adaptation Engines.** The adaptation engines have the adaptation rules that will be applied to select the most appropriate learning analytics and recommendations for each student. These engines deploy: 1) the learning analytics' dashboard to visualize the results based on established criteria, so that the students receive feedback of information retrieved from their learner profile retrieved form the learner model and be able to compare their individual results with those of their peers matched by academic level, and 2) the recommendetions that deliver personalized and specialized recommendations depending on the individual results obtained and the cognitive deficits presented by each student. The adaptation approaches are further explained in Chapter 6.

d) **LMS.** Basically this component serves as the basis for the deployment of the tools of the framework's software toolkit. Is the target system to which the users can interact and provide their personal information. Moreover, the inputs (i.e. information from the students related to all submodels (1) to (4)) and outputs of the adaptation engines (i.e. learning analytics' dashboard and recommendations) can be captured and delivered through the LMS respectively. This component is considered in Chapter 7.

e) **Web Services.** Since the framework may be integrated into an LMS, a web service-oriented mechanism is included to allow the external tools communicate with the LMS and transfer information related to the learner model and adaptation results. Thus, through web services access and visualization of the learner model's information and adaptation results can be delivered to the student. In Chapter 7, a primary approach of the integration of the framework software's toolkit and a selected LMS is presented. More precisely, web services are implemented through a module in the selected LMS.

f) **Multimodal mechanisms.** Multimodal interaction mechanisms were considered with the aim of facilitating the interaction of affected students with the tools of the framework's software toolkit (Mejia, Díaz, et al., 2011; Mejia, Díaz, Jiménez, et al., 2012). Those tools include resources based on visual, auditory and speech communicative channels according to the specific task that each student has to perform. Reported studies in the training of cognitive deficits indicate that the performance of the students can be improved significantly if tasks, excersises or resources provide them use both acoustic and visual modalities (Brünken et al., 2002; Mayer et al., 2004). In Chapter 5, Section 5.2.1.1 is presented the alternatives of communication channels with the framework. Different modes for data input and output (joint use of visual language, spoken and/or written language and devices like a keyboard and a mouse) can be held together in the framework.

Since the framework consists of a set of components to be used in the university context, three types of users were considered in that context (see Figure 3-1):

- *Experts*, who define tasks related to the detection of students with reading difficulties, assessing their cognitive processes, defining criteria to determine a cognitive deficit or dyslexia, checking the learning analytics and students' progress, and creating recommendations that teachers and students may follow.
- *Teachers*, who check the learning analytics and students progress, and view the recommendations given by the experts.
- *Students*, who complete the different detection and assessment tasks proposed by the experts, check their learning analytics and their progress, and view the recommendations given by the experts.

3.3 Learner Model

The learner model plays a crucial role in the proposed framework, because it includes all relevant information that the detection and assessment tools have gathered about the students (see Figure 3-2). This information is then processed by adaptation engines and used as a basis for providing suitable adaptation effects by assistance tools. The process of building the learner model is done automatically based on the responses and actions of the students when they are using the detection and assessment tools.

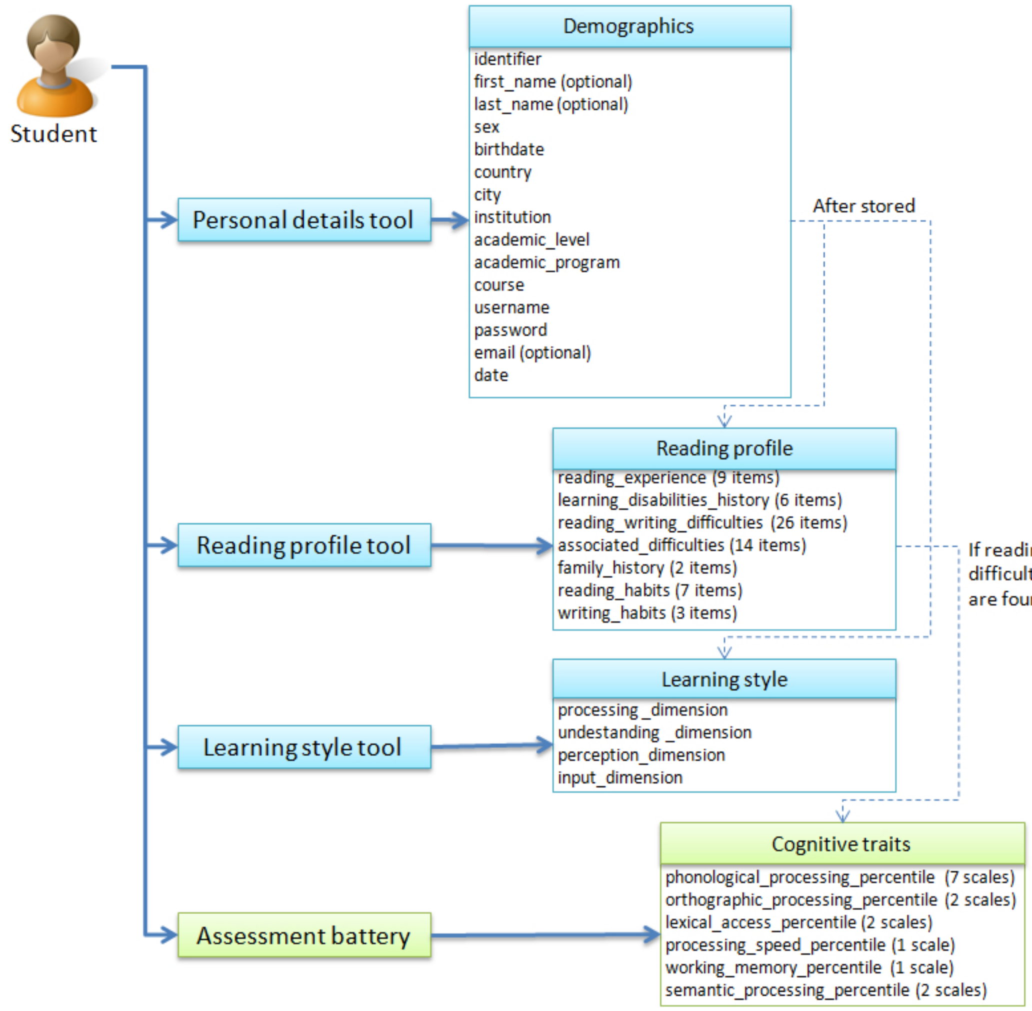


Figure 3-2. Learner model

In this dissertation the inclusion of characteristics of students who have a previous diagnosis of dyslexia and/or are affected with some reading difficulties is proposed. Thus, an analysis of the theoretical foundations provided important issues to be considered in these students such as:

1. Demographics are descriptive data of the type of students that are explored.
2. Reading profiles for classifying students who report current reading difficulties, and normal readers, i.e., students with and without symptoms of dyslexia respectively.
3. Compensatory strategies by students' learning styles which help them in overcoming their difficulties and succeed in their studies.
4. Cognitive processes involved in reading such as *phonological processing, orthographic processing, lexical access, processing speed, working memory, and semantic processing*.

Thereby, the learner model comprises four submodels (Mejia, Díaz, et al., 2011; Mejia et al., 2010): 1) the *demographics submodel* considers variables related to student personal details such as their age, gender, and academic level; 2) the *reading profile submodel* stores information about the school life, personal and family history of learning difficulties (diagnosis and treatment), associated difficulties, and reading and writing habits; 3) the *learning styles submodel* identifies strengths or preferences in learning (seeing or hearing, reflecting or acting, reasoning logically or intuitively, analyzing or visualizing); and 4) the *cognitive traits submodel* describes characteristics of the students that are gathered by assessing the cognitive processes involved in reading (*phonological processing, orthographic processing, lexical access, processing speed, working memory, and semantic processing*).

3.3.1 Demographics

Basically, demographics or demographic data are the personal details of a population (e.g., university students considered in this dissertation). These data have long been useful in the study of special needs because they enable the identification of demographic profiles to define appropriate support to affected people. Commonly-used demographics include sex, race, age, ethnicity, hometown, disabilities, academic level, employment status, and even location.

In this dissertation, the student demographics are collected to support the detection phase presented in the introduction of this chapter. However, it is expected that these data will help to the delivery of better assistance and adaptation of resources and classes to the affected students. As shown in Figure 3-1, these demographic were proposed to be recovered by web-based Forms. Further description is presented in Chapter 4, Section 4.2.

3.3.2 Reading profile

The reading profile refers to the set of characteristics related with the dislexia that defines two groups: students with and without symptoms of dyslexia. As shown in Table 3-1, in this dissertation seven aspects were identified to explore in order to define the reading profile.

Table 3-1. Summary of aspects to consider in the reading profile submodel

Aspect	Description
School and learning to read experience.	This refers to the student's experience at school, learning to read and write, mother tongue, and learning other languages.
History of learning disabilities.	This explores whether participants had been previously diagnosed with LD such as dyslexia, dysorthography, dysgraphia, and/or dyscalculia, and if they had received treatment.
Current reading-writing difficulties.	This refers to the current difficulties expressed by students in their reading and writing skills.
Associated difficulties.	This explores types of difficulties associated with dyslexia: speech, working memory, attention, and spatial-temporal difficulties.
Family history of learning disabilities.	Since one of the predictors for the risk of a LD is the appearance of these disabilities in one or more close relatives (parents, siblings, grandparents), this aspect explores if other family members have difficulty reading or writing or have been diagnosed with some LD, specifically dyslexia.
Reading habits.	This concerns attitudes (likes and frequency) towards reading.
Writing habits.	This concerns attitudes (likes and frequency) towards writing.

A self-report questionnaire is used to collect information from the students about their reading profile in the learner model. According to the literature, self-report questionnaires could be a suitable tool to detect students with or without a previous diagnosis of dyslexia that still show reading difficulties, and identify which reading skills this students lacks in order to provide support to them (Gilger et al., 1991; Gilger, 1992; Lefly & Pennington, 2000). Consequently, as shown in Figure 3-1, in this dissertation a web-based self-report questionnaire, called ADDA, to detect reading profiles and providing different feedback to students was proposed. The feedback provided by ADDA is based on two profiles, namely: students reporting current difficulties (Profile A), and normal readers (Profile B), i.e., students with and without symptoms of dyslexia respectively. After a student is registered (i.e., complete the demographics forms), he/she completes the self-report questionnaire which contains 67 questions regarding to the aspects mentioned in Table 3-1. A complete description of the questionnaire is presented in Chapter 4, Section 4.4.

3.3.3 Learning styles

The learning styles are the forms, methods or strategies that a student uses to select, process and work with information. It basically refers to learning preferences of the students. This submodel is based on the Felder-Silverman's Index of Learning Styles (ILS) (Felder & Silverman, 2002). As shown in Table 3-2, it combines learning styles of four dimensions (i.e., processing, perception, input, and understanding) to define the learning styles of a particular student.

Table 3-2. Variable to consider in the learning styles submodel

Variable	Description
processing	Student preference for processing information. There are 2 posible values: active, reflective.
perception	Type of information that student preferentially perceive. There are 2 posible values: sensitive, intuitive.
input	Sensory channel that student prefer to perceive information. There are 2 posible values: visual, verbal.
understanding	Preferred way by the student to progress in the information. There are 2 posible values: sequential, global.

This submodel includes detailed description of the students learning compensatory strategies, motivation for learning and preferences for organizing information. It is a self-report questionaire of 44 questions which allow inquiring the strategies that a student employs or prefers to learn. As shown in Figure 3-1, this self-report was called ADEA, it was for practical purposes because the Spanish translation of the tool's name. A complete description of the questionnaire is presented in Chapter 4, Section 4.4.2.2.

3.3.4 Cognitive traits

For students with dyslexia and/or reading difficulties, conducting a proper diagnosis, and understanding what their real deficits are, requires a thorough analysis of their cognitive processes. Tasks to identify deficits must be administered and the results studied to establish the foundations upon which different learning adaptations can be based to achieve personalized learning. To enhance the learning process, it is important to identify students' cognitive traits. Thus, author focuses on identifying cognitive traits associated with dyslexia, and take into account the failure of specific cognitive processes involved in reading to define and build an assessment battery that identifies deficits in the cognitive processes mentioned in Section 2.8.6.

The aim of this submodel is to describe the cognitive traits of the students by assessing the cognitive processes involved in reading. Cognitive traits are needed to identify the learning strategies that guide students with dyslexia and/or reading difficulties in their learning process because these students can arise from the deficit in one or more of the cognitive processes (Jiménez & Rodrigo, 1994). As mentioned before, the cognitive processes related with reading that can be assessed and included in this submodel are *phonologic processing, orthographic processing, lexical access, processing speed, working memory, and semantic processing*.

The cognitive trait submodel identifies variables related with each cognitive process, allowing us to represent information about the student's LD. As shown in Figure 3-1, the identified variables are retrieved by a proposed *assessment battery* for dyslexia in adults called BEDA. Table 3-3 presents identified variables related to cognitive processes. These variables store the percentiles of each cognitive process as well as the scale scores of each assessment task.

Table 3-3. Variables to consider in the cognitive traits submodel

Variable	Description
phonological_processing_percentile	Percentile obtained in phonological processing. It is a number between 1 and 100.
pp_task_1_scale	Scale score obtained in the task of segmentation into syllables (i.e., first task of phonological processing). It is a number between 1 and 12.
pp_task_2_scale	Scale score obtained in the task of number of syllables (i.e., second task of phonological processing). It is a number between 1 and 12.
pp_task_3_scale	Scale score obtained in the task of segmentation into phonemes (i.e., third task of phonological processing). It is a number between 1 and 12.
pp_task_4_scale	Scale score obtained in the task of general rhyme (i.e., fourth task of phonological processing). It is a number between 1 and 12.
pp_task_5_scale	Scale score obtained in the task of specific rhyme (i.e., fifth task of phonological processing). It is a number between 1 and 12.
pp_task_6_scale	Scale score obtained in the task of phonemic location (i.e., sixth task of phonological processing). It is a number between 1 and 12.
pp_task_7_scale	Scale score obtained in the task of omission of phonemes (i.e., seventh task of phonological processing). It is a number between 1 and 12.
orthographic_processing_percentile	Percentile obtained in orthographic processing. It is a number between 1 and 100.
op_task_1_scale	Scale score obtained in the task of homophone/pseudohomophone choice (i.e., first task of orthographic processing. It is a number between 1 and 12.
op_task_2_scale	Scale score obtained in the task of orthographic choice (i.e., second task of orthographic processing). It is a number between 1 and 12.
lexical_access_percentile	Percentile obtained in lexical access. It is a number between 1 and 100.
la_task_1_scale	Scale score obtained in the task of reading words (i.e., first task of lexical access). It is a number between 1 and 12.
la_task_2_scale	Scale score obtained in the task of reading pseudowords (i.e., first task of lexical access). It is a number between 1 and 12.
processing_speed_percentile	Percentile obtained in processing speed. It is a number between 1 and 100.
ps_task_1_scale	Scale score obtained in the task of visual speed of letters and numbers (i.e., first task of processing speed). It is a number between 1 and 12.
working_memory_percentile	Percentile obtained in working memory. It is a number between 1 and 100.
wm_task_1_scale	Scale score obtained in the task of retaining letters and words (i.e., first task of working memory). It is a number between 1 and 12.

Variable	Description
semantic_processing_percentile	Percentile obtained in semantic processing. It is a number between 1 and 100.
sp_task_1_scale	Scale score obtained in the task of reading expository text (i.e., first task of semantic processing). It is a number between 1 and 12.
sp_task_2_scale	Scale score obtained in the task of reading narrative text (i.e., second task of semantic processing). It is a number between 1 and 12.

This submodel also includes variable that store the results of each of the assessment exercises from the tasks, determine the difficulty level of each cognitive processes (none, slight, moderate or severe), and let to know whether or not students have a cognitive deficit. Moreover, variables that include the time students take to solve each exercise, right and wrong answers and other information particular to each task where defined. Additionally, variables that determine the diagnosis of the presence or absence of dyslexia taking into account the criteria set (see Section 2.9.3.2), and overall cognitive performance obtained from the scores of the assessment tasks could be created. A complete description of the assessment battery (i.e., BEDA) and variables are presented in Chapter 5, Section 5.2.

3.4 Adaptation Processes

As mentioned in Chapter 2, numerous studies have been carried out at university level in different application domains (Baldiris, 2012; E. Brown et al., 2006; Florian, 2013; Marcos, Martinez, et al., 2006; Paredes & Rodriguez, 2006; Vélez, 2009; Yudelson & Brusilovsky, 2008), however, any meaningful work that develops adaptive processes for students with dyslexia have not been found.

In addition, some works deal with intervention programs for children with dyslexia (Guzmán et al., 2004; Luque et al., 2011; Metsala, 1999; Nicolson & Fawcett, 1990). Many of those programs have been supported by technologies (Barker & Torgesen, 1995; Rojas, 2008; Wise & Olson, 1995). As seen in (Lancaster et al., 2002; MacArthur, 1999; Rojas, 2008) and as presented in (Mejia et al., 2010), assistive technology has been developed to facilitate the learning of these students. But no references of work carried out with university students have been found.

This dissertation presents the achievements in the development of adaptation processes for the proposed framework containing tools and personalized components that facilitate learning for university students who have dyslexia and/or reading difficulties. These achievements, which according to literature are powerful predictors for the academic success of these students, are: (1) creating *awareness* of the reading profile, learning styles, and cognitive traits, (2) promote *reflection* on learning, and (3) facilitate *self-regulation* during the learning process (Goldberg et al., 2003; Raskind et al., 1999; Reiff et al., 1994; Werner, 1993).

- The *awareness* of students about their weaknesses, and some of their strengths (i.e., reading profile, learning styles, and cognitive traits) allow them to learn more about their potential difficulties. In this research work, delivering fragments adapted to different learner models, in an understandable format (e.g., learning analytics), so that affected students can recognize their difficulties as well as their strengths by themselves is proposed.

- The *reflection* process arises in students once the *awareness* is achieved, that is, if a student does become aware of their potential difficulties, he/she can reflect on them so as to engage in a process of continuous learning. By reflecting, students actively evaluate their learning processes and the related outcomes. Thus, the reflection can be the bridge between to be aware and take self-regulated actions. The steps of a student in this bridge of reflection could be planning, monitoring and evaluating (Christian Glahn, 2009). In this research work, such reflection is supported by both learning analytics displayed as well as on feedback provided to clarify these analytics.
- The *self-regulation* refers to the ability to make decisions about the learning process, particularly, within the scope of this dissertation; it refers to the ability of the affected students to be proactive in response to their difficulties. According to Pintrich (2000), self-regulation, is "an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment". To do this, after creating *awareness* and *reflection* is necessary to facilitate the self-regulation, so that affected students will be able to identify the appropriate focus of their efforts, to overcome their difficulties and meet their learning needs. To do this, in this research work, in addition to the feedback given with the learning analytics, creation of specialized recommendations is proposed.

For this reason, an open learner model approach is proposed, in which the learner model is accessible for viewing by the students in an understandable format. Moreover, considering the fact those university students with dyslexia may not have received adequate assistance during their learning process allowing them to know and deal with their difficulties; looks like open learner modeling is an opportunity to promote autonomy in these students so that they can recognize their reading difficulties, learning styles and learn about their cognitive processes for themselves. Consequently, self-regulation is supported, so that students affected will be able to identify the appropriate focus of their efforts, to overcome their difficulties and meet their learning needs (S. Bull & Kay, 2008; Hsiao et al., 2010; Papanikolaou et al., 2003; White et al., 1999).

Alternatively, the data can be processed so that they can be further extended to support other educational roles in decision-making, as remarked in (Donald Norris et al., 2008; Vatrapu et al., 2011; Verbert et al., 2011; Zhang et al., 2007). For instance, in this study the data are extended to teachers and experts to support teaching strategies and assistance for students with dyslexia and/or reading difficulties.

Thereby, based on the learner model information presented in previous section (see Section 3.3), some adaptation mechanisms for assistance of these affected students were designed and implemented. For this, two adaptation engines that provide personalized assistance to each student by processing the learner model are proposed. These engines have the adaptation rules that can be applied to adjust data visualizations, through *learning analytics* and *recommendations* respectively, to the activity and performance of a particular student. These rules are conditional statements that are defined using information from the variables captured and stored during the learner modeling process.

In this sense, it is considering the technical framework called *Activity-based Learner-models* proposed by Florian et al. (2011) so as to offer a solution that can be extended to teachers and experts (e.g., educational psychologists) and deliver visualizations to different perspectives (i.e., students, teachers, or experts) on social planes (e.g., student, class, or group) (see Section 2.9.4.1).

The *Activity-based Learner-models* is based on foundations of different research areas. From the pedagogical area, *Engeström's Activity Theory* is used to model activity dimensions (Engeström, 1987, 1999). From the computer supported collaborative learning (CSCL) area, the Dillenbourg and Jermann's concept of *social planes* allows us to model activities taking into account social interactions (Dillenbourg & Jermann, 2010). From the personalization and context management area the *actuator-indicator model* gives a framework to implements the software architecture by dividing its construction in four well-defined functional layers (i.e. sensor, semantic, control, and indicator) (Zimmermann, Specht, & Lorenz, 2005). Although a detailed explanation of the evolution of these three mentioned pillars and the union of them is described in (Florian et al., 2011), a brief summary of key aspects for this dissertation is presented below.

- **Engeström´s Activity Theory** (Engeström, 1987, 1999) is the pedagogical base. The Activity Theory model describes the structural relations between the components of an activity (1. instruments, 2. a subject, 3. an object, 4. rules, 5. community, and 6. division of labor) to leads an outcome. The activity´s outcomes can trigger new activities and each element can be related to individual activities. Thus, complex process can be described recursively. The three first components, called the action part, are visible. The other components are constrains in the context part. This model has been used widely to identify potential improvements of work settings for instance in (Engeström, 2000; Mirel, 2003) among others. Recently in (Lindgren, 2011) its potential for personalized clinical diagnosis systems has been explored.
- Engeström´s Activity Theory was introduced in educational technology by means of the concept of **social planes** (Dillenbourg & Jermann, 2010). Thus, the original element "community" is better expressed with the concept of "social planes". In (C. Glahn, Specht, & Koper, 2009) authors found evidence for activating awareness and reflection through visualization of information from different social planes. The original Activity Theory had some other adaptations in the new area of research. The elements "teacher" and "learner" replace the "subject" and the "object" of the original model respectively. In addition, the element "division of labor" is understood in educational technology as "cooperative process". Finally, particular constraints of an educational software system (such as a Learning Management System or LMS) add extended relations between instruments, procedural rules (such as institutional policies or instructional rules), and cooperative process. Figure 3-3 shows a parallel view of the original Engeström Activity Theory (Engeström, 1987) and the extended version for educational technology reported in (Engeström, 1999).

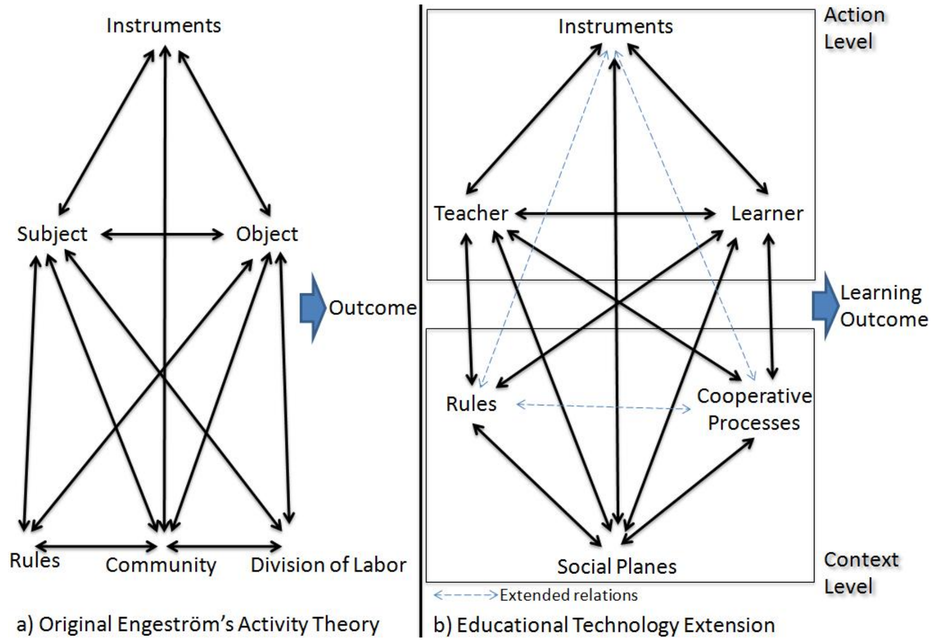


Figure 3-3. Engeström's activity theory and educational technology extension

- The **Actuator-Indicator Model** allows implementation of the extended Activity Theory in educational software. For instance, in (Florian et al., 2011) the implementation of Activity-based Learner-models was related to the LMS Moodle, based on existing data in the Moodle log table and using the Moodle log function for the sensor layer. The Actuator-Indicator Model describes four technological layers to proceed from monitoring and assessment to suitable response to learners (Zimmermann et al., 2005). These four technological layers (1. sensor, 2. semantic, 3. control, and 4. Indicator) are responsible for collecting the data, aggregating semantic meaning, processing aggregated information, and displaying the results.

All in all, with Activity-based Learner-models a wider communal perspective on the learning process could be available for learning analytics, visualization of the learner model, and delivering of recommendations for university students with dyslexia and/or reading difficulties.

Consequently, the adaptation engines consist of (i) a tool to open the learner model using *learning analytics* in order to help increase awareness of the students with dyslexia and/or reading difficulties and to support reflection and self-regulation about their difficulties, and (ii) a tool to provide specialized *recommendations* to support such self-regulation of these affected students. This is further described in Chapter 6.

Additonally, these adaptation engines are proposed to be built with four functional layers. These functional layers are: sensor layer, semantic layer, control layer, and indicator layer. Further description of these layers is presented in Chapter 6.

- The *sensor layer* is responsible for collecting information about traces of learners' interactions, i.e., their activity and performance through forms (i.e., demographics), ADDA (i.e., reading profile), ADEA (i.e., learning styles) and BEDA (i.e., cognitive traits).

- The *semantic layer* collects the data from the databases and transforms these data into higher-level information by using aggregators. These aggregators are functions built from two parameters: the social plane (i.e., student, peers or class), and the perspective (i.e., student, teacher or expert).
- The *control layer* is responsible for interpreting the response of aggregators using different rules. A rule determinates when and how to collect aggregator responses and how to present them to the user (i.e., student, teacher or expert).
- The *indicator layer* is responsible for transforming the returned data of the control layer into representations that are displayed in the corresponding interface to students, teachers or experts.

3.4.1 Learning analytics

The learning analytics are visual representations that allow opening the learner model in order to help increase awareness of the learners (in this research work, students with dyslexia and/or reading difficulties) and to support reflection and self-regulation about their difficulties. Additionally, these analytics are also expected to motivate the interest of the university teachers to revise their teaching practices in order to adapt them to the needs of these affected learners, and provide experts (e.g., educational psychologists) a useful tool that help generate recommendations for learners and teachers about the difficulties detected.

Learning analytics are usually displayed in dashboard-like interfaces (S. Govaerts, Verbert, Klerkx, & Duval, 2010; J. L. Santos, Verbert, Govaerts, & Duval, 2011; Schmitz et al., 2009). The aim of these dashboards is to provide useful support for understanding and decision making in learning and teaching (Duval, 2011; Florian, 2013). Thus, in this dissertation, a dashboard for visualizing and inspecting of reading difficulties and their characteristics, called PADA was proposed (see Figure 3-1).

PADA provides different visualizations on reading performance of learners, so that they can self-identify their particular strengths and weaknesses and self-regulate their learning. For this, it generates visualizations using a variety of techniques (bar-charts, line-charts, and pie-charts) to show learner model fragments. Therefore, PADA provides learning analytics for each of the demographics data forms, questionnaires (i.e., ADDA and ADEA) and cognitive assessment tasks (i.e., BEDA). Thus, PADA interface was divided into four tabs depending on the learner submodel accessed: 1. demographics, 2. reading profile, 3. learning styles or 4. cognitive traits.

These tabs allow learners to explore visualizations of their activity and performance and provide feedback to support them to recognize strengths and weaknesses in their reading competences. These tabs also could provide parallel views of an individual learners, his/her peers, and all as a class, in order to identify the severity of their difficulties according to the results of other matched by age and academic level.

Thus, learning analytics focus on the detection of key-activity and key-performance indicators which can be based on statistical and data mining techniques, so that for instance recommendations can be made for learning activities, resources, training, people, etc. that are likely to be relevant. A complete description of the dashboard (i.e., PADA) is presented in Chapter 6.

3.4.2 Recommendations

Once learning analytics about the learners is available from the learner model, recommendations (i.e., hints, feedback, scaffold guidance and/or advices) can be provided. Different aspects, such as the demographics, reading profile, learning styles, cognitive traits, and even combinations of them, could be considered when aiming at providing learners a variety of recommendations which will fit more with the learner model. In this dissertation it is proposed a first approach to consider only cognitive traits. Thus, a repository for storing and delivering of specialized recommendations that help to mitigate the cognitive deficits, called RADA was proposed (see Figure 3-1), so as to deliver a set of recommendations if a deficit in cognitive processes is found.

RADA stores these recommendations in both audio and text, and they can be delivered to students through PADA depending on their obtained scores and the cognitive deficits presented. The dataset of recommendations was created in collaboration with expert researchers and practitioners in dyslexia from University of La Laguna (Spain) and University of Las Palmas de Gran Canaria (Spain).

3.5 Integration with a LMS

Once the learner model and the adaptation engines have been implemented, the integration of the framework's software toolkit into an LMS could be achieved. As first approach, the exemplary LMS used in this dissertation is Moodle. It was selected mainly for the next reasons: (1) it is an LMS with great pedagogical and technological flexibility and usability that is supported by a large community of developers and users around the world, (2) it has been developed as an open source educational application with a free software license, (3) it is characterized by its simple interface, lightweight, and efficient, which can manage great amounts of educational resources, and that is easy to install, and (4) is currently the LMS used at the University of Girona, as well as other universities that have contributed in the development of this research work.

Basically, an LMS is focus on supporting teachers and administrators in creating, administering, and managing online courses. LMS provide a great variety of features which can be included in the courses such as learning material, quizzes, forums, chats, assignments, wikis, and so on. Thus, they have become very successful in TeL and are commonly used by higher educational institutions, but they provide very little or, in most cases, no support to students with dyslexia and/or reading difficulties.

Besides an LMS brings content management, assessments delivery, and learning flow distribution, using it and achieving personalization considering dyslexia aspects in terms of adapted assistance may bring the following benefits:

- Help students to place greater emphasis on concepts and topics than they have traditionally done.
- Allow students to progress at their own pace.
- Provide students adequate requirements of a course of study (adapted format of exam, objectives of the course, method of instruction).
- Provide students more options to solve and understand problems proposed by teachers.
- Allow students to learn using a variety of materials and activities.

- Provide students the possibility of knowing whether they are doing things correctly.
- Allow students to review materials as many times as needed (even repeat a class).
- Give directions one at a time, and ask students to repeat.
- Allow students to receive regular feedback on performance and ideas.
- Disaggregate tasks into parts.
- Enable students to access instructions at any time.
- Enable students to follow an individualized education program.
- Allow students to monitor their own learning and course progress.
- Allow students increase the independence and reduce frustration and lowered self-esteem.

In addition, other advantages may be seen when the adaptation processes proposed can be tested. The need for specific adaptations may change over time as the student develops compensatory strategies, or as the demands of a particular course, task or teacher change.

This dissertation proposes to extend LMS by incorporating the framework's toolkit through web service-oriented mechanisms (see Figure 3-1). That is, creating a module be into Moodle structure in order access and visualize the information retrieved from the software toolkit. Thus, the learner model (demographics, reading profile, learning styles and cognitive traits) and adaptation results (learning analytic's dashboard and recommendations) are delivered through Moodle.

Web services allow applications to share information and also that invoke functions from other applications regardless of the technology with which they were created, the operating system or platform in which they run and the device from where they can be accessed. In chapter 7 the integration of the framework's software toolkit into an LMS through web services si further explained.

3.6 Summary

This chapter presented the proposal of a *framework for detection, assessment and assistance of university students with dyslexia and/or reading difficulties* which can be integrated into a LMS. In order to achieve this, some specific proposals were defined as follows: i) a learner model based on information related to dyslexia in students; ii) a set of adaptation processes and software tools to detect, assess and assist dyslexia in students; iii) integration of the learner model, adaptation processes and software tools with a LMS so as to support affected students in an e-learning process.

Three phases are considered in this dissertation to achieve these proposals: (1) *detection* of university population with dyslexia and/or reading difficulties, (2) *assessment* of their cognitive processes to determine specific deficits and (3) creating adaptive *assistance* to individual needs so as to improve their personal learning efficiency in reading.

Results obtained from *detection* and *assessment* phases will feed the proposed *learner model*. This model comprises four submodels: 1) the *demographics submodel* considers variables related to student personal details such as their age, gender, and academic level; 2) the *reading profile submodel* stores information about the school life, personal and family history of learning difficulties, associated difficulties, and reading and writing habits; 3) the *learning styles submodel* identifies strengths or preferences in learning; and 4) the *cognitive traits submodel* describes characteristics of the students that are gathered by assessing the cognitive processes involved in reading. In order to capture and store the variables defined in this learner model from the students, tools such as forms to capture students' demographics, questionnaires to detect reading difficulties and learning styles, and a battery to assess the cognitive processes involved in reading were proposed.

During the *assistance* phase, an open learner model approach is proposed, in which the information of the learner model is accessible to students in an understandable format. Thus, this promotes autonomy in students so that they can recognize and be aware of their reading difficulties, learning styles and learn about their cognitive processes. Moreover, reflection is promoted and self-regulation can be facilitated during the learning process. Thereby, the variables of the learner model are used by *adaptation processes* having rules that can be applied to adjust data visualizations, through *learning analytics* and specialized *recommendations*. In order to provide the adaptation effects a learning analytics' dashboard and a first scope of a recommender system were proposed.

Integration of the results of the learner model and adaptation processes with an *LMS* is achieved by a proposed architecture based on web services.

Thus, the components of the framework are: (a) a *software toolkit* that consists of a set of external web-based tools such as forms to capture student demographics, ADDA to detect reading profiles, ADEA to detect learning styles, BEDA to assess cognitive processes, PADA to visualize learning analytics, and RADA to deliver specialized recommendations, (b) a *learner model* that includes information of students regarding the demographics, reading profile, learning styles, and cognitive traits, (c) two *Adaptation engines* to deliver personalized assistance through learning analytics and recommendations, (d) an *LMS* that enables students to access and interact with the software toolkit (e) *web services* to achieve access and communication by the LMS with the software toolkit, and (f) *multimodal interaction mechanisms* for students so as input and output of information can be made through different modals (e.g., visual and auditory).

CHAPTER 4

DETECTION OF UNIVERSITY STUDENTS WITH READING DIFFICULTIES

There are three parallel ways in which the detection of university students with reading difficulties could be made. One way is the detection of the students' ***demographics***, i.e., the personal details of the affected students such as age, gender, and academic level, etc. The second way is the detection of ***reading profiles***, i.e., the individual weaknesses (reading difficulties) of the affected students. The other way is the detection of ***learning styles***, i.e., the strengths (or preferences) of these affected students. Thus, this chapter is concerned with expose the analysis and implement of the methods and tools for performing detection. Four tools were defined as follows:

- A set of ***forms*** to capture the students' demographics.
- A software tool, called **detectLD**, devoted to the delivery and review of self-report questionnaires.
- A self-report questionnaire, called ***ADDA*** (acronym for the Spanish name *Autocuestionario de Detección de Dislexia en Adultos),* for detection of reading difficulties in adults.
- The Felder-Silverman's Index of Learning Styles (ILS) (Felder & Silverman, 2002), a self-report questionnaire to detect learning styles, called ***ADEA*** (acronym for Spanish name *Autocuestionario de Detección del Estilo de Aprendizaje*) for practical purposes in this dissertation.

This chapter is also dedicated to present the findings of a case study to test the functionality and the usability of detectLD, and to check the comprehensibility of ADDA. Furthermore, two cases are conducted to evaluate the usefulness of ADDA and ADEA.

This chapter is structured as follows: Section 4.1 shows a brief introduction about the detection of university students with reading difficulties. Section 4.2 explains the demographics data considered. Section 4.3 describes detectLD and a case study to test its functionality and usability. Sections 4.4 and 4.5 describe ADDA and ADEA, respectively, as well as cases study to evaluate their usefulness. This chapter ends in Section 4.6 with a summary of the chapter.

4.1 Introduction

As mentioned before, there is abundant evidence that dyslexia do not disappear with age or training (Callens et al., 2012; Hatcher et al., 2002; Swanson & Hsieh, 2009). On the contrary, despite their effort, when compared to their peers, adult poor readers still show limited vocabulary, lower general knowledge (Lyon et al., 2003), poorer performance in reasoning and memory tasks (Miller-Shaul, 2005; Simmons & Singleton, 2006), and significantly lower results on phonological tasks (Miller et al., 2006; Miller-Shaul, 2005; Ramus et al., 2003; Wolff & Lundberg, 2003). Furthermore, their reading is characterized by a slow pace rather than by errors (Hatcher et al., 2002; Sally E. Shaywitz et al., 2008; Sally E. Shaywitz, 2005). This difference in reading speed is especially evident in consistent orthographies (Goswami, 2010).

Despite their difficulties, many dyslexic students could develop compensatory strategies to help them succeed in their studies (Firth et al., 2008; Lefly & Pennington, 1991; Mellard et al., 2010; Niemi, 1998; Ransby & Swanson, 2003), and get into university, although they still underperform in reading-related tasks (Callens et al., 2012; Hatcher et al., 2002). For example, according to the Dyslexia Association of Jaen between 6% and 8% of the university students are dyslexics (Bassi, 2010). Surprisingly, not all students whose performance is affected by dyslexia are diagnosed and/or treated before starting their studies at university (Hanley, 1997; Lindgrén, 2012; Löwe & Schulte-Körne, 2004; Parrila, Georgiou, & Corkett, 2007; Pedersen, 2008; Wolff, 2006). Therefore, a considerable number of students enter university without having the skills expected from mature readers, and would require support to cope with high reading demands.

As a consequence, high education institutions are in clear need of specific resources to detect students with or without a previous diagnosis of dyslexia that still show particular reading difficulties, and identify which reading skills this population lacks as well as compensatory strategies they have developed to succeed in their studies.

Accordingly, three parallel ways in which the detection could be made were raised. One way is the detection of the students' *demographics*, i.e., the personal details of the affected students such as age, gender, and academic level, etc. The second way is the detection of *reading profiles*, i.e., the individual weaknesses (reading difficulties) of the affected students. In this sense, findings reported provided reasonable evidence in support of the self-report questionnaire as a highly predictive tool to detect or contact with students with LD (Lefly & Pennington, 2000; Wolff & Lundberg, 2003). It is highlighted the work of (Giménez de la Peña et al., 2010) who designed a self-report questionnaire that is hand-filled by students at the University of Malaga (Spain), making it possible to detect students previously diagnosed with dyslexia and/or those with reading difficulties among this population. The other way is the detection of *learning styles*, i.e., the strengths (or preferences) of these affected students. In this sense, several studies have demonstrated the relevance of detecting the learning style of these students to identify the most effective learning strategies they could use to learn (Mortimore, 2008; G. Reid, 2001; Rodríguez, 2004). Many students with dyslexia and/or reading difficulties have acknowledged that using learning style has helped them to understand the ways in which they learn, to understand their strengths, even their weaknesses, and to develop appropriate strategies (Cooper, 2006; Sumner, 2006). There are many models to detect the learning style (Coffield et al., 2004; Mortimore, 2008; Rodríguez, 2004), it is highlighted the revised version of the Felder-Silverman model (Felder & Silverman, 2002) for reasons such as: it has been tested with dyslexic students (Beacham et al., 2003), it is easy to administer and takes short time, it is also easy to fill-in, it has tested in electronic form, it has been validated and shown to produce reliable results, it has been validated and tested in e-learning systems, and it provides a common language for teachers and students.

In this dissertation, firstly, a tool to capture the student's demographics was implemented. For this, a set of forms that capture personal details of the students such as name, sex, birthdate, country, institution, academic level, among others was proposed. Secondly, a tool to detect reading difficulties among university students was implemented. For this, ADDA, a self-report questionnaire to detect dyslexia in adults (acronym for Spanish name *Autocuestionario de Detección de Dislexia en Adultos*) was proposed; this self-report inquires about school life and learning experience, history of learning disabilities, current reading difficulties, associated difficulties, family history of learning disabilities, and reading and writing habits. Using ADDA the student's reading profile is defined. Thirdly, the Felder-Silverman model to detect learning style of the students was implemented. For this, author make a Spanish translation of the Felder-Silverman's Index of Learning Styles (ILS) (Felder & Silverman, 2002), and for practical purposes it was called ADEA, self-report questionnaire to detect learning styles (acronym for Spanish name *Autocuestionario de Detección del Estilo de Aprendizaje*). In particular, this tool classifies different kinds of learning styles along four dimensions: processing (active or reflective), perception (sensitive or intuitive), input (visual or verbal), and understanding (sequential or global).

Both ADDA and ADEA are self-report questionnaires, which were administered using a web-based software, called detectLD (Mejia, Clara, et al., 2011). Basically, it was designed and developed detectLD (acronym for *software tool to detect learning difficulties*) for the creation and results analysis of self-reports related to LD (e.g., for dyslexia, dyscalculia, dysphasia, and attention deficit disorder). But later its approach was extended to support other self-reports as the ILS.

4.2 Demographics Data Forms

Demographics are descriptive data of the personal details of students. This information is important because it provides general knowledge about each student at a given moment in time, like age, gender, and academic level, etc. In this work, a web-based tool to capture these personal details was implemented. Table 4-1 describes the variables used to store data of the proposed demographics submodel into the learner model.

Table 4-1. Demographics data

Variable	Description
identifier	Unique number that identifies the student. It is simply a small number that is stored in a database and increased by one for each new student registered. This number might be 5 digits, starting 1.
first_name	Given name of the student. It is a text field in the database.
last_name	Family name of the student. It is a text field in the database.
sex	Gender of the student. There are 2 posible values: male, female.
birthdate	Date of birth of the student. It follows the ISO standard of yyyy-mm-dd.
country	Country of birth of the student. There are over 100 countries that student can chose.
city	Hometown of the student. It is a text field in the database.
institution	University of the student. There are 4 universities participating: University of Girona, University of La Laguna, University of Cordoba, and University of Las Palmas de Gran Canaria.
academic_level	Academic level of the student. There are 3 posible values: bachelor's degree, master,

Variable	Description
	doctorate.
academic_program	Academic program in which the student is enrolled. There are over 30 programs that student can chose. For example, Architecture, Electrical engineering, Tourism, Biology, Law, etc.
course	Academic year that the student is performing. There are 5 posible values: 1, 2, 3, 4, or 5.
username	Short name required to log on. It is a text field in the database.
password	Encrypted word required to log on. It is a text field in the database. This might be 8 digits.
email	Email address of the student.
date	Date of registration of the student. It follow the ISO standard of yyyy-mm-dd.

The student's demographics information is captured when a student is registered. Thus, the data can be seemed as the primary data that is captured by a system so as to have a register profile of the user. The mechanism used to capture this information is by means of filling a form when students start work in tools of the framework.

4.3 DetectLD: Software Tool to Detect Learning Difficulties

Author was initially interested in detecting the university students that could have LD (i.e., dyslexia, dysgraphia, dysorthography or dyscalculia), in an easy, in a short time and reaching many of them. As mentioned before, in Spain, university students are not asked for this information when entering the university, and therefore the number of specific cases in university classrooms is unknown. Therefore, detectLD was introduced; a software tool that takes advantage of web-based technologies for easy access and distribution of this type self-reports questionnaires.

In particular, detectLD allowed the creation, delivery and review of the results of a self-report questionnaire for detection of reading difficulties. In addition, it also allowed to be embedded a Spanish translation of the ILS. In next section the architecture and the modules of detectLD as well as its implementation and testing are described.

4.3.1 Architecture and implementation

The main objective of detectLD is to enable the creation, delivery, and review of the results of the self-report questionnaires for university students. Therefore, here author defines some functional and nonfunctional requirements of it, and specify its behavior using the Unified Modeling Language (UML):

- Roles: since detectLD is a web-based tool that creates self-reports to check for possible reading difficulties and learning styles in the university context, it can define three types of users: Experts, or users responsible for performing tasks related to creating self-reports and checking the results; Teachers, or users responsible for scheduling and activating the self-reports in their classes and checking overall results of the course; and Students, or users who respond to the self-reports activated by the teachers.
- Platform: open source technology was used: the Apache Web Server[1] which has support for PHP[2] scripting language and the relational database management Postgres[3], all installed on a Linux Operating System server.

[1] http://www.apache.org/

- Use cases: in order to specify and detail the behavior of detectLD, some use cases for the software tool was defined. They have been organized into different functional groups for better interpretation, as shown in the use case diagram in Figure 4-1.

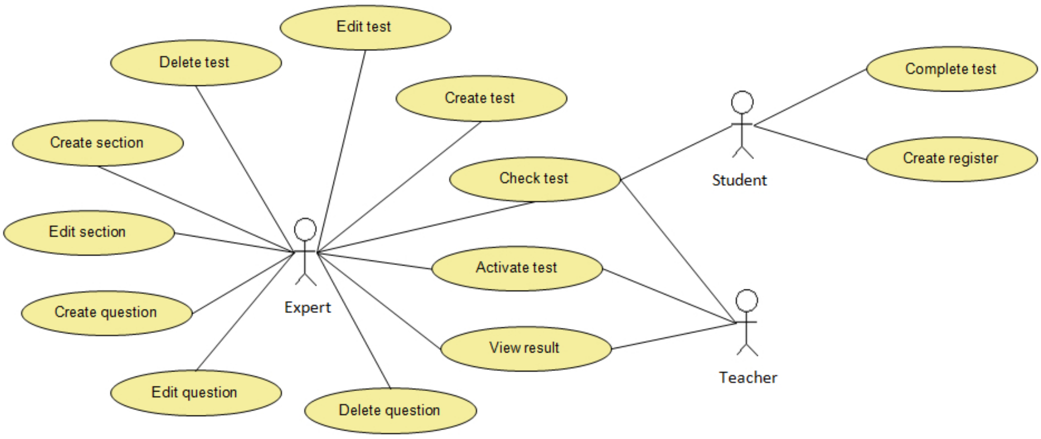


Figure 4-1. Use case diagram of detectLD

The architecture of the software tool is designed to facilitate interaction between the different modules in relation to the user who uses them. For each type of user a different interface is presented depending on the permissions and tasks that can be developed. In the architecture it is specified the behavior of the tool, summarizing both the components and the relationships. In Figure 4-2 the components comprising the architecture are shown: 1) the expert module, 2) the teacher module, 3) the student module, 4) a web server that supports the tool and 5) a database.

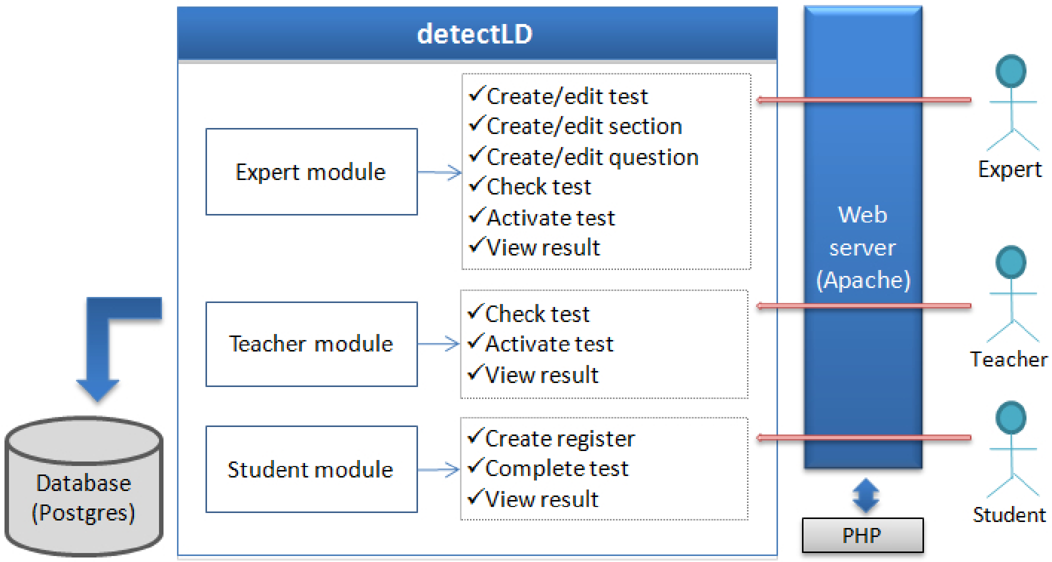


Figure 4-2. DetectLD's architecture

[2] http://www.php.net/
[3] http://www.postgresql.org/

As can be seen in the use case diagram in Figure 4-1, detectLD has three main modules with functions in accordance with the tasks to be developed for each previously defined role. These modules are described as follows:

Expert module: This module was designed and implemented for the exclusive use of a subject matter expert (e.g., an educational psychologist). The module allows the creation of different self-reports (in this case ADDA and ADEA). According to the use cases presented for the experts in Figure 4-1, experts can create different self-reports (see a in Figure 4-3), divide them into sections or issues to be assessed (see b in Figure 4-3), create different types of questions (yes/no, single choice, multiple choice and open-ended), make changes or deletions (see c in Figure 4-3), and check (consult and analyze) the results of the self-report (see d in Figure 4-3).

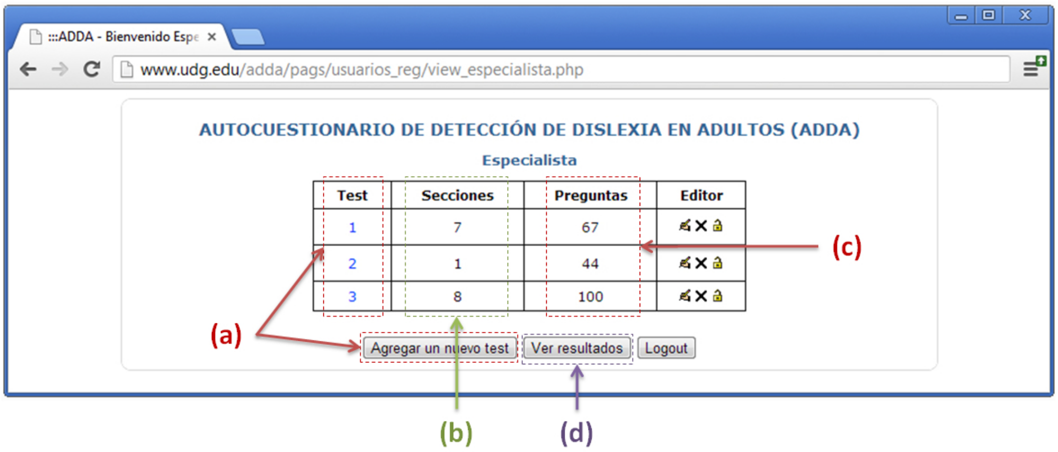


Figure 4-3. DetectLD interface: Expert module

Teacher module: This module was designed and implemented for the teacher who can see the different self-reports (see a in Figure 4-4) as well as view the overall results of the course (see b in Figure 4-4). Also, the teacher is responsible for activating the self-reports to be completed by the students (see c in Figure 4-4).

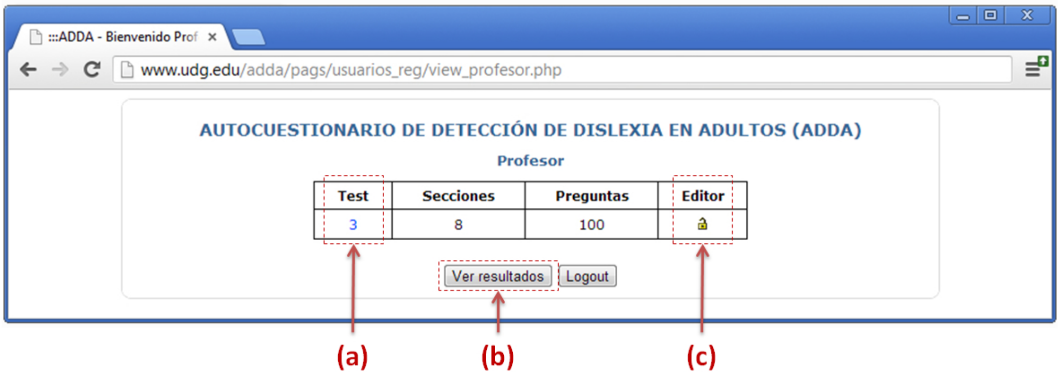


Figure 4-4. DetectLD interface: Teacher module

Student module: This module is exclusively used to complete the self-reports that have been previously activated by the teacher. Initially this module asks the students some demographics (academic program, date of birth and sex) if they have not filled them before, and then it presents the interface to complete the self-report. Figure 4-5 shows the initial interface of this module, and Figure 4-6 shows the interface to start filling in the self-report.

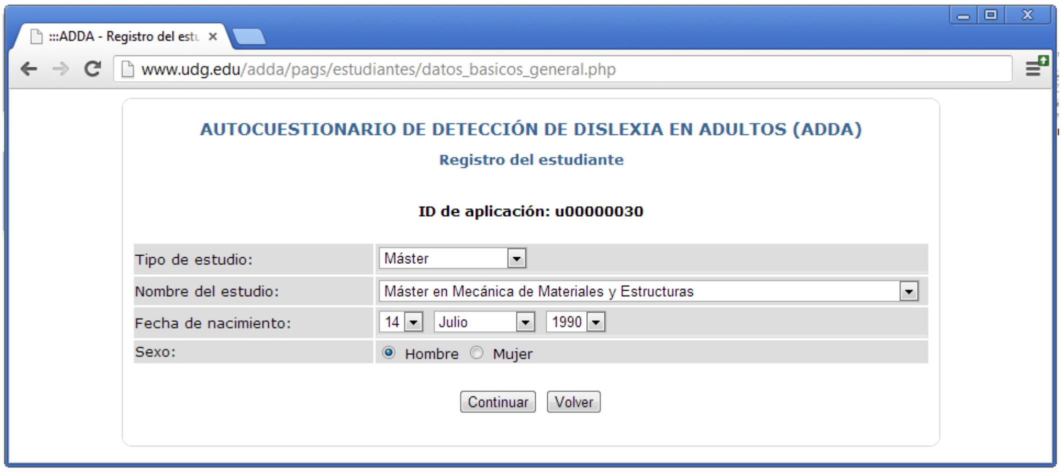


Figure 4-5. DetectLD interface: Student module

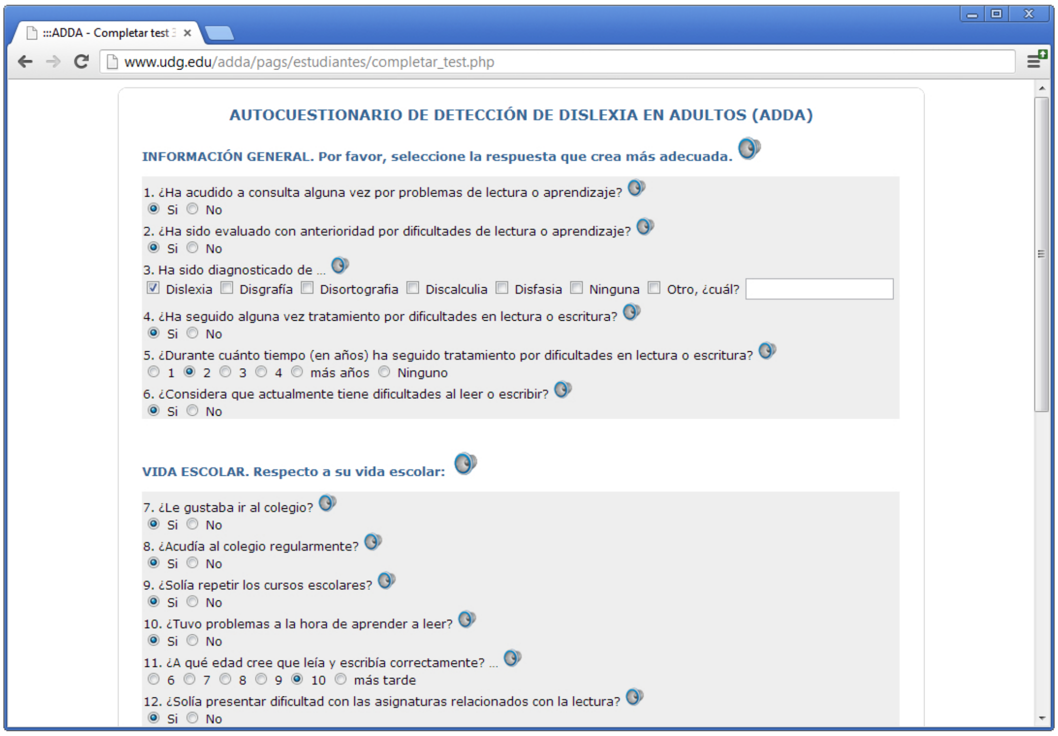


Figure 4-6. DetectLD interface: Example of self-report questionnaire

DetectLD was implemented with standard technology and considering characteristics of reusability, interoperability, accessibility, and extensibility, so that it was easy to integrate into the structure of a LMS. In this research work a particular case was built with the patterns of Moodle styles so that later it could be integrated with this LMS.

- Interface based on XHTML and CSS. The main programming technologies considered for the development of the user interface are: 1) XHTML markup language with content-oriented structure for the presentation of documents via the Web, and 2) CSS to create style sheets for the presentation of content regardless of the structure of the page content (so it can separate presentation and content layers).
- PHP and JavaScript. PHP is used to manage the site structure and dynamics of the application and generate greater interactivity in the interface (part of the password encrypting and dynamic presentation of the contents in function of the data stored in the database, such as different questions and results). JavaScript was used mostly for the validation of forms and for part of the password encrypting.
- Asynchronous communication with the server via XML. AJAX technology enables communication with the server with asynchronous JavaScript and XML and using the XMLHttpRequest object. This technology was used to increase interactivity with the user interface, allowing the partial updating of websites without having to reload the entire page (i.e., reloading some forms according to what the user has chosen in other forms on the same page, without refreshing it).

During the implementation phase of the detectLD, the different modules separately were tested. These tests revealed the need for changes in interface design and programming to achieve a better tool performance. The types of tests used were: connection to the database, requirements, inspection software/programming and functional testing of the different parts (such as creating/deleting new tests, adding/changing sections or adding/changing/deleting questions).

To test the real-time performance and usability (Sauro & Kindlund, 2005) of detectLD, a case study was designed with 17 students from the University of Girona. More than 5 students were asked to carry out this case study, because according to Nielsen (2000), Spool and Schroeder (2001), and Virzi (1992), the functionality and usability tests with at least 5 students provide the most information about the problems presented by the tools. The case study is presented in the next section.

4.3.2 Case study: functionality and usability

This case study had three objectives: to test the functionality and the usability of detectLD, to check the comprehensibility of ADDA (i.e., how easy it is to read this self-report by the students), and to calculate the average time that the students take to complete it.

4.3.2.1 Method

Seventeen students from the University of Girona participated in the case study. For this sample both male and female students from different academic programs and levels, aged between 20 and 30, were selected. Whether or not the student had dyslexia was not taken into account, because the aim of this case study was to assess the functionality and usability of detecLD, how well students understood the questions in the self-report and how long they could take to complete the self-report.

Two examiners (i.e. trained university teachers) conducted the case study. The first examiner was responsible for applying the self-report to undergraduate students, while the second examiner was in charge of graduate students. During the case study, students were accompanied by an examiner experienced in managing detectLD and responsible for taking note of possible questions and problems of the students while they are using the software tool and filling in the self-report. When students have completed the self-report, the examiner gives them a survey to fill in by hand and intended to evaluate the functionality and usability of the software tool and whether or not they understood the questions in the self-report.

The survey used to gather student comments consisted of seven evaluation questions. The students chose the most appropriate response on a scale of 0-4 based on their perception. In addition, at the end of the survey a space was left where the students could include more comments if they wished.

4.3.2.2 Results

The time each student took to fill the self-report was recorded automatically. It was found that students could complete it in 8 to 12 minutes, a relatively short time. The students' answers showed that none of the seventeen who filled in the self-report had potential reading difficulties, which means that the time taken to complete the form by students with dyslexia could be longer. Examiners also noted that detectLD was very user friendly and intuitive: the students never had questions about how to access and complete the self-report. Finally, the examiners reported that students only had difficulty with specific questions, which were subsequently reviewed and restructured by the expert psychologists.

The survey's results showed a good level of usability of the tool as well as a good understanding of the questions in the self-report. The results obtained of the questions are presented in Table 4-2.

Table 4-2. Results of the case study survey filled in by students

Evaluation questions	No				Much	Satisfaction
	0	1	2	3	4	
Do you think the self-report seemed easy to fill in?			1	2	14	94.118%
Do you think the self-report took short time to fill in?		2		6	9	82.353%
Do you think the questions were easy to understand?				4	13	94.118%
Do you think the font size of the questions was appropriated?		2	2	4	9	79.412%
Would you recommend that somebody (friend, relative or other) fill it in?	2		1	7	7	75%
Did the topic of the self-report make you feel motivated to fill it in?		1	3	5	8	79.412%
Do you think the focus of the report (reading difficulties detection) is important?			3	2	12	88.235%

With the survey responses the satisfaction percentage of the students about each question was calculated. The formula to calculate this satisfaction percentage was:

$$\% \text{ Satisfaction} = 100 * (R1*0 + R2*1 + R3*2 + R4*3 + R5*4) / (N*4)$$

In the formula R1, R2, R3, R4 and R5 represent the 5 possible responses that can be given to each question (R1=number of cases in 0, R2=number of cases in 1, and so on), N is the number of students who responded to the survey (17 students), and the multiplying numbers are the values assigned to each type of response (scale of 0 to 4). These results showed that the satisfaction percentage of students is quite high in terms of usability of detectLD and comprehensibility of the questions.

In addition to the results obtained in the above table, each of the comments the students included on the survey answer sheet also were analyzed. In general the results were very positive, except for some comments on the wording of questions; the students did not understand some of them well. Finally, some students expressed interest in knowing the results of the self-report and the steps taken to follow it up.

4.3.2.3 Discussion

The case study helped us appreciate the functionality and the usability of the software tool as well as the effectiveness of the self-report and led to suggestions made and improvements recommended by the students and the examiners.

Based on the satisfactory results, this software tool was also used to embed ADEA. Furthermore, it is believed that this tool can be used as a generic software tool to embed different self-reports (e.g., dyscalculia, dysphasia, and attention deficit disorder).

Minimal changes were made based on the findings of the case study. Only six questions were found ambiguous or difficult to understand. These questions were subsequently reviewed and restructured before being included in a new version of ADDA.

In conclusion, the results obtained in this case study helped us improve the detectLD software tool and ADDA in order to use it with more groups of university students.

4.4 ADDA: Self-report Questionnaire to Detect Dyslexia in Adults

The results from previous research studies have highlighted the usefulness of self-report for detecting students who may have dyslexia. Since, at present, there is no such tool adapted and standardized to the adult Spanish-speaking population, in this dissertation, it was proposed a self-report for detecting students with reading difficulties who may have dyslexia.

Although self-report are unable to provide a diagnosis, they are easy and quick-to-use tools to recognize students with limited reading abilities, and the difficulties exhibited by this population. These attributes make them handy tools to assign students with dyslexia symptoms into study groups for further in-depth assessment, and to provide specialized advice and feedback to overcome their difficulties.

This study is focused on testing the usefulness of a self-report questionnaire to detect dyslexia and/or reading difficulties in university students. It was also intended to identify the most common difficulties presented by these students, and their distribution across university programs. Therefore, the aim in this study was proposing such self-report and providing different feedback to students based on two reding profiles, namely: students reporting current reading difficulties (Profile A), and normal readers (Profile B), i.e., students with and without symptoms of dyslexia respectively.

This aim will be pursued using as main reference the ATLAS, self-report questionnaire of reading disorders for Adult (acronym for Spanish name *Cuestionario de Autoinforme de Trastornos Lectores para Adultos*), a self-report designed for screening purposes and successfully used at the University of Malaga (Giménez de la Peña et al., 2010). So, ADDA was created, based mainly on such self-report. It was available in both a paper-based version and a computer-based application form (i.e., using web-based software).

The analyses of the students' answers would provide information about the reading and writing skills of the university population and allow evaluating the usefulness of this self-report as a tool to detect students who may have dyslexia.

4.4.1 Study description

The present study focused on the difficulties students find when reading or writing a text. Students were questioned about their school life and learning experiences, their history of learning disabilities, current reading difficulties (e.g., reading disorders related to vocabulary, reading comprehension, oral reading fluency, writing, and spelling), and difficulties in associated areas such as speech, working memory, attention, and spatial organization are also explored. There are some questions about any similar incidences in their families, and respondents' reading and writing habits. In addition, although the questionnaire was written in Spanish, as the students in the sample were balanced bilinguals (i.e., Catalan and Spanish speakers), they were also asked about their mother tongue in order to collect this descriptive data in this research study. A complete description of the self-report is presented in next section.

In summary, with ADDA we can: estimate the percentage of students at the university that inform of having dyslexia, know the most common reading difficulties presented by university students, and identify the student's reading profile.

4.4.2 Method

4.4.2.1 Participants

Five hundred and thirteen first year students (257 male and 256 female) from 23 classrooms of different programs at the University of Girona with ages ranging from 18 to 58 years (M=20.91, SD=4.314) participated in this study. Students were all the attendants of the classroom where the questionnaire was applied. Students who reported having sensory, neurological, or other disorders were excluded from the sample. Only 58 students used the computer-based version, while the remaining students used the paper version. Frequencies and percentages by Faculty, Academic Program, and gender are shown in Table 4-3.

Table 4-3. Frequencies and percentages of participation by faculty, academic program, and gender

Faculties and/or Schools	Academic program	Frequency	Gender		%
			M	F	
Polytechnic School	Architecture	5	5	0	1.0
	Electrical Engineering	18	17	1	3.5
	Industrial Electronics and Automatic Control Engineering	25	22	3	4.9

Faculties and/or Schools	Academic program	Frequency	Gender		%
			M	F	
	Computer Engineering	94	78	16	18.3
	Mechanical Engineering	31	26	5	6.0
	Chemical Engineering	16	12	4	3.1
	Total	**189**	**160**	**29**	**36.8**
Faculty of Tourism	Tourism	15	5	10	2.9
	Total	**15**	**5**	**10**	**2.9**
Faculty of Science	Biology	13	4	9	2.5
	Biotechnology	10	6	4	1.9
	Environmental Sciences	6	2	4	1.2
	Chemistry	7	5	2	1.4
	Total	**36**	**17**	**19**	**7**
Faculty of Business and Economic Sciences	Business Administration and Management	27	9	18	5.3
	Economics	23	14	9	4.5
	Total	**50**	**23**	**27**	**9.8**
Faculty of Law	Criminology	30	9	21	5.8
	Law	55	21	34	10.7
	Total	**85**	**30**	**55**	**16.5**
Faculty of Education and Psychology	Pedagogy	35	3	32	6.8
	Psychology	50	14	36	9.7
	Social Work	53	5	48	10.3
	Total	**138**	**22**	**116**	**25.8**
Total		**513**	**257**	**256**	**100.0**

4.4.2.2 Instruments: ADDA

As it was previously mentioned, ADDA was designed and built using as references the tool proposed in (Giménez de la Peña et al., 2010), called ATLAS. Nevertheless, other published questionnaires were reviewed: the Adult Dyslexia Checklist (Vinegrad, 1994), the questionnaires by Lefly and Pennington (2000), the one created by Mcloughlin, Leather, and Stringer (2002), the Dyslexia Questionnaire (Wesson, 2005), and the Learning Styles Self-Assessment Questionnaire (Marken, 2009). The guidelines established by the World Health Organization (WHO), American Psychiatric Association (APA), National Joint Committee of Learning Disabilities (NJCLD), and the National Reading Panel (NRP), as well as recent reviews of the definition of dyslexia (Beatty & Davis, 2007; Jiménez & Artiles, 2007; Sally E. Shaywitz et al., 2008; Snowling, 2000) were also consulted. However, major aspects were taken from ATLAS. Additionally, ADDA was specially designed to identify university students and covered a wide range of aspects.

ATLAS consisted of a list of 50 statements to be answered by making the most suitable choice. The questions covered a wide range of aspects organized into six sections: school and learning to read experience; history of learning disabilities; current reading difficulties; associated difficulties; history of family learning disabilities; and work experience. Finally, a set of questions concerning reading habits to estimate the respondents' exposure to print.

Several changes were introduced in ADDA. Major changes concerned the introduction of questions about writing skills, since students are usually evaluated on the basis of written material (essays, exams). In other words, student achievement is determined not only by their reading skills, but also by their performance on tasks that require a written answer.

In addition, it is well known that reading and writing skills are closely related; poor readers are also less successful in writing tasks than their peers (Berninger, Nielsen, et al., 2008; Berninger, Winn, et al., 2008; Hatcher et al., 2002). Moreover, in accordance with common practice, dyslexia entails not only reading difficulties. It is commonly associated to disorders of writing skills (Høien & Lundberg, 2000; Lindgrén, 2012). Thus, in order to gather information about a wider range of skills, 26 questions were added. More specifically, ADDA included 10 questions about writing difficulties, 3 about writing habits, 4 about reading, and 4 more about associated difficulties. Furthermore, the balanced bilingualism (Spanish-Catalan) that characterizes the population of Girona made of special interest the introduction of 3 questions concerning mother tongue and second language learning and use. A question about the most difficult subjects during the school years was also included. Finally, respondents were asked about their hand preference. The questions related to work experience were removed. Thus, the final version consisted of 67 items that inquired about 7 aspects (see Appendix A):

Section 1. School and learning to read experience (9 items). This section inquires about the student's experience at school, learning to read and write, mother tongue, and learning other languages.

Section 2. History of learning disabilities (6 items). This explores whether students had been previously diagnosed with specific learning disabilities such as dyslexia, dysorthography, dysgraphia, and/or dyscalculia, and if they had received treatment.

Section 3. Current reading-writing difficulties (26 items). The respondents identify which of the difficulties expressed by the statements best describes their reading and writing skills. This section contains the critical items on which reading skills are estimated, and which are used for statistical analysis, and interpretation.

Section 4. Associated difficulties (14 items). This section explores four types of difficulties associated with a specific reading and writing disability: speech, working memory, attention, and spatial-temporal difficulties.

Section 5. Family history of learning disabilities (2 items). Since one of the predictors for the risk of a specific reading and writing disability is the appearance of these disabilities in one or more close relatives (parents, siblings, grandparents), this section explores if other family members have difficulty reading or writing or have been diagnosed with learning disabilities, specifically dyslexia, dysorthography, dysgraphia, or dyscalculia.

Section 6. Reading habits (7 items). This section contains questions concerning attitudes (likes and frequency) towards reading.

Section 7. Writing habits (3 items). This section contains questions concerning attitudes (likes and frequency) towards writing.

As it was intended to access as many students as possible, a paper-based and a computer-based application forms were designed. Previous studies have shown that programs supported by new technologies tend to increase students' motivation (Barker & Torgesen, 1995; Macaruso & Walker, 2008; Rojas, 2008; Timoneda et al., 2005; Wise et al., 2000). Furthermore, using a computer facilitates filling the self-report.

4.4.2.3 Procedure

Three examiners (i.e., trained university teachers) received two sessions training to use and instruct the participants how to fill in both versions of the ADDA self-report: paper-based and computer-based. Care was taken not to bias the participants' responses. Then teachers from different faculties and/or schools were contacted to allow the self-report application during their class. Thus, the survey was conducted in several university classrooms.

The paper-based version was given in the classrooms where the students usually attend lectures. The self-reports were answered individually. The examiner gave instructions and remained in the classroom until the participants completed the form. The total time needed to complete it was 20 minutes.

The computer-based procedure was administered using *detectLD* (Mejia, Clara, et al., 2011). Questions were presented in text and audio format. Participants used the mouse or keyboard to choose answers. Thus, the computers had to be equipped with a screen, a keyboard, a mouse, headphones, and an Internet connection. Participants completed this version within 8 and 12 minutes.

One or two examiners remained in the classroom until the questionnaire was fulfilled.

Previously, participants were asked if they have had problems with hearing, vision, motors, or other serious disorders in order to exclude them from the sample.

4.4.3 Results

4.4.3.1 Descriptive analysis

4.4.3.1.1 Prevalence

This study allows determining a percentage of students showing LD at the University of Girona. Items 10, 11, 12, 13, and 15 from Section 2 were intended to explore the students' history of LD. As shown in Table 4-4, author found that 76 participants (14.8%) had consulted a specialist in LD, and 62 (12.1%) had been assessed for some of these disabilities. A total of 59 participants (11.5%) indicated a previous diagnosis of some type of LD (dyslexia, dysgraphia, dysorthography or dyscalculia), but, only 39 participants (7.6%) reported they had received treatment. Moreover, 32 participants (6.2 %) indicated they might have a reading or writing disability, although only 13 of them had been previously diagnosed with a LD.

Table 4-4. Frequency and percentages of students with a history of LD

Item	N=513	%
10. Have you ever visited a specialist?	76	14.8
11. Have you been assessed?	62	12.1
12. Have you been diagnosed?	59	11.5
13. Have you received treatment?	39	7.6
15. Do you think you have a reading or writing disability?	32	6.2

Of the 59 participants with a previous diagnosis of LD (see item 12 in Table 4-4), only 27 (5.26%) reported that they had consulted a specialist, had been assessed, diagnosed and/or had received treatment; and 10 (1.95%) had consulted a specialist and/or had been assessed and diagnosed, but did not report having received treatment. An unexpected result was that 10 participants (1.95%) reported diagnosis and treatment, however they did not reported having visited a specialist or having been assessed. The remaining 12 participants (2.34%) indicated they had been diagnosed, but did not provide more information about their difficulty. The distribution of the 59 participants with a previous diagnosis of LD is shown in Table 4-5. None of these participants reported having more than one of the three diagnoses.

Table 4-5. Frequency and percentages of students with a previous diagnosis of LD

Diagnosis	N=59	%
Dyslexia	27	5.26
Dysgraphia/dysorthography	29	5.65
Dyscalculia	3	0.58

As shown in Table 4-6, it is worth noting that most of the participants who had been diagnosed with some reading and writing disability (i.e., Dyslexia, Dysgraphia or dysorthography), i.e., all those who have difficulties closely related to dyslexia (see Section 2.8.2) were enrolled at the Polytechnic School (30 participants from the total sample, 15.9% by faculty) and the Faculty of Business and Economic Sciences (7 participants from the total sample, 14% by faculty). It is also interesting to note that of these participants, 39.29% (22 of 56) reported having a family member with a LD. Additionally, this study also allowed us to examine the impact of gender, most participants with reading and writing disabilities were males (33 of 56), whereas females reported in fewer cases any disability (23 of 56).

Table 4-6. Frequency and percentage of reading and writing disability diagnosis distributed by faculty and academic program

Faculties and/or Schools	Academic program	Frequency	Reading and writing disability diagnosis		%[a]
			Dyslexia	Dysgraphia/ Dysorthography	
Polytechnic School	Architecture	0	0	0	**15.9**
	Electrical Engineering	3	1	2	
	Industrial Electronics and Automatic Control Engineering	4	2	2	
	Computer Engineering	14	6	8	
	Mechanical Engineering	5	4	1	
	Chemical Engineering	4	3	1	
	Total	**30**	**16**	**14**	
Faculty of Tourism	Tourism	0	0	0	**0.0**
	Total	**0**	**0**	**0**	
Faculty of Science	Biology	0	0	0	**0.0**
	Biotechnology	0	0	0	
	Environmental Science	0	0	0	
	Chemistry	0	0	0	
	Total	**0**	**0**	**0**	
Faculty of Business and Economic Sciences	Business Administration and Management	3	1	2	**14.0**
	Economics	4	1	3	
	Total	**7**	**2**	**5**	
Faculty of Law	Criminology	3	1	2	**10.6**
	Law	6	4	2	

Faculties and/or Schools	Academic program	Frequency	Reading and writing disability diagnosis		%[a]
			Dyslexia	Dysgraphia/ Dysorthography	
	Total	**9**	**5**	**4**	
Faculty of Education and Psychology	Pedagogy	4	2	2	**7.2**
	Psychology	1	0	1	
	Social Work	5	2	3	
	Total	**10**	**4**	**6**	
Total		**56**	**27**	**29**	**10.9**

[a] Percentage of participants with reading and writing disability diagnosis of the total participants by faculty (see Table 1). For example, 0.159 is of (30 participants with diagnosis) / (189 participants of the Polytechnic School).

4.4.3.1.2 Common reading difficulties

Section 3 aim to explore current reading-writing difficulties. Thus, it could be uses as a tool to identify the most common reading difficulties in a population of university students (see Table 4-7). Misspellings were reported by 46.2% of the participants (item 28), 36.5% needed a second reading of the text (item 21), 35.7% found it difficult to use complex sentences (item 36), and 28.1% found it difficult to concentrate (item 24). Only statements with an answer rate above 25% were considered.

However, when the 56 participants previously diagnosed with a reading and writing disability were considered separately, a different pattern of difficulties emerged. In addition to the above descriptions, these participants indicated difficulties related to finding the right word (37.5%, item 39) and acquisition of new vocabulary (35.7%, item 40); difficulties in extracting the idea of a text (35.7%, item 19) or in expressing it (30.4%, item 33); difficulties due to reading at a slow pace (30.4%, item 20) and the tendency to omit and/or confuse letters (32.1%, item 16). In relation to writing, they acknowledged their poor fluency (33.9%, item 32), their illegible writing (33.9%, item 37), and the constant need to check their spelling (28.6%, item 25). These responses are worth noting since they may be an indication of the kinds of permanent difficulties shown by poor readers in spite of years of training.

Table 4-7. Frequency and percentages from items about current reading-writing difficulties

Items		Total sample (N=513)		With reading and writing disability (N=56)	
No.	Item	N	%	N	%
16	I omit and/or confuse letters when reading.	47	9.2	18	32.1
17	I omit and/or confuse words when reading.	51	9.9	14	25
18	I do not understand well what I read.	70	13.6	13	23.2
19	I have difficulties extracting the main idea of a text in a first reading.	121	23.6	20	35.7
20	I have to read slowly to avoid confusion.	122	23.8	17	30.4
21	I usually need to go back to the text.	187	36.5	26	46.4
22	I find it difficult to read aloud.	59	11.5	12	21.4
23	My understanding of a text is better when someone reads it for me.	95	18.5	14	25.0
24	I find it difficult to concentrate on reading.	144	28.1	20	35.7
25	I need to constantly check my spelling.	128	25	16	28.6
26	I omit and/or confuse letters when writing.	41	8	11	19.6
27	I omit and/or confuse words when writing.	36	7	13	23.2

Items		Total sample (N=513)		With reading and writing disability (N=56)	
No.	Item	N	%	N	%
28	I often misspell words.	237	46.2	28	50.0
29	I confuse the order of numbers.	15	2.9	4	7.1
30	I change word order when writing.	14	2.7	7	12.5
31	I have difficulties using punctuation.	59	11.5	13	23.2
32	I find it difficult to write fluently and accurately.	74	14.4	19	33.9
33	When writing, I find it difficult to express myself.	90	17.5	17	30.4
34	I find it difficult to organize an essay.	86	16.8	10	17.9
35	When writing, I find it difficult to distinguish between nouns, verbs, adjectives, and adverbs.	46	9	11	19.6
36	When writing, I rarely use complex and embedded sentences (with more than two verbs).	183	35.7	26	46.4
37	My handwriting is illegible or difficult to read.	126	24.6	19	33.9
38	I frequently mix lowercase and capital letters at random.	44	8.6	10	17.9
39	I find it difficult to find the right word.	115	22.4	21	37.5
40	I find it difficult to acquire new vocabulary.	97	18.9	20	35.7
41	I mispronounce or use the wrong words.	68	13.3	11	19.6

4.4.3.1.3 Profiles of reading difficulties

In order to discriminate between students with and without symptoms of dyslexia, two profiles were defined based on the number of YES responses to the items in Section 3, concerning current reading-writing difficulties.

Profile A includes students who reported having five or more difficulties. These students were advised to seek an in-depth assessment to determine whether or not they have dyslexia and to provide specialized help and feedback to overcome their difficulties.

Profile B includes students who reported not having difficulties or did it in fewer than five items. These students were not advised to seek assessment and/or advice.

All participants were provided with a report (feedback) that explained their profile. The report included the mean frequency of occurrence of any difficulty, so that participants could know how frequent their difficulties were into the general university population.

The information provided in other sections was also included: how they managed during their school years (section 1) or their personal (section 2) and family (section 5) history of LD, as well as what reading and writing habits they have (sections 6 and 7). All these information could be used as criteria to tune up the profiles in a clinical context as well as to facilitate the creation of personalized recommendations from the experts. What is more, answers to section 4 could be used to provide some clues about other difficulties commonly found among people with LD, and could be used to determine the severity of these difficulties. However, this exceeds the goals of this study.

Two hundred and twelve participants (41.3%) were classified in ***profile A***. These participants were recommended for an in-depth assessment to determine whether or not they have dyslexia and to provide specialized advice that could help them overcome their difficulties and improve their academic outputs. The remaining 58.7% were ***profile B*** students.

On the other hand, when the answers given by *profile A* participants in the other sections were analyzed, it was found that 42.5% of them did not fare well during their school years, 25.45% reported a history of LD, and 31.81% reported having a family history of LD. Regarding the answers for associated difficulties, 57.5% of these participants reported four or more difficulties, which could indicate a severe dyslexia. Finally, 12.7% of these participants reported they did not engage in activities related to reading, and 53.1% did not engage in activities related to writing.

Finally, it is worth noting that the mean frequency of occurrence of difficulties in section 3 and 4 reported by the total sample was 4.591 (SD=3.99), and 3.345 (SD=2.37), respectively.

4.4.3.2 *Reliability and correlation analysis*

4.4.3.2.1 Reliability

Cronbach's alpha (α) was calculated to assess the reliability of ADDA. Analyses were performed both taking all the items together and each section separately. The coefficient value for the total self-report questionnaire was 0.850, which indicates satisfactory reliability and demonstrates internal consistency. However, the reliability could be improved to 0.862 if items 36 (*use complex sentences*), 55 (*use a computer*) and 67 (*writing preferences*) were removed. In the analysis by sections, it is worth noting a satisfactory reliability value obtained for section 3 (α=0.842), since it would be used to predict the presence or absence of dyslexia and suggest specialized advice. It is also interesting that sections 2 (α=0.713) and 5 (α=0.579) corresponding to personal and family history of LD have satisfactory values, considering that these are key factors for the detection of dyslexia. Additionally, section 4 (α=0.689) which provide some clues about associated difficulties have a satisfactory value, and it could be used to determine the severity of dyslexia. Section 6 (α=0.533) and 7 (α=0.576) corresponding to reading and writing practices have moderate values. However, section 1 (α=0.167) which refer to school years has a low reliability.

4.4.3.2.2 Correlation

ADDA correlations were calculated using the Kappa coefficient and studying the relationship of items 16-41 to current reading-writing difficulties and previous diagnosis of a reading and writing disability. Correlations are shown in Table 4-8. Items with very low correlations were dropped.

Table 4-8. Correlations between previous diagnosis of reading and writing disability and reported difficulties

Item	R
16. I omit and/or confuse letters when reading.	.278***
17. I omit and/or confuse words when reading.	.176***
18. I do not understand well what I read.	.097*
19. I have difficulties extracting the main idea of a text in a first reading.	.090*
22. I find it difficult to read aloud.	.109*
26. I omit and/or confuse letters when writing.	.148***
27. I omit and/or confuse words when writing.	.216***
29. I confuse the order of numbers.	.070*
30. I change word order when writing.	.163***
31. I have difficulties using punctuation.	.128**
32. I find it difficult to write fluently and accurately.	.192***
33. When writing, I find it difficult to express myself.	.114**

Item	R
35. When writing, I find it difficult to distinguish between nouns, verbs, adjectives and adverbs.	.130**
38. I frequently mix lowercase and capital letters at random.	.115**
39. I find it difficult to find the right word.	.116**
40. I find it difficult to acquire new vocabulary.	.143***

*$p < .05$.**$p < .01$.***$p < .001$.

The items with a higher correlation were confusing letters (r=0.278, p< .001), or words (r=0.176, p <.001) when reading; omitting and/or confusing words (r=0.216, p <.001), omitting and/or confusing letters (r = 0.148, p <.001) or changing word order when writing (r=0.163, p <.001), lack of fluency and accuracy (r=0.192, p < .001), and poor acquisition of new vocabulary (r=0.143, p < .001). Thus, it is expected that these items might best discriminate between students with and without reading and writing disabilities.

One-way ANOVAs confirmed that having a previous diagnosis of reading and writing disability influences affirmative answers in items 16 (F=43.086, p < .001), 17 (F=16,367, p < .001), 26 (F=11,826, p < .001), 27 (F=26,479, p < .001), 30 (F=23,558, p < .001), 32 (F=20,053, p < .001) y 40 (F=11,801, p < .001). It was also found a main effect in items 31 (F=8,582, p < .01), 33(F=7,207, p < .01), 35 (F=8,895, p < .01), 38 (F=6,971, p < .01), and 39 (F=8,324, p < .01). As expected, items 20, 21, 23, 24, 25, 28 and 34 obtained low scores. This could be interpreted as a lack of relationship with having been previously diagnosed.

4.4.4 Discussion

The present study was designed to assess the usefulness of ADDA as a tool for detecting students with reading difficulties. To do that, first, it was estimated the proportion of students with and without previous diagnosis of reading and writing disability (i.e., Dyslexia, Dysgraphia or dysorthography) at the University of Girona, and their distribution across university programs. Second, it was explored the most common reading difficulties. Third, two profiles were defined: Students reporting current reading difficulties (Profile A), and normal readers (Profile B), and feedback was provided to every student. Finally, reliability and correlation analysis were made in order to assess the items of ADDA, one-way ANOVAs were also calculated.

As earlier studies (Corley & Taymans, 2007; Heiman & Precel, 2003), it was intended to characterize adult populations. The results showed a high percentage of students who reported a previous diagnosis of LD (Allor, Fuchs, & Mathes, 2001; Bassi, 2010; Hatcher et al., 2002; Jameson, 2009; Kalmár, 2011; Madaus, Foley, Mcguire, & Ruban, 2001; Scanlon et al., 1998). There was a prevalence of reading and writing as opposed to other types of disabilities, e.g., mathematics (Díaz, 2007; Gregg, 2007; Roongpraiwan, Ruangdaraganon, Visudhiphan, & Santikul, 2002; Sally E. Shaywitz, 2005; Sparks & Lovett, 2010). It is also worth noting that these results were consistent with results reported by some epidemiological studies (see Section 2.8.4).

Unexpectedly, there was a weak relationship between having a diagnosis of reading and writing disability in the past and receiving treatment. Most students with a previous diagnosis had not received suitable training to cope with their difficulties, so they had to develop their own strategies to succeed in their secondary school studies and to start a university program (Lefly & Pennington, 1991; Ransby & Swanson, 2003). These results revealed the lack of well-defined procedures for establishing the diagnosis of reading and writing disabilities and the absence of strategies for tracking previously diagnosed students. Therefore, it is clearly important to establish university programs to provide advice and support. In this sense, the use of self-report questionnaires could be effective tools to detect students, as has been verified in Gilger et al. (1991), Gilger (1992), and Lefly and Pennington (2000).

Students' perceived ability to read and write undoubtedly plays an important role when they have to choose an academic program (Ingesson, 2007; Mcloughlin et al., 2002). Since reading is one of the most resources used during school life in any academic program, it tend to think that engineering careers as well as those related to numbers offer less demand on reading, while careers of the health and humanities areas offer increased reading load. Thus, it is believed that most students with a previous diagnosis of dyslexia or some reading difficulties prefer academic programs with low demands on reading skills. This preference is clearly observed since most of the students classified in *Profile A* (i.e., students with some reading difficulties) of this sample were enrolled at the Polytechnic School and the Faculty of Business and Economic Sciences.

Another interesting observation concerns to family history. The findings underline the effect of familial risk of dyslexia: a representative percentage of affected students reported that their relatives were also affected. This result is relevant since previous studies had considered having a family history of LD one of the best predictors for the presence of reading and writing disabilities (DeFries & Gillis, 1993; Lefly & Pennington, 2000; R. Olson & Byrne, 2005).

Regarding students' gender, a higher rate of males than women reported having difficulties, as has often been found in previous studies (Allred, 1990; Newman, Fields, & Wright, 1993).

There were some difficulties commonly reported. Declaring *having misspellings, needing a second reading, finding it difficult to use complex sentences,* and *finding it difficult to concentrate* was independent of the students' reading status. However, items such as *I omit and/or confuse letters when reading, I omit and/or confuse words when writing, I omit and/or confuse letters when writing,* and *I change word order when writing* were reported almost three times more frequently by students with a previous diagnosis (Ahissar, 2007; Démonet, Taylor, & Chaix, 2004; Goswami, 2011; Ramus et al., 2003). These students also reported difficulties that show their inability to accurately access words and letters, to speak fluently, and to read efficiently. As a consequence, these items could be regarded as criteria to discriminate between students with and without diagnosis of dyslexia

Altogether, these results point out, once again, that difficulties do not disappear with age or training. On the contrary, compared to their peers students with dyslexia, despite their efforts, show a rather poorer performance (Bekebrede, Van Der Leij, Plakas, Share, & Morfidi, 2010; Goswami, 2010; Hatcher et al., 2002; Lyon et al., 2003; Miller et al., 2006; Miller-Shaul, 2005; Ramus et al., 2003; Sally E. Shaywitz et al., 2003, 2008; Simmons & Singleton, 2006; Wolff & Lundberg, 2003). On the other hand, there is some evidence that students make accurate reports of their abilities. First, all of the students with a previous diagnosis were classified as *profile A*. Second, the reported difficulties were not equally distributed among students. Common difficulties such as *having misspellings* were frequently reported, while those related to *word or letter scrambling* were mainly reported by students who had been previously diagnosed.

Furthermore, the average number of difficulties reported did not exceed 4, so having five or more difficulties, as it is assumed, could be regarded as an appropriate criterion to include the students within the group of *Profile A*.

Finally, it is worth noting that correlations between reported difficulties and previous diagnosis of reading and writing disability were associated with the common difficulties that were detected. These correlations indicate that higher values (see Table 4-8) are more related to a reading and writing disability; again, the significant correlations were to *word or letter scrambling* as well as *lack of fluency and accuracy* and *poor acquisition of new vocabulary*. Fact which is evidenced with the one-way ANOVAs calculated.

Moreover, the satisfactory reliability of ADDA and the relatively high alphas in each section give us confidence to develop further research using this self-report questionnaire. It has demonstrated an internal reliability and furthermore of at least 6 of its aspects separately.

Nevertheless, the findings of this study need to be viewed in light of several limitations. First, ADDA is a tool to detect the presence of reading difficulties or subjective symptoms implying dyslexia, which may lead to recommendations for specific testing. Second, as mentioned in Section 2.8, ADDA might also consider motivational and affective aspects, which could be used as criteria to adjust more the reading profiles found and facilitate the creation of personalized recommendations from the experts. Third, although students were balanced bilinguals (i.e., Catalan and Spanish speakers), further research should be carried out to explore the influence of bilingualism on the development of reading-writing skills, specifically in those cases with difficulties.

Hence, it is necessary to continue this research study to consider its validity as a predicting tool using specific standard tests (e.g., performance on a battery of cognitive tasks). Moreover, it is necessary to analyze the influence of new sections in ADDA as "motivation" and "affective", as well as the restructuration of some questions based on the findings of this case study (see Appendix B). Furthermore, it is recommended to study the influence of each section of ADDA for defining the profiles (i.e., Profile A or Profile B). Although the profile currently relies on the analysis of questions in Section 3 (i.e., Current reading-writing difficulties); further analysis can be carried out on other sections to improve the definition of this profile. Future research may provide a clearer picture of the distribution of reading-writing difficulties among Spanish-speaking university students. There is, of course, a need to replicate these findings and to validate them in other university contexts.

4.5 ADEA: Self-report Questionnaire to Detect Learning Styles

Many students with dyslexia have acknowledged that using learning style has helped them to understand the ways in which they learn, to understand their strengths, even their weaknesses, and to develop appropriate strategies (Coffield et al., 2004; Mortimore, 2008; G. Reid, 2001; Rodríguez, 2004; Scanlon et al., 1998). Therefore, in this dissertation, the use of a Spanish translation of the Felder-Silverman's Index of Learning Styles (ILS) (Felder & Silverman, 2002) to detect learning styles of students with reading difficulties who may have dyslexia was proposed.

This tool was selected after reviewing numerous model in electronic and/or paper form (Coffield et al., 2004; Curry, 1987; Graf, 2007; Mejia, 2009; Mortimore, 2008; Rodríguez, 2004; Vélez, 2009), in particular, reasons such as (1) it it has aimed at university students, particularly it has been tested with dyslexic students (Beacham et al., 2003), (2) it is easy to administer and takes short time, (3) it is also easy to fill-in, which helps to avoid biased responses, and (4) it has tested in electronic form, (5) to date, it has been the most validated and tested in e-learning systems (see Table 2-7), (6) it provides a common language for teachers and students to discuss and promote changes in learning-teaching process, and (7) it has been validated, and shown to produce reliable results. In addition, it provides feedback about stratetegies to learn.

This study is focused on testing the usefulness of ILS to detect learning styles in university students with dyslexia symptoms, i.e., reading difficulties. It was also intended to identify the most preferred learning styles of these students. Besides it was intented to inquire whether or not students were satisfied with their learning style.

To achieve these aims, as mentioned above, the ILS also was administered using detectLD (Mejia, Clara, et al., 2011). And for practical purposes this translated and computer-based version was called ADEA, self-report questionnaire to detect learning styles (acronym for Spanish name *Autocuestionario de Detección del Estilo de Aprendizaje*).

The analyses of the students' answers would provide information about the learning style of these students and allow evaluating the usefulness of ADEA as a tool to detect compensatory strategies or preferences in students who may have dyslexia. Thus, issues raised for studying the learning style of students with reading difficulties (see Section 2.9.2.1): How these students learn? How can these students improve their performance? and How to enhance their learning? could be answered.

4.5.1 Study Description

The present study focused on the learning styles of university students who may have dyslexia (i.e., students with symptoms of dyslexia). Students were questioned about four learning dimensions: processing (active or reflective), perception (sensitive or intuitive), input (visual or verbal), and understanding (sequential or global). For each dimension, the students responded 11 questions about their preferred way of learning. The self-report consisted of a total of 44 questions, and it was delivered to students in Spanish language.

4.5.2 Method

4.5.2.1 Participants

Thirty-seven students (18 male and 19 female) of one course at the University of Girona (Spain) and the other at the University of Cordoba (Colombia) with ages ranging from 21 to 53 years (M=26.43, SD=6.067) participated in this study. All these students previously completed ADDA and they were selected because had a *Profile A*: students with symptoms of dyslexia (see Section 4.4.3). Eight students were found with a previous diagnosis of dyslexia, i.e., they had been formally diagnosed with dyslexia during their primary or secondary schooling, through an official psychoassessment procedure. All students used the computer-based version. Frequencies and percentages by university and gender are shown in Table 4-9.

Table 4-9. Frequencies and percentages of participation by university and gender

University	Frequency	Gender		%
		M	F	
University of Girona	26	11	15	70.3
University of Córdoba	11	7	4	29.7
Total	**37**	**18**	**19**	**100**

4.5.2.2 *Instruments: ADEA*

The Felder-Silverman's Index of Learning Styles (ILS) (Felder & Silverman, 2002), called in the cases studies of this dissertation ADEA combines several learning style models in its four dimensions (i.e., processing -*Active/Reflective*-, perception -*Sensitive/Intuitive*-, input -*Visual/Verbal*-, and understanding -*Sequential/Global*-), giving a more detailed description of the students. Additionally, it includes learning strategies, motivation for learning and preferences for organizing information.

Fundamentally, the four dimensions come from the anwwers given by the authors to the questions close to the model of learning styles proposed by Curry (Curry, 1987):

- How does the student prefer to process information?
- What type of information does the student preferentially perceive?
- Through which sensory channel is external information most effectively perceived?
- How does the student progress toward understanding?

This tool is a set of 44 questions which allow inquiring the strategies that a student employs or prefers to select, process and work with information. These questions are organized into groups of 11 to evaluate each of the four dimensions. Each question poses two possible situations as answer. Although an answer does not necessarily exclude the other, students tend to prefer one over another. For example, in the processing dimensión a student can be sometimes active and others reflective, but frequently a preference (strong or moderate) exists for one category or the other. Some studies of Felder (1989; 1990; 1993) have found that the most students (normal students) are visual and sequential. However, a balance of the two values for each dimension and to be able to perform actions in both directions is desirable. In any case, when a preference for one category is strong, the learning process could improve its effectiveness with an instruction adapted to this learning style. Table 4-10 provides the students' preferences in each category and dimension.

Table 4-10. Students's preferences according to learning style

Dimension	Learning style	Preferences
Processing	Active	They prefer to learn by doing and tend to rush into learning situation.
	Reflexive	They prefer to think about the situations on their own before starting.
Perception	Sensitive	They prefer learning facts and solving problems by well-known methods.
	Intuitive	They prefer to discover possibilities and relationships. Initiative students also tend to be more comfortable with abstractions and mathematical detail.
Input	Visual	They prefer to learn using pictures, diagrams, flow charts, time lines, films and demonstrations.

Dimension	Learning style	Preferences
	Verbal	They prefer to learn using words – written or spoken.
Understanding	Sequential	They prefer to learn in linear steps, with each step following on logically from the previous one.
	Global	They prefer to absorb the material randomly without necessarily seeing connections. Global students also tend to learn in large jumps.

The preference for a particular learning style may vary on a scale of 1 to 11, it can be from very strong to almost nonexistent and be sensitive to the time and circumstances of the student.

4.5.2.3 *Procedure*

Two examiners (i.e., trained university teachers) conducted the case study. The first examiner was responsible for applying the self-report in University of Girona, while the second examiner was in charge apply it in University of Cordoba. The self-report was administered individually according to the time available for each participant. It was delivered to participants in Spanish language.

For that, *detectLD* (Mejia, Clara, et al., 2011) was used. Questions were presented in text and audio format. Participants used the mouse or keyboard to choose answers. Thus, the computers had to be equipped with a screen, a keyboard, a mouse, headphones, and an Internet connection. Participants completed the self-report approximately in 10 minutes.

Once the questionnaire was completed by participant, he/she can visualize the generated report and indicates whether or not he/she agree with it.

4.5.3 Results

Table 4-11 shows the types of learning styles preferred by 37 participants. For example, in the processing dimension there were 27 participants (73%) who possess an *Active* learning style preference, 26 (70.3%) who possessed a *Sensitive* learning style preference in the perception dimension, 32 (86.5%) who possessed a *Visual* dimension in the input dimension, and 23 (62.2%) who possessed a *Sequential* learning style preference in the understanding dimension. Thus, participants in this case study tend to be *Active*, *Sensitive*, *Visual*, and *Sequential.*

Table 4-11. Frequencies and percentages of learning styles for the students with reading difficulties

Dimension	Learning style	Frequency	Percentage
Processing	*Active*	27	73
	Reflective	10	27
Perception	*Sensitive*	26	70.3
	Intuitive	11	29.7
Input	*Visual*	32	86.5
	Verbal	5	13.5
Understanding	*Sequential*	23	62.2
	Global	14	37.8

With a few exceptions, the distribution of each type of learning style was shown in broad agreement with the distribution obtained in previous studies for university students

(Baldiris, 2012; Graf, 2007; Peña, 2004). For example, in Baldiris (2012) a sample of 30 participants, 60% of the participants were found to have an active preference, 63.33% a sensitive preference, 83.33% a visual preference, and 53.33% a global preference. In Graf (2007), a sample of 207 participants revealed that 57% of them had an active preference, 58% a sensitive preference, 87% a visual preference, and 56% a global preference. In Peña (2004), a sample of 25 participants showed that tends to be active, sensitive, visual and sequential. According with the results of these studies, there was only a small difference regarding the preference of sequential participants. In this study, the results show that the most participants possess a sequential preference while Graf (2007) found a greater global preference and Baldiris (2012) did not find significant differences.

Figure 4-7 presents the preferred learning style of 8 participants with a previous diagnosis of dyslexia (namely dyslexic) and 29 participants with symptoms of dyslexia (namely possible-dyslexic). According to the results, dyslexic participants tend to be *Active*, *Sensitive*, *Visual*, and *Sequential.* No difference was found in this tendency with the group of possible-dyslexic participants. The most significant difference was in the processing dimension where 34.5% of possible-dyslexic participants were *reflective* while none were found dyslexic. Furthermore, 8 dyslexic participants (100%) favour the *active* and *visual* learning styles while 24 possible-dyslexic participants (82.8%) favour the *visual* learning style. A small percentage of participants in both groups demonstrated a *verbal* learning style.

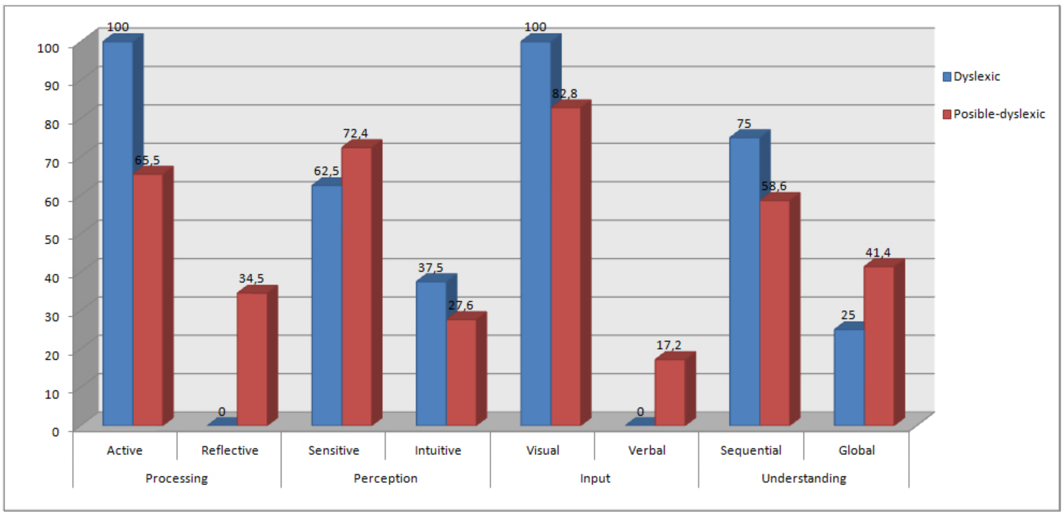


Figure 4-7. Learning styles of dyslexic and possible-dyslexic students

These results in the Figure 4-7 agreed with previous studies (Alty, 2002; Beacham et al., 2003; Mortimore, 2008). There was a small difference regarding the preference of visual students (Alty, 2002). However, in subsequent studies of the author (Beacham et al., 2003), the results shown that the dyslexic participants possess a strong visual preference.

In this study, the visual preference of the dyslexic participants (100%) is stronger than that of the possible-dyslexic participants (82.8%). It was to be expected since dyslexic people do tend to be talented in the areas of creativity and visual thinking (Mortimore, 2008; West, 1997).

There is also a small difference in the preference of sequential learning style compared with other studies (Beacham et al., 2003; Mortimore, 2008). In these studies, dyslexic participants' preferences were skewed towards global students. Further research would need to be carried out in order to assess whether there is a significant difference.

With regard to the question of satisfaction with the learning style, participants indicated being "*satisfied*", "*neutral*" or "*not satisfied*" with their learning style. As shown in Table 4-12, it was found that 35 students (94.6%) were satisfied with the learning style detected. Only 2 students (5.4%) were neutral, and none of the participants indicated being not satified. All dyslexic participants were satisfied.

Table 4-12. Frequencies and percentages of satisfaction with the learning styles

Learning style	Frequency	Percentage
Satified	35	94.6
Neutral	2	5.4
Not satisfied	0	0

4.5.4 Discussion

This study was designed to investigate the preferred learning style of students with symptoms of dyslexia (i.e., students with reading difficulties). It also seeks to know whether students were or not according to the delivered learning style.

Regarding the preference, students showed a preference for learning styles Active, Sensitive, Visual, and Sequential. Separating the sample 8 dyslexics found, it is noted that the learning style preference did not vary for this group. It might indicate that students with reading difficulties, either because they are dyslexics or because they are poor readers, may have similar learning preferences due to reading difficulties presented. However, to reach this conclusion, it is necessary to expand the sample of students and consider if they are really dyslexics or just poor readers. Future work includes the execution of additional experiments with larger samples of university students with reading difficulties knowing if they are dyslexics and poor readers, so as to evaluate their learning preferences. Additionally, it may be interesting to consider the preference for a particular learning style in the scale of 1 to 11 proposed in the model of Felder and Silverman (2002), in order to refine the preferences of each student and provide a tighter feedback. This preference can be set at levels of strong, moderate or mild, in each of the dimensions.

In relation to the degree of agreement of students with learning style delivered, the most students were agreed with their learning styles. However, it is necessary to continue this research study to consider its validity with a large sample of university students with dyslexia.

There is, of course, a need to replicate these findings and to validate them in different academinc programs and other university contexts.

4.6 Summary

Dyslexia often persists into adulthood. Though adult dyslexics are able to compensate with certain strategies, they continue to show several difficulties during the learning process at the university. A review of the literature shown that university students with dyslexia may not have been diagnosed and/or treated before starting their studies at university. Furthermore, in Spain, university students are not questioned about their learning disabilities and specially the dyslexia; therefore, the number of specific cases is unknown. In this chapter three parallel ways for detecting university students with reading difficulties were proposed:

1. Detect their demographics: to achieve this, a set of forms that capture demographics of the students such as name, sex, birthdate, country, institution, academic level, among others was proposed.
2. Detect their reading profiles: since, at present, there is no tools adapted and standardized for detecting adult Spanish-speaking population with reading difficulties who may have dyslexia, in this chapter, a self-report questionnaire, called ***ADDA*** (acronym for the Spanish name *Autocuestionario de Detección de Dislexia en Adultos)* that define two reding profiles, namely: students reporting current reading difficulties (Profile A), and normal readers (Profile B) was proposed. Thus, a first version of ADDA, which consisted of 67 items (see Appendix A), was created, and later, based on the case study presented in this chapter, ADDA version was extended to 100 items (see Appendix B).
3. Detect their learning styles: in this case, the Felder-Silverman's Index of Learning Styles (ILS) was adopted. This is a self-report questionnaire to detect learning styles, which for practical purposes was called ***ADEA*** (acronym for Spanish name *Autocuestionario de Detección del Estilo de Aprendizaje*) in this research work. The Spanish translation of the ILS used in this research work is presented in Appendix C.

Both ADDA and ADEA were administered using a software tool devoted to the delivery and review of self-report questionnaires, called detectLD. This tool was originally designed and developed for storing self-reports related to LD (e.g., for dyslexia, dyscalculia, dysphasia, and attention deficit disorder), but later its approach was extended to support other self-reports as the ILS.

This chapter also presented different case studies in order to test the tools proposed. First, a case study with 17 students from the University of Girona (Spain) allows testing the functionality and the usability of detectLD, to check the comprehensibility of ADDA (i.e., how easy it is to read this self-report by the students), and to calculate the average time that the students take to complete it. Results showed a satisfaction percentage of students quite high in terms of usability of detectLD and comprehensibility of the ADDA's questions. In addition, these results allowed improving this tool with new functionalities in order to use it with more self-reports and university students.

Second, a case study with 513 students from the University of Girona (Spain) allows estimating the percentage of students that inform of having dyslexia, know the most common reading difficulties presented by these students, and identify their reading profiles. This case study endorses the view that adult students are good at assessing their skills. Consequently, ADDA gather the advantages of self-reports. It is easy to administer and short time taken, what makes it a suitable tool for screening university students with reading difficulties from fairly large samples with low cost. It is also worth noting that the responses to ADDA have revealed a number of students with subjective symptoms that have not received any assistance. Then, ADDA may play an important role in screening students that could greatly benefit from advice and training. Furthermore, ADDA explores both reading and writing performances. Dyslexia studies have frequently disregarded spelling or writing. However, it has been noted that while reading ability may improve over time, writing skills often remain poor (Høien & Lundberg, 2000). Finally, it was emphasized the novelty of ADDA, to date, there are no self-reports for adults available with Spanish language background.

Third, a case study with 36 students from the University of Girona (Spain) and the University of Cordoba (Colombia) allows testing the usefulness of ILS to detect learning styles in university students with reading difficulties, identify the most preferred learning styles, and inquire whether or not students were satisfied with their learning style. Results showed that students tend to be *Active*, *Sensitive*, *Visual*, and *Sequential*. This tendency was found in both students with previous diagnosis of dyslexia and students with symptoms of dyslexia. It was also found that all students were satisfied with the learning style detected.

Finally, it was concluded that is necessary to continue these studies to determine the effectiveness of ADDA and ADEA with larger samples of university students with dyslexia. Regarding ADDA consider its validity as a predicting tool using specific standard tests (e.g., performance on a battery of cognitive tasks). In relation to ADEA adjust the preference (i.e., strong, moderate, or mild) in each of the dimensions as well as analyze if it could be applicable in all university programs.

CHAPTER 5

ASSESSMENT OF UNIVERSITY STUDENTS WITH READING DIFFICULTIES

As mentioned in the theoretical foundations of this dissertation, reading is a complex activity that involves different ***cognitive processes*** operating without the student being aware of them and which take place while the eye moves by words. These cognitive processes are: *phonological processing, orthographic processing, lexical access, processing speed, working memory* and *semantic processing*. All these processes are essential for reading comprehension to be successful, and not all students perform them properly, and as a consequence, there are individual differences and hence, reading difficulties that may have a different origin (i.e. different cognitive processes that can be affected) in each case.

Thus, this chapter studies these cognitive processes involved in reading among Spanish-speaking university students with reading difficulties, and proposes to evaluate these processes to identify specific cognitive deficits. On this basis, an automated battery for the assessment of cognitive processes, called ***BEDA*** (acronym for the Spanish name *Batería de Evaluación de Dislexia en Adultos*), which is aims to capture cognitive deficits in these affected students was proposed. BEDA has been built based on a multimodal communication mechanism that delivers evaluation tasks using the visual, auditory, and speech communication channels of human-computer interaction.

The chapter also includes some case studies to test the functionality and usability of BEDA, as well as to recover the score scales defining when a student presented or not a cognitive deficit and to analize and debug the BEDA's items used to assess each of the cognitive processes.

This chapter is structured as follows: Section 5.1 shows a brief introduction about the assessment of university students with reading difficulties. Section 5.2 describes BEDA, its architecture and implementation, as well as the cases studies, one for testing its functionality and usability and other for recovering its score scales and debugging its items. This chapter ends in Section 5.3 with a summary of the chapter.

5.1 Introduction

As mentioned before (see Section 2.8) , dyslexia is a significant LD in the acquisition of reading, writing, spelling, and even speech (Berninger, Winn, et al., 2008; Hatcher et al., 2002; Høien & Lundberg, 2000; Lindgrén, 2012; Lyon et al., 2003), which may be caused by a combination of phonological, orthographic and/or lexical deficits (Booth et al., 2000;

Forster, 1976; Marslen-Wilson, 1987; Swinney, 1979; Waters et al., 1984). Furthermore, it may be accompanied by deficits in the processing speed, working memory and semantic processing (Bar-Shalom et al., 1993; R. Bull & Scerif, 2001; Van den Bos, 1998).

In practice, if students at high risk of dyslexia could be diagnosed and assisted before their deficits impede the acquisition of reading skills, i.e., in primary school, it would be possible to prevent many failures school of these students (Jiménez & Hernández-valle, 2000). However, there are few studies focused on dyslexia in secondary school (Bassi, 2010; Giménez de la Peña et al., 2010; D. González et al., 2010) and little work at the university level (Gregg, 2007; Jiménez et al., 2004; Sparks & Lovett, 2010), which reveal that the assistance initiated in primary school does not continue into secondary school and university. That is, there is no advice or support given after primary school, and older dyslexic students have to cope with their deficits on their own. Moreover, if the student's deficits have not been identified in primary school, they are not likely to be detected later on. Thereby, a considerable number of students whose performance is affected by dyslexia enter university without having a previously diagnosis and assistance.

Therefore, according to what has been presented, it is concluded that: (1) dyslexia affects both children and adults, (2) dyslexia may be caused by a combination of deficits in different cognitive processes, and (3) there is a clear need of high education institutions to provide resources to diagnose dyslexia and identify deficient cognitive processes.

In this sense, the building of an assessment tool of cognitive processes related to dyslexia in university students could represent a useful complementary resource for students affected, as well as for teachers and experts in higher education institutions.

This chapter is focused on designing, developing and evaluating of BEDA, an assessment battery of dyslexia in adults (acronym for the Spanish name *Batería de Evaluación de Dislexia en Adultos*), which is aims to identify the cognitive processes that are deficient in university students with dyslexia. Thereby, this chapter is also intended to design the tasks and items (or exercises) that assess the cognitive processes involved (i.e., phonological processing, orthographic processing, lexical access, processing speed, working memory, and semantic processing). Additionally, this chapter seeks analyze the items used to assess each of the cognitive processes and recover the scores defining when a student presented or not a cognitive deficit.

5.2 BEDA: Assessment Battery of Dyslexia in Adults

According to Jiménez et al. (2004), there are not tools in the Spanish language that assess all cognitive processes (*phonological processing, orthographic processing, lexical access, processing speed, working memory and semantic processing*) in the population of adult dyslexics. Only one approach that adapted a battery from English to Spanish was reported in (Díaz, 2007). Diaz adapted the UGA Phonological/Orthographic Battery developed at the University of Georgia (Gregg et al., 2002), which assesses *phonological processing* and *orthographic processing* to Spanish language. In this thesis, that work and the analysis made in Section 2.9.3.1 of assessment tools to identify LD were used as references so as to create a new battery that assess all cognitive processes involved in reading in adults (e.g. university students). This battery, namely BEDA, involves modules with different tasks to assess *phonological processing* (tasks of segmentation into syllables, phonemes, rhyme), *orthographic processing* (tasks of orthographic choice), *lexical access* (tasks of reading words and pseudowords), *processing speed* (task of visual speed of letters and numbers), *working memory* (task of retaining letters and words), and *semantic processing* (task of reading comprehension), all of which are necessary to identify dyslexia in university students.

BEDA has been developed using web-based technology so as to benefit of the affordances that these technologies (specifically e-learning) can bring to the assessment of cognitive processes. For instance, BEDA can provide precise measures such as the response time for a task item, which is an extremely important measure in reading and otherwise it is very difficult to obtain. In this sense, according to Fawcett, A.J., Pickering, S., Nicolson (1993), "*computer-assisted assessment provides the opportunity to build a new generation of psychometric tests, more sensitive than traditional tests and easier to apply, allowing, also a lower cost assessment for dyslexia (and other problems)*".

Thereby, BEDA has been developed as a psychometric test, since the ultimate goal of this study is to create a standardized procedure consisting of items, selected and organized in tasks, which measure cognitive processes involved in dyslexia in adults. To carry out the standardization of BEDA, an exploratory case study that let managing and evaluates the battery with students of the University of Girona was done. This is further explained in next sections. Moreover, at present more case studies are being conducted at the University of La Laguna and the University of Las Palmas Gran Canaria in order to create a more refined standardized procedure. The evaluation of BEDA have been done in similar conditions for all students examined (normative group), with the goal of creating a scale that serves to diagnose dyslexia and identifying underlying cognitive deficits in the university population. After a standardization process, validity and reliability indexes can be extracted.

5.2.1 Architecture

As mentioned before, BEDA is a computer-assisted tool developed with web-based technology. It main objectives are to assess the cognitive processes that are deficient in students with dyslexia, and allow the students, teachers and experts to review and analyze the results obtained. The architecture of BEDA is modular to facilitate interaction between the different modules. For each type of battery user a different interface is presented depending on the permissions and tasks that can be developed. Figure 5-1 presents the architecture of the battery illustrating the components and their relationships. The components are: 1) *assessment modules*, 2) *management modules*, 3) a *web server* that stores the modules and allows communication between users and the battery by means of a browser, and 4) a *database* where the data from the users, results, history, etc. can be stored.

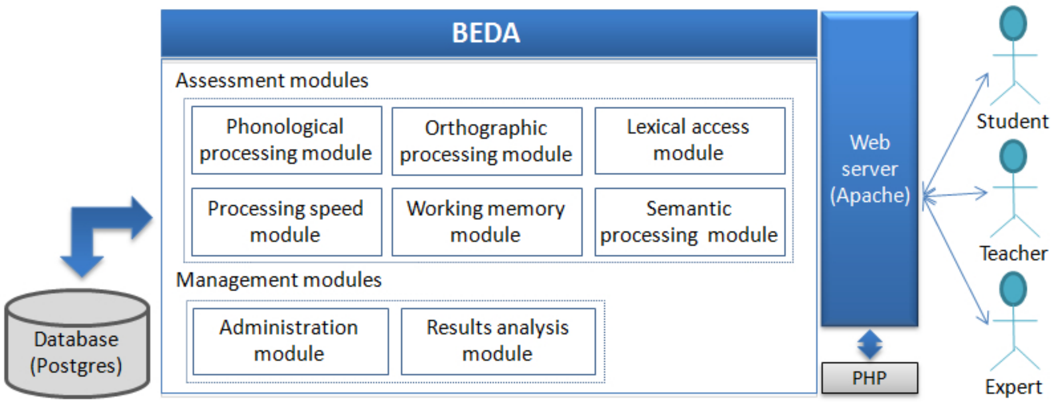


Figure 5-1. BEDA's architecture

Thus, BEDA consists of eight modules: six for the assessment of each cognitive process involved, one for the analysis of results, and one for administration purposes. Each module designed with functions for each user type.

Since the battery is a software tool designed to be used in the university context, three types of users in this context were identified: *Experts*, or users responsible for performing activities related to the creation of tasks, the assessesment of each cognitive process, the definition of the guidelines to present the results of students and teachers, the provision of recommendations that teachers could follow for each student with cognitive deficits, and the checking of student results; *Teachers*, or users responsible for scheduling and activating the battery in their classes, checking the results report of the students, and viewing the recommendations given by experts for each student with cognitive deficits; and *Students*, or users that complete the battery evaluation tasks (activated by the teachers) and check their results report.

5.2.1.1 Assessment modules

BEDA is composed of 15 assessment tasks that can be completed by students 16 years old[1] and older. These tasks are spread over six assessment modules corresponding to each cognitive process to assess (i.e., phonological processing, orthographic processing, lexical access, processing speed, working memory, and semantic processing). In BEDA, these assessment modules are independent modules designed to bring together the different assessment tasks for each cognitive process, as shown in Table 5-1.

The selection of the tasks used to assess each cognitive process is based on the research works of different expert authors in accessing dyslexia in children and adults (Díaz, 2007; E. García, 2004; C. S. González, Estevez, Muñoz, Moreno, & Alayon, 2004b; D. González et al., 2010; Guzmán et al., 2004; Jiménez et al., 2004; Jiménez & Ortiz, 1993; Rojas, 2008). The administration of these tasks could detect and verify if a student has dyslexia and identify the associated cognitive processes that may be affected. Dyslexia detection and verification is the first essential step to intervening with and/or assisting affected students during their learning processes to minimize the negative impact associated with reading difficulties.

[1] 16 years old is the age at which students begin their university careers.

Table 5-1. Assessment tasks for each cognitive process

Modules	Tasks
Phonological processing	• Segmentation into syllables • Number of syllables • Segmentation into phonemes • General rhyme • Specific rhyme • Phonemic location • Omission of phonemes
Orthographic processing	• Homophone/pseudohomophone choice • Orthographic choice
Lexical access	• Reading words and pseudowords
Processing speed	• Visual speed of letters and numbers
Working memory	• Retaining letters and words
Semantic processing	• Reading comprehension of expository and narrative texts

The following paragraphs describe the six assessment modules in BEDA and their corresponding assessment tasks:

- The **phonological processing module** contains seven tasks that assess mental manipulation skill over the segments that belong to speech (phonemes, syllables and rhymes): 1) *segmentation into syllables* (Johnson & Blalock, 1987) requires segmentation into syllables of words which are delivered to the user aurally; 2) *number of syllables* (Johnson & Blalock, 1987) requires counting the number of syllables of aurally presented words; 3) *segmentation into phonemes* (Johnson & Blalock, 1987) requires separating aurally presented words in phonemes; 4) *general rhyme* (Johnson & Blalock, 1987) requires saying three words that rhyme with a word aurally delivered; 5) *specific rhyme* (Johnson & Blalock, 1987) requires comparing two pairs of words aurally presented and indicates whether they rhyme or not; 6) *phonemic location* (Vellutino & Scanlon, 1987) requires comparing two pairs of words aurally presented including a different sound and indicating whether the different sound is located at the beginning, middle or the end; and 7) *omission of phonemes* (Berninger, 1996) requires repeating one word presented aurally, and then repeating the word aurally omitting a segment from it.
- The **orthographic processing module** contains two tasks in which orthographic knowledge of words is assessed: 1) *homophone/pseudohomophone choice* (R. K. Olson, Forsberg, & Wise, 1994), which requires choosing, between two homophones presented visually, the one that is the answer to a question presented aurally; and 1) *orthographic choice* (Stanovich & West, 1989), which requires choosing between two words presented visually the one that is properly written.
- The **lexical access module** consists of two tasks, *reading words* (Guzmán & Jiménez, 2001) and *reading pseudowords* (De Vega et al., 1990), where the user has to read out loud, precisely and quickly, words (or pseudowords) presented visually.

- The **processing speed module** contains one task, *visual speed of letters and numbers* (DeFries & Baker, 1983) that requires the user to select as quickly as possible groups of equal numbers and letters from a set of distractor groups.
- The **working memory module** contains one task, retaining *letters and words* (Berninger, 1996), which visually presents a pseudoword for one second and then requires the user to write the entire pseudoword or just a part of it, according to the instructions presented aurally.
- The **semantic processing module** contains two *text-reading* tasks (expository and narrative texts) that assess reading comprehension. These tasks require the user to answer a list of questions per text.

These tasks have been designed based on multimodal communication that allows students to communicate with BEDA through different modes (visual, auditory, and speech) according to the specific objective of each assessment task. Hence, students are presented with different modes of interaction; some tasks ask them for instructions to follow (inputs) and others to deliver an answer (outputs). For input information the BEDA architecture includes: an automatic speech recognition system called Sphinx4 which converts human speech into individual words (Walker et al., 2004), the insertion of written words and characters for specific commands by means of using the keyboard, and the selection of options using the mouse device. As output information BEDA gives students instructional information, support and guidance using output mechanisms such as text on screen, graphical representation, recorded audio and synthesized voice. Figure 5-2 depicts the channel alternatives for communication between the student and the battery.

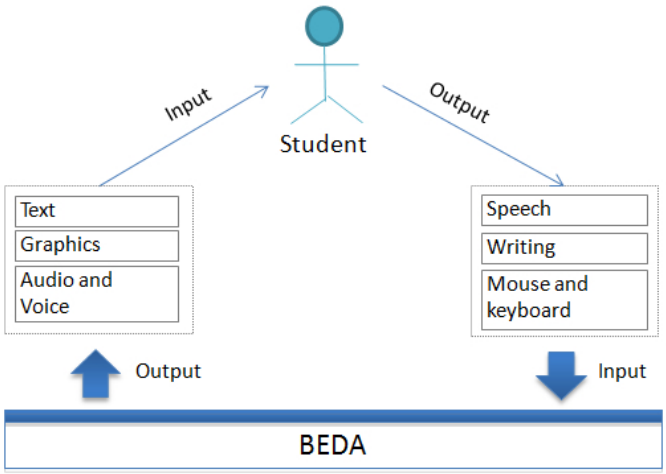


Figure 5-2. Multimodal communication input and ouput

In BEDA, the tasks are composed of different items (or exercises) that students must perform. Every task has an associated message explaining how to do it, and each item of a task has an associated stimulus to complete it (e.g., a word, a question, etc.). Moreover, every item has an associated solution that is used to determine whether or not the student has answered the stimuli correctly. In some cases, the item also has information about the audio of the stimuli, the number of syllables or phonemes of words related to the item, the dictionary and grammar used for the speech recognition system, and/or the syllabic structure, depending on whether the task involves it. Additionally, in every task some example items provide associated feedback in case the user is right or makes a mistake.

5.2.1.2 *Analysis of results and administration modules*

The **analysis of results module** let delivers the students' results report after they have completed the assessment tasks. It automatically generates an individual report for each student with: 1) the scores obtained and the difficulty level (none, slight, moderate or severe) presented on each assessment task, 2) the identification of cognitive processes that are deficient and the specific difficulty level of them (none, slight, moderate or severe) according to the results of the assessment tasks used in each one, 3) overall cognitive performance obtained from the scores of the assessment tasks, 4) the scores profile, 5) the diagnosis of the presence or absence of dyslexia taking into account the criteria set (see Section 2.9.3.2), and 6) a set of recommendations for students based on their difficulty levels of each cognitive process. Moreover, the report explains in detail each of the cognitive processes assessed and interprets the students' scores, and specifies the processes that are more and less dominant for each student and the strong and weak points presented in assessment tasks.

To determine the difficulty level that is delivered to the student in each assessment task and cognitive process, the scores that the student obtained are automatically compared with standardized data considering the student's educational level; i.e., individual results are compared with the results of a population or group to which the student belongs. This requires the establishment of reference levels or percentiles ranges, which will done to obtain a rating after making the relevant statistical analysis when BEDA is administered to a representative sample of the population.

On the other hand, the **administration module** is designed and implemented for the exclusive use of a subject matter expert (e.g., an educational psychologist). It allows the creation and/or edition of different assessment tasks, the creation and/or edition of reference levels for each assessment task, and the creation and/or edition of recommendations for intervention and/or assistance according to difficulty level presented in the assessment tasks.

5.2.1.3 *Report's interpretation*

The interpretation of the results of a psychological test is a complex process, because in the interpretation thereof is not taken into account only the information provided by the test itself but generally additional information has to be taken into account. Therefore, it is recommended that the unique results obtained by means of a standardized test should not be accepted as a general assessment, since not all the situations where the behavior occurs is captured (in this case the development of reading). Thereby, both this test and any other have to be considered a supplement to the evaluation of the aspects to be measured. In this regard, when performing the identification of cognitive deficits evaluating the report of students' results delivered by BEDA, special emphasis on considering the report obtained from the *ADDA* and the *exclusion criteria* for dyslexia (i.e., sensory, physical, educational deficiencies or problems) must be declared besides to the information provided by the test. This way, a proper interpretation of the results obtained in the test can be performed.

On the other hand, one of the most important causes of inappropriate use of the tests is that students do not receive adequate guiding in this test. For this reason, it can be stated that it is essential for the student to understand the theoretical basis of BEDA (included in the theoretical justification and user manual of BEDA (Díaz, Mejia, Jiménez, & Fabregat, 2012). Similarly, another issue that may adversely affect the interpretation of the results is when a student is not adequately informed of the self-administration of the test, so the results probably get contaminated by the way in which the students self-administer rather than their own performance. For this reason, it is considered crucial that the student read the user manual carefully before complete BEDA.

In addition, interpretation of an assessment battery such as BEDA, in which a report of students' results can be produced automatically, differs from those provided to be filled by handwriting in which an examiner has to: conduct the test, evaluate it, calculate scores, look at the scales the obtained score and perform interpretation of the results. The difference is that in this test the student can perform a self-assessment of their cognitive processes at any time. Accordingly, one benefit of BEDA is that the student can self-assess the cognitive processes and receive the results immediately.

Student's results report is automatically recorded as well as the interpretation of the obtained scores by BEDA. Only with exception of those tasks which answers need of the speech-recognition mechanism since they require to be reviewed by an expert. This means that the prototype of the voice recognition system implemented in BEDA requires further research and development work. However, while this information is provided in an automated way, it is believed that in order to make a proper interpretation of the reports, the students must know how to analyze the report. It is therefore essential that the student knows what it means and involves reading, and the importance of certain cognitive processes involved in reading compared to other processes, that besides from being facilitators they are not essential for reading to be developed.

Moreover, for the correct interpretation of the report it is important to consider the fluency, a variable that is essential to the proper development of reading (it is collected from measuring response time and execution time of some tasks). Thus, the time (response and execution) should be taken into account for proper interpretation, and therefore as a measure of fluidity or automating processes involved in reading.

In BEDA, the report is generated from the module of analysis of results once the student completed all tasks. In this report percentiles of the obtained scores are presented, processes are analyzed independently and a joint assessment of the results is made. Besides, feedback to the student is provided in this report. This feedback follows suggested guidelines of the criteria for diagnosing dyslexia proposed by Jiménez and Artiles (2007) and Siegel (1999) (see Section 2.9.3.2). Thereby, if a student obtains a score below the 25th percentile in a task, he/she presents a level of difficulty in such task. In case of reading comprehension tasks, he/she could present a level of difficulty with a percentile below 50. Additionally, a time of reading words or pseudowords above the percentile 75 could be considered as a level of difficulty.

In Table 5-2, an illustrative example that summarizes a report of one student produced by BEDA. Further details on how direct and scale scores as well as the percentiles are obtained in BEDA are presented in Section 5.2.4.

Table 5-2. Example of converting direct scores to percentiles

Cognitive process	Task	Direct score	Scale score	Percentile
Phonological processing	1.Segmentation into syllables	6	6	**32**
	2.Number of syllables	4	1	
	3.Segmentation into phonemes	8	8	
	4.General rhyme	4	4	
	5.Specific rhyme	16	6	
	6.Phonemic location	5	1	
	7.Omission of phonemes	8	6	
	Total	**51**	**32**	
Orthographic processing	8.Homophone/pseudohomophone choice	11	8	59
	9.Orthographic choice	13	7	
	Total	**24**	**15**	
Lexical access	10.Reading words (successes)	31	11	**73**
	Reading words (execution time)	1.614,3	-	
	11.Reading pseudowords (successes)	42	7	
	Reading pseudowords (execution time)	1.586,75	-	
	Total (successes)	**73**	**18**	
	Total (execution time)	**1.604,15**	**-**	
Processing speed	12.Visual speed of letters and numbers	19	5	36
	Total	**19**	**5**	
Working memory	13.Retaining letters and words	5	6	46
	Total	**5**	**6**	
Semantic processing	14.Reading narrative text	4	5	36
	15.Reading expository texts	5	5	
	Total	**9**	**10**	

In Figure 5-3, the scores profile of the exemplified student in Table 5-2 is presented. The x axis represents the assessed cognitive processes while the y axis represents the percentile achieved in each cognitive process.

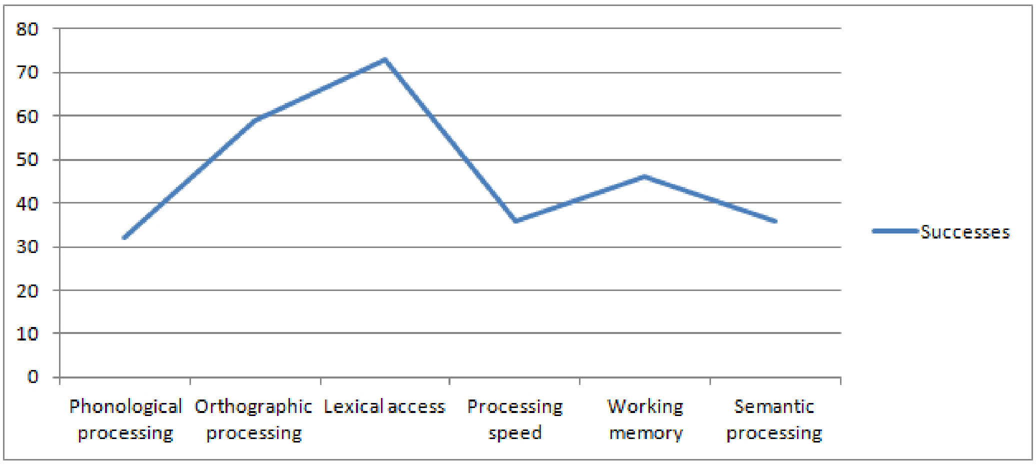


Figure 5-3. Example of the scores profile of the BEDA report

5.2.2 Implementation

As detectLD (see Section 4.3.1), BEDA was implemented with standard technology and considering characteristics of reusability, interoperability, accessibility, and extensibility to make it easy to integrate with a LMS. Moreover, BEDA was implemented using free and open source software such as Linux Operating System (specifically Ubuntu 9.04, with kernel version 2.6.28), Apache Web Server (version 2.0), Postgres (version 8.3.9), and PHP (version 5.2.6), due to their great popularity on different servers, their high performance, and their easy setup, configuration and acquisition. In terms of security, user authentication is based on the widely used reduction algorithm MD5, and permission levels are set by the developer according to the module the user wishes to enter. BEDA was also implemented using standard programming technologies that provide interoperability with other web-based tools such as interface based on XHTML and CSS, interactivity based on PHP and JavaScript, Java and Java Speech Library to implement functionalities related to the speech recognition system (sphinx4), and AJAX for asynchronous communication with the server via XML.

During the BEDA implementation the different modules were tested separately. These tests revealed the need for changes in the graphical user interface design and in the programming and structure of the task to achieve better tool performance. The types of tests used were: connection to the database and proper storage of data, requirements, inspection programming and functional testing of the different modules. For the real-time tests (performance and usability) it was followed the guidelines proposed in (Sauro & Kindlund, 2005), and designed a case study with groups of students from the University of Girona and the University of La Laguna, as well as some volunteer teachers from University of Girona. More than 5 students were asked to carry out this case study, because according to Nielsen (2000), Spool and Schroeder (2001), and Virzi (1992), the functionality and usability tests with at least 5 students provide the most information about the problems presented by the tools. The case study is presented in the next section.

In terms of graphical user interfaces, BEDA was built with Moodle style patterms so that later it could be integrated with this LMS. BEDA delivers different interfaces for each type of user (student, teacher or expert) depending on the permissions and activities that can be developed. Figure 5-4 shows the graphical interface of menu cognitive processes that are assessed in the students. This interface shows the assessment modules (see a in Figure 5-4), the full name of the student in session (see b in Figure 5-4), and the buttons to perform other actions like seeing the results report and log out (see c in Figure 5-4). Figure 5-5 shows the graphical interface of an example item of the “phonemic location” task. This interface shows the title of the task (see a in Figure 5-5) the "example" label in red indicating that is an example item (see b in Figure 5-5), and the buttons to respond to the item (see c in Figure 5-5). Figure 5-6 shows the graphical interface of an assessment item of the “number of syllables” task to assess phonological processing. This interface shows the title of the task (see a in Figure 5-6) and the buttons to respond to the item (see b in Figure 5-6).

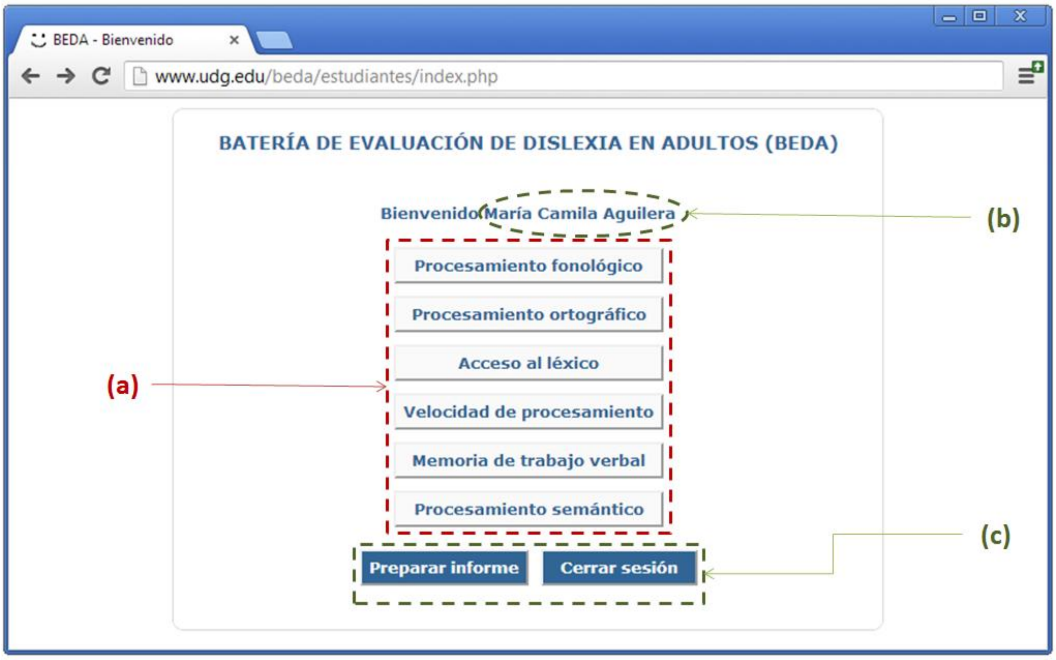


Figure 5-4. BEDA interface: Menu of assessment modules

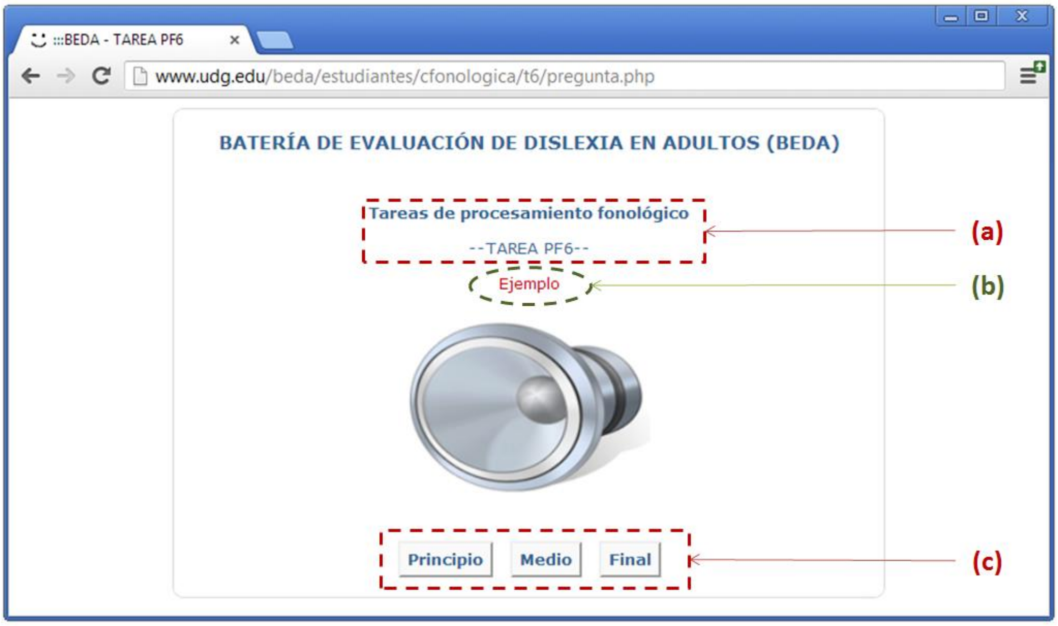


Figure 5-5. BEDA interface: Example item of phonemic location task

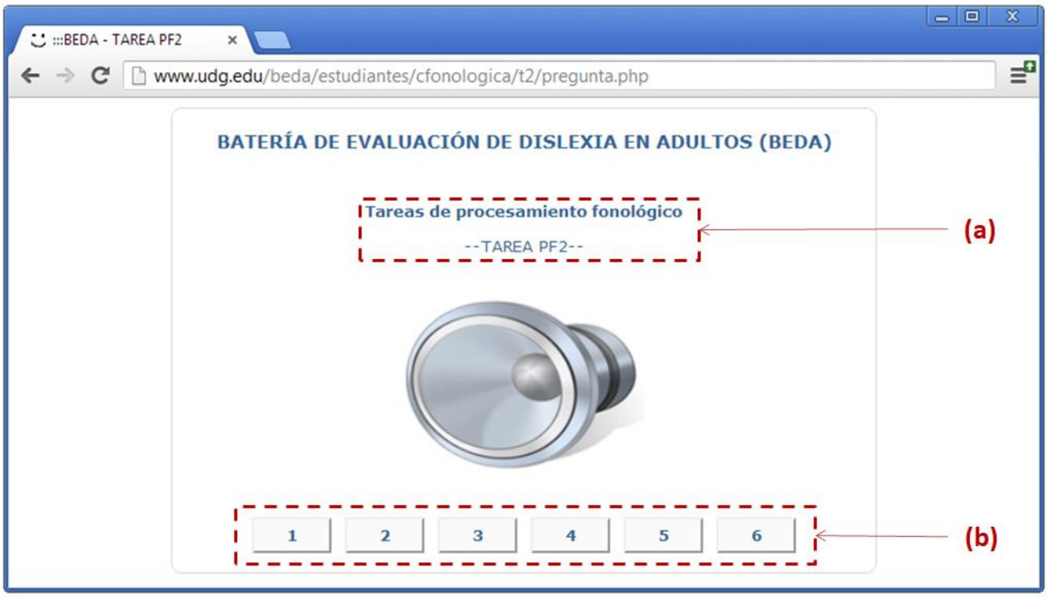


Figure 5-6. BEDA interface: Assessment item of number of syllables task

5.2.3 Case study: functionality and usability

The aim of this case study was to evaluate the functionality and the usability of BEDA, to check the comprehensibility of BEDA's items (i.e., how easy it is to read or hear the different items by the students), and to calculate the average time and sessions that the students require to complete it without feel them tired.

5.2.3.1 Method

Nineteen students, all from the University of Girona (Spain) and the University of La Laguna (Spain) participated in this case study: 9 men and 10 women with ages ranging from 18 years to 62 years (M=27.47, SD=9.125) and from different academic programs and levels (undergraduate and graduate). Whether or not the student had dyslexia was not taken into account. Five volunteer teachers, all from the University of Girona also participated in this case study. Teachers were from humanities and engineering programs with pedagogical experience between 2 and 21 years.

Two examiners (university teachers) conducted the case study. The first examiner was responsible for applying BEDA in University of Girona, while the second examiner was in charge apply it in University of La Laguna. BEDA was administered in individual sessions according to the time available for each student. During the case study, student was accompanied by an examiner experienced in managing BEDA and responsible for taking note of possible questions and problems of the student while he/she is using the software tool and completing the different tasks. When student have completed all tasks, the examiner asked him/her to fill an online survey and intended to evaluate the functionality and usability of BEDA and whether or not he/she understood the items.

In this online survey the students answered questions about how well they understood each of the task instructions, the number of sessions they needed to complete all the tasks, if they performed the tasks in more than one attempt, and if they used some strategies or additional tools to complete the tasks. Moreover, in order to know how many were satisfied, students answered a series of questions where they had to choose the most appropriate response on a scale of 1 to 5 based on their perception of the question. Finally, at the end of the survey a space was left where the students could write additional comments if they wished.

For teachers, the study is based on interviews, during which they complete all tasks and exposed their comments in order to evaluate the functionality and usability of BEDA.

The case study was conducted in a computer lab using a Windows desktop computer equipped with a screen, a keyboard, a mouse, headphones, microphone, and Internet connection. Other software requirements were installing Java and an appropriate version of the Firefox, Internet Explorer, Google Chrome, and Opera web browsers.

5.2.3.2 Results

As show in Table 5-3, the results show that the satisfaction of students is quite high in terms of the usability of BEDA and the comprehensibility of the assessment tasks. Basically, students had difficulty understanding the audio instructions of some tasks and items, complying with BEDA's functional requirements (e.g., using an appropriate version of the browser, installing java when required, or setting the microphone), and repeating items that involve speech recognition, because students reported difficulties when receiving the feedback of some tasks that involve recording. Other findings were that students reported they needed an average of two sessions to complete the tasks without feeling tired, some students said they performed the tasks in only one attempt, and only two students reported using paper and pencil as a strategy to solve some of the tasks. Finally, the average time it took the students to complete the entire battery was between 40 and 50 minutes.

Table 5-3. Results of the case study survey filled in by students

Evaluation questions	M	SD	Satisfaction (%)
Was it easy for you to complete the tasks?	3.89	0.875	77.895
Were the instructions to perform the tasks clear?	3.74	1.046	74.737
Do you think it took a short time to complete the tasks?	2.74	0.933	74.737
Is the overall appearance of the elements of the battery (images, background colors, etc.) suitable?	3.89	1.100	77.895
How satisfied are you to complete the BEDA tasks using a web browser?	3.47	0.841	69.474
Was it easy to navigate through and locate the tasks in BEDA's graphical user interface?	4.47	0.697	89.474
Did BEDA adequately respond to your navigation pace?	3.84	1.119	76.842
In general, was BEDA intuitive (i.e., did it not require much effort and time to learn to handle it)?	4.26	0.991	85.263
Would you recommend this battery to other people or peers?	4.21	0.787	84.211

On the other hand, five teachers completed the BEDA tasks. Despite previously indicating that they had limited awareness of dyslexic students in their courses, after completing BEDA they said it was user friendly and intuitive and they expressed interest in knowing how they could use it in their classrooms. Moreover, teachers expressed curiosity about the student results and in knowing which teaching strategies could be used with affected students.

5.2.3.3 *Discussion*

According to the results obtained in the case study, BEDA was subsequently reviewed and restructured: audio instructions were again recorded in an appropriate setting, some items were modified by psychologists, help guides were incorporated, an automated functional requirement validation at the beginning of BEDA execution was introduced, and a module to verify the accuracy of the tasks using voice recognition was developed, since the acoustic model of the speech recognition software needs more training to improve the accuracy of voice recognition for all students. Considering that the results obtained were positive and the revision and restructuring process improved BEDA, it is believed BEDA is prepared to be used on a sample of university students with and without reading disabilities in order to analyze its discriminate validity, and subsequently recover the scales of each assessment task to identify whether or not the student has a cognitive deficit and to confirm the dyslexia diagnosis. It was also believed that using BEDA in a learning-teaching environment can be useful in terms of enabling students to know about their deficient cognitive processes and to know about strategies or recommendations they could follow to address these deficits. Furthermore, teachers may become aware of these disabilities and provide more appropriate learning resources for students who are affected.

5.2.4 Case study: analysis and debug of items

Since it has been empirically demonstrated that some cognitive processes may be present as deficits in adults with dyslexia (Bruck, 1993b; Decker, 1989; Felton et al., 1990; Lachmann & Van Leeuwen, 2008) BEDA assesses the cognitive processes and let identify specific cognitive deficits in university students. Thus, when students complete BEDA's tasks, their cognitive process performances are stored to identify whether or not a deficit is present, and therefore appropriate assistance can be prepared.

In BEDA, student's cognitive processes are assessed by different tasks presented through web-based software. The responses to these tasks (responses of successes, errors and execution time for some tasks in which performance time is measured) have to be automatically compared with standardized data considering the student's educational level, i.e., individual results have to be compared with the results of a group of the population (sample) to which the student belongs. This requires the establishment of a reference level, which is done to obtain a rating after making the relevant statistical analysis when BEDA is administered to a representative sample of the population.

Thus, first in this study, a descriptive analysis of the overall distribution of the sample results in BEDA was performed, of which measures of central tendency, variability, skewness and kurtosis could be obtained. This is a quick way to recognize the behavior of the frequency of the data and the dispersion between them, and to have benchmarks to interpret the results obtained by applying each of the tasks. Secondly, score scales of BEDA's tasks were obtained, with which a priori check of the student's performance level in different cognitive processes assessed can be done. However, it is worth noting that these scales are not definitive, thus, BEDA's tasks must go through different feasibility and reliability statistical analyzes. In this study the scales are used to provide a preliminary feedback and recommendations to students. Third, BEDA's item were analyzed by means of a set of statistical analysis (difficulty, discrimination and correlation), which constitute the Analysis of Items. Finally, the study involved the debugging of items. Thus, items that can be removed and those which will be part of the tasks of BEDA can be identified.

5.2.4.1 *Study Description*

As discussed in Section 2.8, deficits in cognitive processes related to reading are presented in both children and adults. Moreover, research in dyslexia has focused primarily on children, leaving out research in adults with these disabilities. In this sense, and probably caused by the lower number of conducted investigations, there are not tools to assess the adult population with these disabilities. Therefore, in this dissertation a conducted study aims to evaluate the proposed assessment battery, namely BEDA.

Thus, the study carries out an establishment of the metric properties of each task so as BEDA serves as a tool for assessment of cognitive processes in Spanish-speaking adults. To do so, analysis on the distribution of the sample is performed, score scales for tasks are obtained, and analysis and debugging of items of BEDA are performed.

5.2.4.2 *Method*

5.2.4.2.1 Participants

Although 118 students (60 male and 58 female) of the University of Girona participated in this study, only 106 students (57 male and 49 female) from 22 programs with ages ranging from 19 to 50 years (M=26.76, SD=7.01) were considered. Thus, 12 students were discarded as follows: 5 of them reported having a previous diagnosis of dyslexia (i.e., they had been formally diagnosed with dyslexia during their primary or secondary schooling, through an official psychoassessment procedure) and these type of analysis require normal population; and 7 students did not complete all tasks, consequently they were removed of the sample. In addition, it is worth noting that students who reported having sensory, neurological, or other disorders were excluded from the sample of participants.

Students were recruited by the coordinators of the faculties and/or schools through e-mails, website and classroom announcements. Students took part in an individual session that lasted an average of 60 minutes. Frequencies and percentages by Faculty, Academic Program, and gender are shown in Table 5-4.

Table 5-4. Frequencies and percentages of participation by faculty, academic program, and gender in the BEDA's case study

Faculties and/or Schools	Academic program	Frequency	Gender		%
			M	F	
Polytechnic School	Electrical Engineering	1	1	0	0,9
	Industrial Electronics and Automatic Control Engineering	1	1	0	0,9
	Computer Engineering	16	12	4	15,1
	Building Engineering	3	2	1	2,8
	Chemical Engineering	1	1	0	0,9
	Master	9	7	2	8,5
	Doctorate	12	11	1	11,3
	Total	44	35	9	39,6

Faculties and/or Schools	Academic program	Frequency	Gender		%
			M	F	
Faculty of Tourism	Advertising and Public Relations	1	0	1	0,9
	Total	1	0	1	0,9
School of Nursing	Master	6	0	6	5,7
	Total	6	0	6	5,4
Faculty of Business and Economic Sciences	Business Administration and Management	3	1	2	2,8
	Accounting and Finance	3	2	1	2,8
	Economics	2	1	1	1,9
	Master	2	1	1	1,9
	Total	10	5	5	9,0
Faculty of Law	Political Science and Public Administration	2	1	1	1,9
	Law	9	3	6	8,5
	Total	11	4	7	9,9
Faculty of Education and Psychology	Pedagogy	5	1	4	4,7
	Pre-School Education	1	0	1	0,9
	Primary School Education	7	3	4	6,6
	Psychology	8	3	5	7,5
	Social Education	5	2	3	4,7
	Social Work	5	2	3	4,7
	Master	4	2	2	3,8
	Total	39	13	26	35,1
Total		106	57	49	100.0

5.2.4.2.2 Instruments: BEDA

BEDA was the main and only instrument used in this case study. As mentioned before, BEDA consists of fifteen tasks, namely: segmentation into syllables, number of syllables, segmentation into phonemes, general rhyme, specific rhyme, phonemic location, omission of phonemes, homophone/pseudohomophone choice, orthographic choice, reading words and pseudowords, visual speed of letters and numbers, retaining letters and words, and reading comprehension of expository and narrative texts. These tasks help measuring the cognitive processes and they have been incorporated into the framework's software toolkit (see Section 3.2), meaning that it can be completed through a computer. Student responses to each item of a task are automatically stored in a database when the key is pressed, the option is clicked, the word(s) is(are) wirtten, or the word(s) is(are) spoken by the student. The value of a response is: 1 (one) if the answer was correct or 0 (zero) if it was a mistake. Additionally, the responses in text, the recorded response, the execution time of each item and, in some cases, student reaction time to a stimulus are stored.

Every task has example items and assessment items. The assessment items are those that measure the student performance on the task, while the example items guide and help students to train so as they can complete the assessment items. The example items provide associated feedback in case the student answers right or make a mistake. If the student said he/she had not understood the item description, the examiner could explain him/her with details how to complete the item. Next paragraphs describe the tasks that compose BEDA (Items of each tasks is shown in Appendix D):

1. **Segmentation into syllables**. The objective of this task is to assess the student's ability to break words into syllables. The task requires students to spread word families (of 3, 4, 5 and 6 syllables) that are presented aurally. It starts with two items of example, followed by twelve items of assessment. For example, the student listen to a word (e.g., /horrible/) and he/she has to separate it orally into syllables and at the same time press the spacebar for every syllable he/she utters.
2. **Number of syllables**. The student must say the number of syllables in a word (aurally presented). The task begins with two items of example, followed by twelve items of assessment. In this case the student hears a word (e.g., /carpeta/) and then, the numbers from 1 to 6, are displayed on the computer screen. Thus, the student must check with the mouse the number corresponding to the syllables of the word he/she had heard.
3. **Segmentation into phonemes**. In this case the student has to count phonemes (from 3 to 7) of a familiar word that is presented aurally, and touch the space bar for each phoneme that he/she identifies. This task has three example items and twelve assessment items. For example, the student listens to a word (e.g., /bar/) and he/she has to utter loud the sounds while pressing the space bar for each sound.
4. **General rhyme**. In this task the student listens to a word and then he/she should say three words that rhyme with it. The example items illustrate the concept of rhyme and not rhyme. For example, two words that rhyme with "sal" and "mal" are aurally presented to the student and it is explained that in both vowel and consonant words match, therefore, those are rhyming words. Then, two words that share sounds but that do not rhyme (e.g. "par" and "pan") are presented. Afterwards, assessment items are presented.
5. **Specific rhyme**. In this task the student listen to a word first and then, five words are presented are one by one and aurally presented so that he/she can indicate if they rhyme or not with the first one. For example, the stimulus word "/dos/" and the list of the five words would consist of the following: "par", "los", "vez", "tos", "bis". On the computer screen two buttons are presented: one with the word "yes" and other with "no". Whenever he/she listen to a word from the list, the student must click over the button that he/she thinks corresponds to the answer. Four lists of words are presented.
6. **Phonemic location**. In this task, two words are presented aurally (3 to 6 phonemes) that share all sounds except one. On the computer screen are displayed three buttons: "beggining", "middle" and "end". The student must say whether the different sound is at the beginning of the word, in the middle or at the end by clicking on the appropriate button. An example of this task is /cal/ and /col/, the student must click the button 'medium' as the sound is different in the middle.
7. **Omission of phonemes**. In this task the student listen to a pseudoword (containing one to four syllables) and he/she should repeat it. Then the student is asked to repeat but omitting a segment of it, then he/she must say the word again but without saying the segment that has been asked not to say. The parts that can be omitted are syllables intrasyllabic units (i.e., onset-rhyme), vowel phonemes and/or consonant phonemes in initial, medial and/or end position. An instruction example of this task is: Say "Tarin", now say it but without the /a/.

8. **Homophone/pseudohomophone choice**. In this tarea are presented in the computer screen pairs of words that sound the same but are spelled differently, but only one of them is spelled correctly. That is, in each pair there is a word and a pseudohomophone (pseudoword homophone to the word). The student has to identify the word that is spelled correctly by clicking over the button below the word. For example, it is presented in the computer screen "aveja" and "abeja", so the student should click on the button below "abeja" which is spelled correctly.
9. **Orthographic choice**. In this task are shown two homophones words and then is aurally asked questions about the meaning of one of them. The student must click the button below the word that he/she believes the meaning corresponds to. An example, the words "vaca" and "baca" are showed and then is asked: Which is an animal?
10. **Reading words**. In this task are presented in the computer screen words so that the student read them aloud as quickly as possible. This task consists of words that include six types of syllables that can be sorted in one of the following order: CV, VC, CVC, CVV, CVCC, CVVC[2], and their familiarity and their word length must be considered. An example of the task would be: "Bola" (CV, familiar and 2 syllables).
11. **Reading pseudowords**. In this task pseudowords (made up words) are presented in the computer screen, so that the student read them aloud as quickly as possible. This task consists of words that include six types of syllables that can be sorted in one of the following order: CV, VC, CVC, CVV, CVCC, CVVC, and their word length. An example of the task would be: "Tonte" (CVC and 2 syllables).
12. **Visual speed of letters and numbers**. In this task are presented in the computer screen groups of mixed letters and numbers, and next four very similar groups. However, only one of the groups is the same as the first group. What the student should do is to pick as fast as possible, the group is equal to the first one. An example of the task would be: zxc6: zxc6 zxc9 zcx6 z6cx.
13. **Retaining letters and words**. In this task is shown, for one second, a pseudoword on the computer screen, and then asked the student to write the whole pseudoword or a part of it. In the latter case it may be one or more letters of the pseudoword. The pseudowords vary in length and syllabic structure. For example, the word "Blin" is presented and once a second just passed, the word disappears from the screen and it is asked the student to enter the second and third letter of the word.
14. **Reading narrative text**. In this task, it is presented in the computer screen narrative text that the student must read. Upon ending to read, an instruction is presented so that the student must answer a set of questions regarding the text he/she just read.
15. **Reading expository text**. In this task, it is presented in the computer screen expository text that the student must read. Upon ending to read, an instruction is presented so that the student must answer a set of questions regarding the text he/she just read.

[2] C = Consonant, V = Vowel. Example, CVC = Consonant + Vowel + Consonant.

5.2.4.2.3 Procedure

Two examiners (university teachers) received four training sessions about using and instructing the students how to complete the tasks of BEDA. Meanwhile, coordinators from different faculties and/or schools of university were contacted to authorize and schedule the BEDA application in the respective faculties and/or schools. Thus, BEDA was conducted in a classroom assigned for such purpose in the participant faculty and/or school.

BEDA was evaluated in individual sessions according to the time available of each participant. Thus, the examiners had to move to different faculties and/or schools where the classrooms assigned were available. These classrooms were isolated from noises and interruptions (this was mandatory since tasks in BEDA use multimodal mechanisms). During the case study, participant was accompanied by an examiner while he/she completed the different tasks. The total time needed to complete BEDA was 60 minutes.

Previously, participants were asked if they have had problems with hearing, vision, motors, or other serious disorders in order to exclude them from the sample.

5.2.4.3 Results

The descriptive analysis of the overall distribution of the sample results in BEDA will reveal measures of *central tendency*, *variability*, *skewness* and *kurtosis*. For obtaining the score scales, it is used the *maximum* and *minimum* values, and it defines a number of *intervals*. For analysis of the items, it identifies three types of indexes: *difficulty*, *discrimination*, and *correlation*. Index of discrimination and difficulty provide information on the "goodness" or "badness" of each item, while the correlation gives the relationship of each item with the total of the task which it is part.

5.2.4.3.1 Sample distribution

Table 5-5 shows the results of the measure of central tendency and variability before analysis and debugging of the items in BEDA (see Section 5.2.4.3.3). The mean of the proportion of correct answers report that participants respond adequately more than half of the items of each task, since all mean are greater than 0,50. Moreover, it is noted that the population has a bias to the right, which breaks the equality of mean, median and mode. Consequently, this confirmed the negative skewness of the distribution since for every task the mean is lower than median, and median lower than mode. Additionally, the skewness indexes, being negatives indicate that the percentage of participants' high scores is greater than the percentage of low scores.

Table 5-5. Measures of central tendency and variability of BEDA's tasks

Task	Mean	Median	Mode	Maximum	Minimum	Range	Variance	Std. dev.	Skewness	Kurtosis
1.Segmentation into syllables	0,77	0,92	0,92	1,00	0,00	1,00	0,16	0,39	-1,60	1,73
2.Number of syllables	0,78	0,88	0,83	1,00	0,00	1,00	0,15	0,38	-1,67	1,86
3.Segmentation into phonemes	0,82	1,00	1,00	1,00	0,00	1,00	0,14	0,37	-2,03	3,36
4.General rhyme	0,72	1,00	1,00	1,00	0,00	1,00	0,19	0,43	-1,10	-0,48
5.Specific rhyme	0,97	1,00	1,00	1,00	0,14	0,86	0,03	0,16	-5,15	35,73
6.Phonemic location	0,88	0,93	0,93	1,00	0,00	1,00	0,07	0,24	-4,34	24,78
7.Omission of	0,78	0,94	0,94	1,00	0,00	1,00	0,15	0,37	-1,89	3,53

Task	Mean	Median	Mode	Maximum	Minimum	Range	Variance	Std. dev.	Skewness	Kurtosis
phonemes										
8.Homophone/pseudohomophone choice	0,88	0,92	0,92	1,00	0,00	1,00	0,07	0,25	-4,35	28,26
9.Orthographic choice	0,84	0,91	0,88	1,00	0,18	0,82	0,10	0,28	-2,11	7,01
10.Reading words	0,98	1,00	1,00	1,00	0,25	0,75	0,02	0,11	-5,51	43,47
11.Reading pseudowords	0,96	1,00	1,00	1,00	0,00	1,00	0,04	0,18	-6,04	41,57
12.Visual speed of letters and numbers	0,95	1,00	1,00	1,00	0,00	1,00	0,05	0,21	-4,95	26,72
13.Retaining letters and words	0,93	1,00	1,00	1,00	0,00	1,00	0,07	0,24	-4,12	19,31
14.Reading narrative text	0,67	0,80	0,80	1,00	0,00	1,00	0,19	0,43	-1,12	1,02
15.Reading expository text	0,63	0,70	0,70	1,00	0,00	1,00	0,21	0,46	-0,62	-1,11

Regarding the results of variability, very low variances for tasks 5, 6, 8, 9, 10, 11, 14 and 15 are observed, indicating that these tasks presented little dispersion in the correct answers given by students. While in the other tasks, the number of correct answers can vary between a very low level, such as 0, and all items of the task.

With regard to the kurtosis, it is observed that the participants are distributed so that the values are more concentrated around the mean, i.e., there is a high degree of concentration around the central values. It happens when the values are higher than 0. This is a leptokurtic distribution, which has higher peaks around the mean compared to normal distributions, which leads to thick tails on both sides.

5.2.4.3.2 Obtaining the scales

In order to provide a preliminary version of the students' results report (see Section 5.2.1.2), as well as feedback and recommendations, the scales for the BEDA's tasks are obtained. However, these scales are not definitive. BEDA's tasks must go through different statistical analysis of viability and reliability.

First differences in gender were reviewed. Table 5-6 presents the mean and standard deviation of scores on each task obtained by men, women and the total sample. It is observed that although execution of men was higher than women in *Number of syllables*, *Specific rhyme*, *Phonemic location*, *Orthographic choice*, *Reading words and Reading pseudowords*, and the execution of women was better than men in the other nine tasks, these differences were not significant and therefore this led to not develop scales by sex, but only for the total sample. Here, it is noted that the maximum possible scores for task is as follows: *Segmentation into syllables*, *Number of syllables*, *Segmentation into phonemes*, and *General rhyme* is 12 points, *Specific rhyme* 18 points, *Phonemic location* is 15 points, *Omission of phonemes* is 16 points, *Homophone/pseudohomophone choice* is 13 points, *Orthographic choice* is 18 points, *Reading words* is 32 points, *Reading pseudowords* is 48 points, *Visual speed of letters and numbers* is 35, *Retaining letters and words* is 18 points, and *Reading narrative text* and *Reading expository text* is 10 points, which makes a total of 281 possible points.

Table 5-6. Mean and standard deviation of the scores obtained by men, women and the total sample

Task	Man		Women		Total sample	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
1.Segmentation into syllables	8.98	2.43	9.48	1.86	9.21	2.19
2.Number of syllables	9.36	2.04	9.28	2.06	9.33	2.04
3.Segmentation into phonemes	9.47	1.97	10.26	2.21	9.83	2.11
4.General rhyme	9.75	2.64	10.02	2.40	9.87	2.52
5.Specific rhyme	17.24	1.18	17.18	1.31	17.21	1.24
6.Phonemic location	13.10	1.26	12.91	1.53	13.01	1.39
7.Omission of phonemes	12.08	2.74	12.89	2.78	12.46	2.77
8.Homophone/pseudohomophone choice	11.31	1.05	11.44	1.00	11.37	1.02
9.Orthographic choice	13.80	1.78	13.79	1.98	13.80	1.87
10.Reading words	31.49	1.11	31.36	1.16	31.46	1.13
11.Reading pseudowords	46.12	2.45	46.08	2.83	46.10	2.62
12.Visual speed of letters and numbers	32.68	4.66	33.89	1.82	33.24	3.67
13.Retaining letters and words	16.66	1.83	16.71	2.10	16.68	1.95
14.Reading narrative text	6.68	2.30	6.77	1.79	6.72	2.07
15.Reading expository text	6.01	1.98	6.44	1.75	6.26	1.88

Table 5-7, Table 5-8, and Table 5-9 presents scalar scores obtained for each of the 15 tasks in BEDA. These tables provide a column for each task with different direct scoring intervals or successes. On the right of the table is the column with the scalar scores ranging from 1 to 12. To obtain these scales is used: the maximum and minimum value of successes achieved by the participants, the range between these values and a number of intervals equal to 12.

Table 5-7. Scale score of phonological processing tasks from BEDA

Scale score	Phonological processing module						
	Segmentation into syllables	Number of syllables	Segmentation into phonemes	General rhyme	Specific rhyme	Phonemic location	Omission of phonemes
1	0-1	0-4	0-2	0-1	0-14	0-8	0-1
2	2	5	3	2	-	9	2-3
3	3	6	4	3	-	-	4
4	4	-	5	4	15	10	5
5	5	7	6	5	-	11	6-7
6	6	8	-	6	-	-	8
7	7	-	7	7	16	12	9
8	8	9	8	8	-	-	10-11
9	9	10	9	9	-	13	12
10	10	-	10	10	17	-	13
11	11	11	11	11	-	14	14-15
12	12	12	12	12	18	15	16

Table 5-8. Scale score of orthographical processing and lexical access tasks from BEDA

Scale score	Orthographic processing module		Lexical access module	
	Homophone/ pseudohomophone choice	Orthographic choice	Reading words	Reading pseudowords
1	0-8	0-9	0-25	0-35
2	-	-	26	36
3	9	10	-	37-38
4	-	11	27	39
5	10	12	28	40
6	-	-	-	41
7	-	13	29	42
8	11	14	-	43
9	-	15	30	44-45
10	12	-	-	46
11	-	16	31	47
12	13	17-18	32	48

Table 5-9. Scale score of processing speed, working memory and semantic processing tasks from BEDA

Scale score	Visual speed of letters and numbers	Retaining letters and words	Reading narrative text	Reading expository text
1	0-11	0-7	0-1	0-2
2	12-13	8	2	-
3	14-16	9	-	3
4	17-18	10	3	4
5	19-20	11	4	5
6	21-22	12	5	-
7	23-24	13	6	6
8	25-26	14	7	7
9	27-29	15	-	8
10	30-31	16	8	-
11	32-33	17	9	9
12	34-35	18	10	10

The operation of the above tables is as follows: a direct score of 11 successes for the task "*phonemic location*" corresponds to the scale score 5, while the same direct score for the task "*orthographic choice*" corresponds to the scale score 4. Do not confuse or try to compare the range of scores between tests, since each test has a different number of items.

Table 5-10 presents the percentages for each cognitive process. In the case of processes containing more than one task, the scale scores were totaled. So the maximum scale score for *phonological processing* is 84 since it has related 7 tasks, while for *lexical access* is 24 for having 2 tasks.

Table 5-10. Percentile of cognitive processes from BEDA

Percentiles	Scalar sum					
	Phonological processing	Orthographical processing	Lexical access	Processing speed	Working memory	Semantic processing
1	0-8	0-2	0-2	0-1	0-1	0-2
3	9	-	-	-	-	-
5	11	3	3	-	-	3
8	13	-	-	-	-	-
9	14	4	4	2	2	4
12	16	-	-	-	-	-
14	18	5	5	-	-	5
18	21	6	6	3	3	6
23	25	7	7	-	-	7
25	**26**	**-**	**-**	**-**	**-**	**-**
27	28	8	8	4	4	8
29	29	-	-	-	-	-
32	32	9	9	-	-	9
34	33	-	-	-	-	-
36	35	10	10	5	5	10
39	37	-	-	-	-	-
41	39	11	11	-	-	11
46	42	12	12	6	6	12
50	**46**	**13**	**13**	**-**	**-**	**13**
53	48	-	-	-	-	-
55	49	14	14	7	7	14
57	51	-	-	-	-	-
59	52	15	15	-	-	15
62	55	-	-	-	-	-
64	56	16	16	8	8	16
68	59	17	17	-	-	17
73	63	18	18	9	9	18
75	**65**	**-**	**-**	**-**	**-**	**-**
77	66	19	19	-	-	19
80	69	-	-	-	-	-
82	70	20	20	10	10	20
84	72	-	-	-	-	-
86	73	21	21	-	-	21
88	75	-	-	-	-	-
91	77	22	22	11	11	22
95	80	23	23	-	-	23
97	82	-	-	-	-	-
100	84	24	24	12	12	24

The table above highlights the allowable lower limit of percentiles, which is the 25th percentile. For example, it is observed that for *phonological processing*, the participant with a sum of scale score of 26 obtain the 25th percentile, whereas for *orthographic processing*, the participant with a sum of scale score of 8 obtained the 25th percentile. That is, with 26 of 84 on the total scale score of *phonological processing* is considered acceptable, whereas with 8 of 24 in *orthographic processing* is considered acceptable.

5.2.4.3.3 Analysis and debugging of the items

At this point, the items that make up each of the tasks are analyzed in order to select those that are likely to be deleted. To this, individual behavior of items was analyzed, counting the number of successes and errors (i.e., frequencies of correct and wrong responses), detecting the number of missing values for each item (i.e., frequencies of responses that were not stored). Then, indices of difficulty (*p* and *p**100 respectively) can be calculated, establishing the level of difficulty of each item on a scale of: easy ($p> 0.75$), medium (*p* between 0.75 and 0.25) or difficult ($p <0.25$). The indices of discrimination (D) were also calculated, as well as levels of discrimination were established on a scale of: high (D> 0.40), medium (D between 0.39 and 0.30), low (D between 0.29 and 0.16), very low (D between 0.15 and 0.0) or discard (D <= 0.0). Finally, the correlations (R) between the responses to the item and the total score on the task were also calculated. Below, a summary of the statistical measures used for the analysis of items of BEDA is presented:

- Difficulty Index (*p*): refers to the degree of difficulty or ease of an item. This index reports the items that have an extreme difficulty or ease, which should be revised or eliminated because they do not contribute to the task. Fundamentally, this index indicates that the difficulty of an item is the proportion of participants responding correctly to item (i.e., successes) with respect to those who have tried to solve (i.e., successes plus errors).

  $$p = Successes / (Sucesses + Errors)$$

  This index ranges from a minimum value of $p = 0$, which implies a difficult item (i.e., an item that any subject has responded correctly), and a maximum value of $p = 1$, an easy item (i.e., which has been answered correctly by all participants). The items with extreme values ($p = 1$ and $p = 0$) are discarded because they do not contribute to measure differences between participants, since all participants respond the same way: correctly or incorrectly. In subsequent analyzes, the *p* value of each item is multiplied by 100 (i.e., $p * 100$) to ease the interpretation. For instance, an item with a value $p = 0.67$, meaning that 67% participants in the sample have answered correctly.
  According to Garcia (2004) and Diaz (2007), to interpret the results, the average level of difficulty of an item should range between 25% and 75% of correct answers, in which *p* values are distributed as follows: one item with $p > 0.75$ is considered easy, an item with *p* between 0.75 and 0.25 is considered medium difficulty and an item with $p < 0.25$ is considered difficult.
- Discrimination Index (D): refers to the degree in which each of the items of a task discriminate between participants with a high level in the task and participants with a low level in the task. To calculate this index, according to Kelley (1939), participants have to sort based on overall task score and divide them into two groups: uppert (formed by 27% of participants with the highest scores) and lower (formed by 27% of participants with the lowest scores). Thus, the difference between the proportion of participants with high scores that respond correctly to item and the proportion of participants with low scores that also respond correctly to item expresses the discrimination index of an item.

$$D = p_{upper} - p_{lower}$$

Where,

$$p_{upper} = Successes_{upper} / (Sucesses_{upper} + Errors_{upper}), \text{ and}$$

$$p_{lower} = Successes_{lower} / (Sucesses_{lower} + Errors_{lower}).$$

According to Garcia (2004) and Diaz (2007), to interpret the results, an item with D > 0.40 presents a great discriminative power, with D between 0.39 and 0.30 the item discrimination is acceptable, with D between 0.29 and 0.16 the item can be little discriminated and needs a review, with D between 0.15 and 0.0 the item is not appropriate and should be modified or removed from the task, with D <= 0.0 the item must be removed directly.

- Correlation (R): Refers to discrimination index based on the item-task correlation. This index expresses the degree of similarity, connection or association between the responses to the item and the other items measured by the total score on the task. It differs from D because its calculation allows to consider all participants in the sample, not just the 54% (27% of the upper group and 27% of the lower group).

In order to debug the items and select those that are likely to be deleted a set of criteria (Díaz, 2007; E. García, 2004) was used:

- The item whose correlation is negative.
- The item whose variance is zero.
- The item whose D = 0.0 (very low) or D <= 0.0 (discard), as well as those items whose D was close to zero.
- The item whose p was very high.

Table 5-11 to Table 5-25 contain the results for the 273 items (see Appendix D) among the 15 tasks defined in BEDA. Each table contains: the item, the number of successes (Successes), the number of errors (Errors), and the missing cases (Missing), as well as the difficulty index (*p*), the difficulty index as a percentage (p*100), the interpretation of the difficulty index (p level), the discrimination index (D), the interpretation of the level of discrimination (D level), and the correlation of the item with the task (R).

Table 5-11. Analysis of the items of the task (1) segmentation into syllables

Item	Successes	Errors	Missing	*p*	*p**100	*p* level	D	D level	R
1	98	8	0	0,92	92,45	Easy	0,21	Low	0,421
2	71	35	0	0,67	66,98	Medium	0,66	High	0,492
3	95	11	0	0,90	89,62	Easy	0,28	Low	0,558
4	36	70	0	0,34	33,96	Medium	0,21	Low	0,157
5	76	30	0	0,72	71,70	Medium	0,62	High	0,475
6	87	19	0	0,82	82,08	Easy	0,34	Medium	0,395
7	75	31	0	0,71	70,75	Medium	0,66	High	0,519
8	86	20	0	0,81	81,13	Easy	0,52	High	0,622
9	96	10	0	0,91	90,57	Easy	0,24	Low	0,579
10	86	20	0	0,81	81,13	Easy	0,45	High	0,556

Item	Successes	Errors	Missing	*p*	*p**100	*p* level	D	D level	R
11	95	11	0	0,90	89,62	Easy	0,24	Low	0,501
12	76	30	0	0,72	71,70	Medium	0,52	High	0,475

Table 5-12. Analysis of the items of the task (2) number of syllables

Item	Successes	Errors	Missing	*p*	*p**100	*p* level	D	D level	R
1	90	16	0	0,85	84,91	Easy	0,38	Medium	0,547
2	86	20	0	0,81	81,13	Easy	0,59	High	0,67
3	85	21	0	0,80	80,19	Easy	0,59	High	0,708
4	77	29	0	0,73	72,64	Medium	0,90	High	0,827
5	94	12	0	0,89	88,68	Easy	0,24	Low	0,277
6	90	16	0	0,85	84,91	Easy	0,28	Low	0,185
*7	53	53	0	0,50	50,00	Medium	-0,10	Discard	-0,162
8	96	10	0	0,91	90,57	Easy	0,24	Low	0,401
9	47	59	0	0,44	44,34	Medium	0,59	High	0,415
10	88	18	0	0,83	83,02	Easy	0,45	High	0,604
11	99	7	0	0,93	93,40	Easy	0,10	Very low	0,099
12	84	22	0	0,79	79,25	Easy	0,62	High	0,689

* It was removed from the analysis according to the criteria used to delete the items.

Table 5-13. Analysis of the items of the task (3) segmentation into phonemes

Item	Successes	Errors	Missing	*p*	*p**100	*p* level	D	D level	R
1	95	11	0	0,90	89,62	Easy	0,21	Low	0,459
2	101	5	0	0,95	95,28	Easy	0,14	Very low	0,448
3	77	29	0	0,73	72,64	Medium	0,24	Low	0,174
4	81	25	0	0,76	76,42	Easy	0,76	High	0,675
5	80	26	0	0,75	75,47	Easy	0,76	High	0,633
6	99	7	0	0,93	93,40	Easy	0,17	Low	0,395
7	76	30	0	0,72	71,70	Medium	0,28	Low	0,29
8	97	9	0	0,92	91,51	Easy	0,31	Medium	0,571
9	92	14	0	0,87	86,79	Easy	0,31	Medium	0,433
10	79	27	0	0,75	74,53	Medium	0,59	High	0,5
11	76	30	0	0,72	71,70	Medium	0,76	High	0,648
12	90	16	0	0,85	84,91	Easy	0,45	High	0,531

Table 5-14. Analysis of the items of the task (4) general rhyme

Item	Successes	Errors	Missing	*p*	*p**100	*p* level	D	D level	R
1	101	5	0	0,95	95,28	Easy	0,17	Low	0,705
2	102	4	0	0,96	96,23	Easy	0,10	Very low	0,637
3	84	22	0	0,79	79,25	Easy	0,66	High	0,728
4	101	5	0	0,95	95,28	Easy	0,17	Low	0,718

Table 5-15. Analysis of the items of the task (5) specific rhyme

Item	Successes	Errors	Missing	*p*	*p**100	*p* level	D	D level	R
1	93	2	11	0,98	97,89	Easy	0,11	Very low	0,235
*2	94	1	11	0,99	98,95	Easy	0,00	Discard	0,056
3	92	3	11	0,97	96,84	Easy	0,11	Very low	0,225
*4	106	0	0	1,00	100,00	Easy	0,00	Discard	**
*5	106	0	0	1,00	100,00	Easy	0,00	Discard	**
6	97	9	0	0,92	91,51	Easy	0,28	Medium	0,546
7	102	4	0	0,96	96,23	Easy	0,14	Very low	0,275
8	95	11	0	0,90	89,62	Easy	0,34	Medium	0,41
*9	106	0	0	1,00	100,00	Easy	0,00	Discard	**

Item	Successes	Errors	Missing	*p*	*p**100	*p* level	D	D level	R
10	100	6	0	0,94	94,34	Easy	0,14	Very low	0,175
*11	103	3	0	0,97	97,17	Easy	0,07	Very low	0,26
*12	102	4	0	0,96	96,23	Easy	0,07	Very low	0,155
*13	105	1	0	0,99	99,06	Easy	0,03	Very low	0,254
*14	106	0	0	1,00	100,00	Easy	0,00	Discard	**
*15	106	0	0	1,00	100,00	Easy	0,00	Discard	**
*16	106	0	0	1,00	100,00	Easy	0,00	Discard	**
*17	105	1	0	0,99	99,06	Easy	0,00	Discard	0,017
18	101	5	0	0,95	95,28	Easy	0,17	Low	0,471

* It was removed from the analysis according to the criteria used to delete the items.

** It was removed from the analysis for having zero variance.

Table 5-16. Analysis of the items of the task (6) phonemic location

Item	Successes	Errors	Missing	*p*	*p**100	*p* level	D	D level	R
1	79	16	11	0,83	83,16	Easy	0,33	Medium	0,345
2	103	3	0	0,97	97,17	Easy	0,10	Very low	0,289
3	101	5	0	0,95	95,28	Easy	0,17	Low	0,42
*4	104	1	1	0,99	99,05	Easy	0,04	Very low	0,155
5	92	13	1	0,88	87,62	Easy	0,25	Low	0,241
6	100	5	1	0,95	95,24	Easy	0,14	Very low	0,354
*7	104	2	0	0,98	98,11	Easy	0,07	Very low	0,302
8	102	4	0	0,96	96,23	Easy	0,14	Very low	0,253
9	103	3	0	0,97	97,17	Easy	0,10	Very low	0,289
*10	104	2	0	0,98	98,11	Easy	0,07	Very low	0,352
*11	102	4	0	0,96	96,23	Easy	0,03	Very low	0,11
12	100	6	0	0,94	94,34	Easy	0,14	Very low	0,18
*13	22	73	11	0,23	23,16	Hard	0,44	High	0,456
14	96	10	0	0,91	90,57	Easy	0,21	Low	0,237
15	68	27	11	0,72	71,58	Medium	0,59	High	0,497

* It was removed from the analysis according to the criteria used to delete the items.

Table 5-17. Analysis of the items of the task (7) omission of phonemes

Item	Successes	Errors	Missing	*p*	*p**100	*p* level	D	D level	R
1	81	25	0	0,76	76,42	Easy	0,52	High	0,519
2	93	13	0	0,88	87,74	Easy	0,31	Medium	0,468
3	75	31	0	0,71	70,75	Medium	0,55	High	0,475
4	59	47	0	0,56	55,66	Medium	0,52	High	0,431
5	63	43	0	0,59	59,43	Medium	0,55	High	0,437
6	68	38	0	0,64	64,15	Medium	0,55	High	0,395
7	95	11	0	0,90	89,62	Easy	0,31	Medium	0,538
8	102	4	0	0,96	96,23	Easy	0,10	Very low	0,499
9	98	8	0	0,92	92,45	Easy	0,21	Low	0,422
10	93	13	0	0,88	87,74	Easy	0,24	Low	0,468
11	98	8	0	0,92	92,45	Easy	0,17	Low	0,487
12	96	10	0	0,91	90,57	Easy	0,21	Low	0,521
13	67	39	0	0,63	63,21	Medium	0,38	Medium	0,361
14	45	61	0	0,42	42,45	Medium	0,66	High	0,443
15	92	14	0	0,87	86,79	Easy	0,34	Medium	0,589
16	96	10	0	0,91	90,57	Easy	0,24	Low	0,544

Table 5-18. Analysis of the items of the task (8) homophone/pseudohomophone choice

Item	Successes	Errors	Missing	*p*	*p**100	*p* level	D	D level	R
*1	94	0	12	1,00	100,00	Easy	0,00	Discard	**
2	97	9	0	0,92	91,51	Easy	0,24	Low	0,278
3	94	12	0	0,89	88,68	Easy	0,28	Low	0,481
4	100	6	0	0,94	94,34	Easy	0,14	Very low	0,29
5	94	12	0	0,89	88,68	Easy	0,38	Medium	0,568
*6	104	2	0	0,98	98,11	Easy	0,07	Very low	0,322
*7	105	1	0	0,99	99,06	Easy	0,03	Very low	0,322
*8	105	1	0	0,99	99,06	Easy	0,00	Discard	0,036
9	93	13	0	0,88	87,74	Easy	0,24	Low	0,335
*10	22	84	0	0,21	20,75	Hard	0,17	Low	0,016
*11	104	2	0	0,98	98,11	Easy	0,07	Very low	0,458
12	100	6	0	0,94	94,34	Easy	0,21	Low	0,33
13	94	12	0	0,89	88,68	Easy	0,31	Medium	0,452

* It was removed from the analysis according to the criteria used to delete the items.
** It was removed from the analysis for having zero variance.

Table 5-19. Analysis of the items of the task (9) orthographic choice

Item	Successes	Errors	Missing	*p*	*p**100	*p* level	D	D level	R
1	62	32	12	0,66	65,96	Medium	0,51	Low	0,369
*2	94	0	12	1,00	100,00	Easy	0,00	Discard	**
3	103	3	0	0,97	97,17	Easy	0,10	Low	0,165
*4	0	94	12	0,00	0,00	Hard	-0,41	Discard	**
5	90	16	0	0,85	84,91	Easy	0,17	Low	0,096
*6	106	0	0	1,00	100,00	Easy	0,00	Discard	**
7	100	6	0	0,94	94,34	Easy	0,10	Very low	0,149
8	99	7	0	0,93	93,40	Easy	0,14	Very low	0,318
*9	106	0	0	1,00	100,00	Easy	0,00	Discard	**
10	87	19	0	0,82	82,08	Easy	0,31	Medium	0,333
11	85	9	12	0,90	90,43	Easy	0,26	Low	0,268
12	71	35	0	0,67	66,98	Medium	0,38	Medium	0,194
*13	101	5	0	0,95	95,28	Easy	0,07	Very low	0,215
14	42	64	0	0,40	39,62	Medium	0,24	Low	0,272
15	78	28	0	0,74	73,58	Medium	0,28	Low	0,292
16	101	5	0	0,95	95,28	Easy	0,14	Very low	0,382
17	91	3	12	0,97	96,81	Easy	0,12	Very low	0,214
*18	47	47	12	0,50	50,00	Medium	0,07	Very low	0,372

* It was removed from the analysis according to the criteria used to delete the items.
** It was removed from the analysis for having zero variance.

Table 5-20. Analysis of the items of the task (10) reading words

Item	Successes	Errors	Missing	*p*	*p**100	*p* level	D	D level	R
*1	104	2	0	0,98	98,11	Easy	0,07	Very low	0,298
*2	105	1	0	0,99	99,06	Easy	0,03	Very low	0,124
*3	104	2	0	0,98	98,11	Easy	0,07	Very low	0,114
*4	106	0	0	1,00	100,00	Easy	0,00	Discard	**
5	101	5	0	0,95	95,28	Easy	0,17	Low	0,203
*6	105	1	0	0,99	99,06	Easy	0,03	Very low	0,21
*7	104	2	0	0,98	98,11	Easy	0,03	Very low	0,237
*8	106	0	0	1,00	100,00	Easy	0,00	Discard	**
*9	104	2	0	0,98	98,11	Easy	0,07	Very low	0,237
*10	106	0	0	1,00	100,00	Easy	0,00	Discard	**

Item	Successes	Errors	Missing	*p*	*p**100	*p* level	D	D level	R
*11	104	2	0	0,98	98,11	Easy	0,07	Very low	0,298
*12	105	1	0	0,99	99,06	Easy	0,03	Very low	0,21
13	102	4	0	0,96	96,23	Easy	0,14	Very low	0,382
*14	106	0	0	1,00	100,00	Easy	0,00	Discard	**
*15	106	0	0	1,00	100,00	Easy	0,00	Discard	**
*16	106	0	0	1,00	100,00	Easy	0,00	Discard	**
17	99	7	0	0,93	93,40	Easy	0,24	Low	0,337
*18	106	0	0	1,00	100,00	Easy	0,00	Discard	**
*19	104	2	0	0,98	98,11	Easy	0,07	Very low	0,42
*20	105	1	0	0,99	99,06	Easy	0,03	Very low	0,554
21	101	5	0	0,95	95,28	Easy	0,17	Low	0,517
*22	104	2	0	0,98	98,11	Easy	0,03	Very low	0,053
*23	104	2	0	0,98	98,11	Easy	0,03	Very low	0,42
*24	104	2	0	0,98	98,11	Easy	0,07	Very low	0,543
25	100	6	0	0,94	94,34	Easy	0,21	Low	0,454
*26	105	1	0	0,99	99,06	Easy	0,03	Very low	0,554
*27	106	0	0	1,00	100,00	Easy	0,00	Discard	**
*28	105	1	0	0,99	99,06	Easy	0,03	Very low	0,382
*29	104	2	0	0,98	98,11	Easy	0,03	Very low	0,053
30	103	3	0	0,97	97,17	Easy	0,10	Very low	0,417
*31	105	1	0	0,99	99,06	Easy	0,03	Very low	0,382
32	103	3	0	0,97	97,17	Easy	0,10	Very low	0,316

* It was removed from the analysis according to the criteria used to delete the items.

** It was removed from the analysis for having zero variance.

Table 5-21. Analysis of the items of the task (11) reading pseudowords

Item	Successes	Errors	Missing	p	p*100	p level	D	D level	R
*1	105	1	0	0,99	99,06	Easy	0,00	Discard	0,004
*2	105	1	0	0,99	99,06	Easy	0,00	Discard	0,004
*3	105	1	0	0,99	99,06	Easy	0,03	Very low	0,452
*4	105	1	0	0,99	99,06	Easy	0,03	Very low	0,452
5	102	4	0	0,96	96,23	Easy	0,10	Very low	0,33
*6	105	1	0	0,99	99,06	Easy	0,03	Very low	0,153
7	103	3	0	0,97	97,17	Easy	0,10	Very low	0,638
*8	103	3	0	0,97	97,17	Easy	0,07	Very low	0,377
9	103	3	0	0,97	97,17	Easy	0,10	Very low	0,595
10	102	4	0	0,96	96,23	Easy	0,14	Very low	0,519
11	103	3	0	0,97	97,17	Easy	0,10	Very low	0,616
12	101	5	0	0,95	95,28	Easy	0,17	Low	0,622
*13	105	1	0	0,99	99,06	Easy	0,03	Very low	0,079
*14	104	2	0	0,98	98,11	Easy	0,07	Very low	0,324
*15	105	1	0	0,99	99,06	Easy	0,03	Very low	0,377
16	97	9	0	0,92	91,51	Easy	0,24	Low	0,323
*17	104	2	0	0,98	98,11	Easy	0,07	Very low	0,112
*18	105	1	0	0,99	99,06	Easy	0,00	Discard	0,004
19	101	5	0	0,95	95,28	Easy	0,17	Low	0,452
20	101	5	0	0,95	95,28	Easy	0,10	Very low	0,435
21	100	6	0	0,94	94,34	Easy	0,17	Low	0,385
22	102	4	0	0,96	96,23	Easy	0,14	Very low	0,273
*23	103	3	0	0,97	97,17	Easy	0,07	Very low	0,464
24	101	4	0	0,96	96,19	Easy	0,17	Low	0,724
25	101	5	0	0,95	95,28	Easy	0,17	Low	0,281
*26	103	3	0	0,97	97,17	Easy	0,07	Very low	0,029

Item	Successes	Errors	Missing	p	p*100	p level	D	D level	R
*27	101	5	0	0,95	95,28	Easy	0,07	Very low	0,179
*28	104	2	0	0,98	98,11	Easy	0,03	Very low	0,297
29	98	8	0	0,92	92,45	Easy	0,10	Very low	0,121
*30	104	2	0	0,98	98,11	Easy	0,07	Very low	0,43
*31	105	1	0	0,99	99,06	Easy	0,00	Discard	0,004
*32	105	1	0	0,99	99,06	Easy	0,03	Very low	0,041
*33	103	3	0	0,97	97,17	Easy	0,07	Very low	0,333
34	101	5	0	0,95	95,28	Easy	0,14	Very low	0,366
*35	103	3	0	0,97	97,17	Easy	0,07	Very low	0,29
36	102	4	0	0,96	96,23	Easy	0,10	Very low	0,159
*37	102	4	0	0,96	96,23	Easy	0,03	Very low	0,027
*38	104	2	0	0,98	98,11	Easy	0,03	Very low	0,112
39	87	19	0	0,82	82,08	Easy	0,38	Medium	0,301
40	101	5	0	0,95	95,28	Easy	0,17	Low	0,281
41	96	10	0	0,91	90,57	Easy	0,24	Low	0,309
42	91	15	0	0,86	85,85	Easy	0,21	Low	0,254
43	100	6	0	0,94	94,34	Easy	0,21	Low	0,307
44	103	3	0	0,97	97,17	Easy	0,10	Very low	0,181
45	100	6	0	0,94	94,34	Easy	0,10	Very low	0,15
*46	104	2	0	0,98	98,11	Easy	0,07	Very low	0,112
47	102	4	0	0,96	96,23	Easy	0,10	Very low	0,235
48	97	9	0	0,92	91,51	Easy	0,17	Low	0,271

* It was removed from the analysis according to the criteria used to delete the items.

Table 5-22. Analysis of the items of the task (12) visual speed of letters and numbers

Item	Successes	Errors	Missing	p	p*100	p level	D	D level	R
*1	104	2	0	0,98	98,11	Easy	0,07	Very low	0,881
*2	104	2	0	0,98	98,11	Easy	0,07	Very low	0,483
3	98	8	0	0,92	92,45	Easy	0,17	Low	0,556
4	99	7	0	0,93	93,40	Easy	0,17	Low	0,267
5	101	5	0	0,95	95,28	Easy	0,10	Very low	0,599
*6	105	1	0	0,99	99,06	Easy	0,03	Very low	0,647
7	103	3	0	0,97	97,17	Easy	0,10	Very low	0,866
8	101	5	0	0,95	95,28	Easy	0,17	Low	0,599
9	100	6	0	0,94	94,34	Easy	0,14	Very low	0,362
10	98	8	0	0,92	92,45	Easy	0,21	Low	0,37
*11	104	2	0	0,98	98,11	Easy	0,07	Very low	0,597
12	102	4	0	0,96	96,23	Easy	0,14	Very low	0,703
13	102	4	0	0,96	96,23	Easy	0,14	Very low	0,636
*14	104	2	0	0,98	98,11	Easy	0,03	Very low	0,407
*15	104	2	0	0,98	98,11	Easy	0,07	Very low	0,445
*16	105	1	0	0,99	99,06	Easy	0,03	Very low	0,647
17	100	6	0	0,94	94,34	Easy	0,21	Low	0,585
18	103	3	0	0,97	97,17	Easy	0,10	Very low	0,4
19	97	9	0	0,92	91,51	Easy	0,21	Low	0,566
20	95	11	0	0,90	89,62	Easy	0,28	Low	0,369
21	100	6	0	0,94	94,34	Easy	0,14	Very low	0,385
22	102	4	0	0,96	96,23	Easy	0,10	Very low	0,379
23	102	4	0	0,96	96,23	Easy	0,14	Very low	0,433
24	93	13	0	0,88	87,74	Easy	0,38	Medium	0,536
25	103	3	0	0,97	97,17	Easy	0,10	Very low	0,804
26	102	4	0	0,96	96,23	Easy	0,14	Very low	0,703
27	96	10	0	0,91	90,57	Easy	0,17	Low	0,463

Item	Successes	Errors	Missing	p	p*100	p level	D	D level	R
28	101	5	0	0,95	95,28	Easy	0,10	Very low	0,355
29	99	7	0	0,93	93,40	Easy	0,21	Low	0,392
30	103	3	0	0,97	97,17	Easy	0,10	Very low	0,804
31	100	6	0	0,94	94,34	Easy	0,14	Very low	0,585
32	100	6	0	0,94	94,34	Easy	0,21	Low	0,451
33	101	5	0	0,95	95,28	Easy	0,14	Very low	0,404
*34	103	3	0	0,97	97,17	Easy	0,07	Very low	0,447
35	90	16	0	0,85	84,91	Easy	0,31	Medium	0,295

* It was removed from the analysis according to the criteria used to delete the items.

Table 5-23. Analysis of the items of the task (13) retaining letters and words

Item	Successes	Errors	Missing	p	p*100	p level	D	D level	R
1	99	7	0	0,93	93,40	Easy	0,21	Low	0,622
2	103	3	0	0,97	97,17	Easy	0,10	Very low	0,207
3	96	10	0	0,91	90,57	Easy	0,31	Medium	0,529
4	99	7	0	0,93	93,40	Easy	0,24	Low	0,563
5	97	9	0	0,92	91,51	Easy	0,28	Low	0,543
6	102	4	0	0,96	96,23	Easy	0,14	Very low	0,681
7	101	5	0	0,95	95,28	Easy	0,14	Very low	0,353
8	94	12	0	0,89	88,68	Easy	0,31	Medium	0,463
*9	104	2	0	0,98	98,11	Easy	0,07	Low	0,37
10	92	14	0	0,87	86,79	Easy	0,34	Medium	0,482
11	99	7	0	0,93	93,40	Easy	0,10	Very low	0,368
12	81	25	0	0,76	76,42	Easy	0,41	High	0,46
13	99	7	0	0,93	93,40	Easy	0,17	Low	0,114
*14	105	1	0	0,99	99,06	Easy	0,03	Very low	0,486
15	101	5	0	0,95	95,28	Easy	0,17	Low	0,353
16	101	5	0	0,95	95,28	Easy	0,10	Very low	0,331
17	95	11	0	0,90	89,62	Easy	0,28	Low	0,423
18	101	5	0	0,95	95,28	Easy	0,14	Very low	0,514

* It was removed from the analysis according to the criteria used to delete the items.

Table 5-24. Analysis of the items of the task (14) reading narrative text

Item	Successes	Errors	Missing	*p*	*p*100*	*p* level	D	D level	R
1	94	12	0	0,89	88,68	Easy	0,17	Low	0,356
2	77	29	0	0,73	72,64	Medium	0,66	High	0,656
3	58	48	0	0,55	54,72	Medium	0,66	High	0,503
4	95	11	0	0,90	89,62	Easy	0,24	Low	0,374
5	48	58	0	0,45	45,28	Medium	0,66	High	0,496
6	52	54	0	0,49	49,06	Medium	0,76	High	0,522
7	58	48	0	0,55	54,72	Medium	0,38	Medium	0,384
8	60	46	0	0,57	56,60	Medium	0,79	High	0,63
9	100	6	0	0,94	94,34	Easy	0,14	Very low	0,343
10	71	35	0	0,67	66,98	Medium	0,48	High	0,441

Table 5-25. Analysis of the items of the task (15) reading expository text

Item	Successes	Errors	Missing	*p*	*p*100*	*p* level	D	D level	R
1	80	26	0	0,75	75,47	Easy	0,45	High	0,408
2	74	32	0	0,70	69,81	Medium	0,31	Medium	0,323
3	62	44	0	0,58	58,49	Medium	0,52	High	0,486
4	49	57	0	0,46	46,23	Medium	0,48	High	0,384
5	49	57	0	0,46	46,23	Medium	0,66	High	0,475

Item	Successes	Errors	Missing	*p*	*p**100	*p* level	D	D level	R
6	38	68	0	0,36	35,85	Medium	0,41	High	0,325
7	66	40	0	0,62	62,26	Medium	0,62	High	0,525
8	82	24	0	0,77	77,36	Easy	0,38	Medium	0,341
9	75	31	0	0,71	70,75	Medium	0,31	Medium	0,334
10	89	17	0	0,84	83,96	Easy	0,41	High	0,487

After debugging, 190 items were selected from the 273 initial item considering the criteria used to delete the items (the 83 items that were deleted are marked with an asterisk (*) in Table 5-11 to Table 5-25). As result of this process of analysis and debugging of items, in *Appendix E* all BEDA's definitive items are presented.

To sum up, the tasks (1) *segmentation into syllables* (see Table 5-11), (3) *segmentation into phonemes* (see Table 5-13), (4) *general rhyme* (see Table 5-14), (7) *omission of phonemes* (see Table 5-17), (14) *reading narrative text* (see Table 5-24), and (15) *reading expository text* (see Table 5-25) had not removed items, keeping the 12, 12, 4, 16, 10 and 10 items initially proposed, respectively. On the other hand, the task (2) *number of syllables* (see Table 5-12) consisted of 11 items of the 12 initially proposed. The task (5) *specific rhyme* (see Table 5-15) was reduced to 7 items of the 18 initially proposed. The task (6) *phonemic location* (see Table 5-16) was reduced to 10 items of the 15 initially proposed. The task (8) *homophone/pseudohomophone choice* (see Table 5-18) was reduced to 7 items of the 13 initially proposed. The task (9) *orthographic choice* (see Table 5-19) was reduced to 12 of the 18 items initially proposed. The tasks (10) *reading words* (see Table 5-20) and (11) *reading pseudowords* (see Table 5-21) were substantially reduced to 7 and 25 items, respectively, of the 32 and 48 initially proposed. The task (12) *visual speed of letters and numbers* (see Table 5-22) was reduced to 27 of the 35 initially proposed. Finally, the task (13) *retaining letters and words* (see Table 5-23) was reduced to 16 of the 18 initially proposed.

Finally, each of the descriptive statistics for each of the tasks of BEDA were recalculated (See Table 5-26):

Table 5-26. Measures of central tendency and variability of BEDA's tasks after debugging of the items

Task	Mean	Median	Mode	Maximum	Minimum	Range	Variance	Std. dev.	Skewness	Kurtosis
1.Segmentation into syllables	0,77	0,92	0,92	1,00	0,00	1,00	0,15	0,39	-1,62	1,81
2.Number of syllables	0,80	0,91	0,91	1,00	0,00	1,00	0,14	0,37	-1,82	2,21
3.Segmentation into phonemes	0,82	1,00	1,00	1,00	0,00	1,00	0,14	0,36	-2,05	3,40
4.General rhyme	0,72	1,00	1,00	1,00	0,00	1,00	0,19	0,44	-1,08	-0,53
5.Specific rhyme	0,95	1,00	1,00	1,00	0,00	1,00	0,05	0,22	-4,43	19,80
6.Phonemic location	0,91	1,00	1,00	1,00	0,00	1,00	0,08	0,26	-3,69	14,35
7.Omission of phonemes	0,77	0,94	0,94	1,00	0,00	1,00	0,15	0,38	-1,84	3,40
8.Homophone/pseudohomophone choice	0,91	1,00	1,00	1,00	0,00	1,00	0,09	0,29	-2,94	7,18
9.Orthographic choice	0,82	0,92	0,92	1,00	0,00	1,00	0,12	0,33	-2,62	8,67
10.Reading words	0,96	1,00	1,00	1,00	0,00	1,00	0,04	0,20	-4,65	20,69
11.Reading pseudowords	0,94	1,00	1,00	1,00	0,00	1,00	0,05	0,23	-4,22	17,34
12.Visual speed of letters and numbers	0,94	1,00	1,00	1,00	0,00	1,00	0,06	0,23	-4,11	16,27

Task	Mean	Median	Mode	Maximum	Minimum	Range	Variance	Std. dev.	Skewness	Kurtosis
13.Retaining letters and words	0,92	1,00	1,00	1,00	0,00	1,00	0,07	0,26	-3,54	11,94
14.Reading narrative text	0,67	0,80	0,80	1,00	0,00	1,00	0,19	0,43	-1,14	1,19
15.Reading expository text	0,62	0,70	0,70	1,00	0,00	1,00	0,22	0,46	-0,60	-1,15

5.3 Summary

This chapter presented the definition of an automated battery for the assessment of cognitive processes involved in reading, called **BEDA** (acronym for the Spanish name *Batería de Evaluación de Dislexia en Adultos*). BEDA is a software tool, which is composed of 15 tasks that can be completed by students 16 years old and older. Basically, this tool consists of eight modules: six for the assessment of each cognitive process involved, one for the analysis of results, and one for administration purposes.

Assessment modules involve tasks to assess *phonological awareness, orthographic processing, lexical access, processing speed, verbal working memory,* and *semantic processing*, all of which are necessary to identify dyslexia in university students. To implement these tasks, it was relied on a multimodal architecture that allows the student to communicate with BEDA through different modes according to the specific objective of each assessment task. BEDA uses modes of interaction for inputs and outputs that allow the combined use of spoken and written language and other devices like the keyboard and the mouse. BEDA includes 15 assessment tasks; each task consists of set of items or exercises that assess the differente cognitive processes. Each item has an associated stimulus to complete it (e.g., a word, a sound, a question, etc.). There are example items and assessment items. In total 308 items were defined (35 of example and 273 of assessment) (see Appendix D).

Analysis results module is created to design and deliver the results report of the students after they have completed the assessment tasks. It automatically generates an individual report for each student with: 1) the scores obtained and the difficulty level (none, slight, moderate or severe) presented on each assessment task, 2) the identification of cognitive processes that are deficient, 3) the overall cognitive performance, 4) the scores profile, 5) the diagnosis of the presence or absence of dyslexia, and 6) a set of recommendations for students based on their difficulty levels of each cognitive process. This module can be accessed by experts, teachers, and students: experts who are responsible for the content of the reports to be delivered, teachers who wish to know student results and recommendations for each case, and students that want to see their personal result report.

Administration module is designed and implemented for the exclusive use of a subject matter expert (e.g., an educational psychologist); this module allows the creation and/or edition of different assessment tasks needed to identify cognitive deficits in students.

This chapter also presented two case studies in order to test the functionality and usability of BEDA as well as to recover the score scales defining when a student presented or not a cognitive deficit and to analize and debug the BEDA's items used to assess each of the cognitive processes.

In the first case study, 19 students from the University of Girona (Spain) and the University of La Laguna (Spain) were asked about the functionality and the usability of BEDA, as well as the comprehensibility of BEDA's items (i.e., how easy it is to read or hear the different items by the students). In addition, it was explored the average time and sessions that the students require to complete it without feel them tired. According to the results, BEDA was reviewed and restructured: audio instructions were again recorded in an appropriate setting, some items were modified by psychologists, help guides were incorporated, an automated functional requirement validation at the beginning of BEDA execution was introduced, and a module to verify the accuracy of the tasks using voice recognition was developed, since the acoustic model of the speech recognition software needs more training to improve the accuracy of voice recognition for all students.

Then, in the second case study, the preliminary score scales of the BEDA's tasks were obtained, as well as the analysis and debug of BEDA's items was performed. In order to achieve this, a sample of 106 students from the University of Girona (Spain) who completed all tasks of BEDA was studied. To calculate the score scales, first, differences in gender were reviewed, however, significant differences were not found and therefore the scales were defined for the total sample. Then, scalar scores ranging from 1 to 12 were calculated. It is worth noting that these scales are not definitive, due to they require a larger population and different university contexts. These scales were calculated to provide a preliminary feedback and recommendations to students. Results of the analysis and debugging of BEDA's items allow selecting 190 items from the 273 initial items considering the criteria defined to delete the items. The BEDA's definitive items are presented in Appendix E.

Finally, it is highlighted that more case studies are being conducted at the University of La Laguna (Spain) and the University of Las Palmas Gran Canaria (Spain) in order to refine the score scales and the depuration of the BEDA's items.

CHAPTER 6

ASSISTANCE OF UNIVERSITY STUDENTS WITH READING DIFFICULTIES

In previous chapters methods and tools to detect and support university students with earlier diagnosis of dyslexia and/or reading difficulties, as well as, tools to detect their learning style and assess their cognitive processes were developed. In this chapter, a dashboard for visualizing and inspecting these reading difficulties and their characteristics, called ***PADA*** (acronym for the Spanish name *Panel de Analíticas de Aprendizaje de Dislexia en Adultos*), as well as a repository for storing and delivering of recommendations to overcome such difficulties, called ***RADA*** (acronym for the Spanish name *Recomendador de Actividades para la Dislexia en Adultos*), are presented.

PADA is a web-based tool designed to facilitate the creation of descriptive ***visualizations*** required for a better understanding of students about their learner model. Through information visualization techniques, PADA shows students the knowledge in their learner models in order to help them to increase their *awareness* and to support *reflection* and *self-regulation* about their difficulties in reading. PADA provides different visualizations on reading performance of students, so that they can self-identify their particular strengths and weaknesses and self-regulate their learning. Examples that cover a variety of visualizations (bar-charts, line-charts, and pie-charts) to show learner model fragments as personal details, reading profiles, learning styles, and cognitive traits of the students are described. PADA was tested in a case study with 26 students of different academic programs and levels, dyslexic and those with symptoms of dyslexia. The results show that PADA can assist students in creating awareness, and help them to understand their strengths and weaknesses associated with the reading tasks, as well as facilitate reflection and self-regulation in the learning process.

On the other hand, RADA is a tool that stores ***recommendations*** of learning activities for students with cognitive deficits. These recommendations were created in collaboration with expert researchers and practitioners in dyslexia. Currently, RADA contains 36 recommendations to support the different cognitive processes were assessed. Examples of these recommendations are described. The functionality of RADA and the comprehensibility of the recommendations were tested in a case study with 20 students from engineering programs.

This chapter is structured as follows. Section 6.1 gives an introduction about assistance of university students with reading difficulties. Section 6.2 describes PADA and its architecture, as well as a case study to evaluate its usefulness. Section 6.3 presents RADA and some of its recommendations, as well as a case study to evaluate its functionality and comprehensibility. Finally, Section 6.3.1 presents a summary of the chapter.

6.1 Introduction

The vision of this dissertation is that students with dyslexia and/or reading difficulties can learn at their own pace, knowing their strengths and weaknesses, and using their own strategies. To do so, the effectiveness and quality of their learning experience should be enhanced, by providing a better fit between the needs of affected students at a particular time and the learning facilities provided. However, the awareness of their reading difficulties (weaknesses) and learning styles (strengths) as well as their cognitive deficits should be encouraged in order to facilitate the learning reflection and self-regulation of it. In this sense, technologies have the potential to make a real difference for those with special learning needs, so that all students can make the most of their skills, irrespective of their disabilities. Accordingly, it is highlighted the construction of learner models (see Section 2.3.1) in order to gather students' information and hence delivering of suitable personalized and adapted learning to their needs in a learning context.

By opening this learner model (see Section 2.4), students are provided with additional information (e.g. reading difficulties, learning styles and cognitive deficits) about their learning process that is not usually available to them, so that they may then decide where they need or wish to improve their skills, and carry out the corresponding learning activities autonomously to achieve this improvement. In this sense, the use of learning analytics solutions to open the learner model is proposed.

Taking into account the foundations on *Activity-based Learner-models* (see Section 2.9.4.1), it is believed that this technical framework is suitable for providing appropriate learning analytics to students with dyslexia and/or reading difficulties. Therefore, this study raises new challenges to describe activity-based learner-models for the effective application of learning analytics in the support of the affected students. On one hand, it is necessary to clarify how to implement this technical framework in independent educational software such as PADA (see Section 6.2). On the other hand, new roles need to be supported as important subjects of educational activities for assistance of dyslexia and/or reading difficulties; in this dissertation the role of expert psychologist emerges and requires different communal perspectives. It is important to note that this role is not mentioned in the theories of learning orchestration and in this research work is essential for the design of the learning analytics and the creation recommendations provided by RADA. Finally, this work requires moderation of two types: *activity centered* and *outcome centered*. The prototypes of indicators implemented in (Florian et al., 2011) were only activity centered. The first type of moderation (activity centered) provides task support. This support can take many forms such as outlines, recommendations, storyboards, or key questions. It focuses on the modeling of a task, give advice or provide coaching. The second type of moderation (outcome centered) is guiding by feedback. This type of learning support tackles the problem solving skills of students by providing them an external view on their performance. Thus, such learning support is related to the assessment procedures that are defined for an educative process.

Figure 6-1 shows the Activity-based Learner-model technical framework adapted from (Florian et al., 2011) to this research work. This technical framework was extended to *Outcome-based Learner-model*. Thus, the monitoring and assessment can be either activity centered (e.g., Activity-based Aggregators) or outcome centered (e.g., Outcome-based Aggregators). Therefore, learning analytics can be on activities and performance of the students in terms of demographics, reading difficulties, learning styles and cognitive processes. From these learning analytics, the provision of recommendations by expert psychologists could be achieved. In Section 6.2, the architecture of PADA is described and the challenges previously defined are answered. In Section 6.3, a first approach of the implementation of RADA is described.

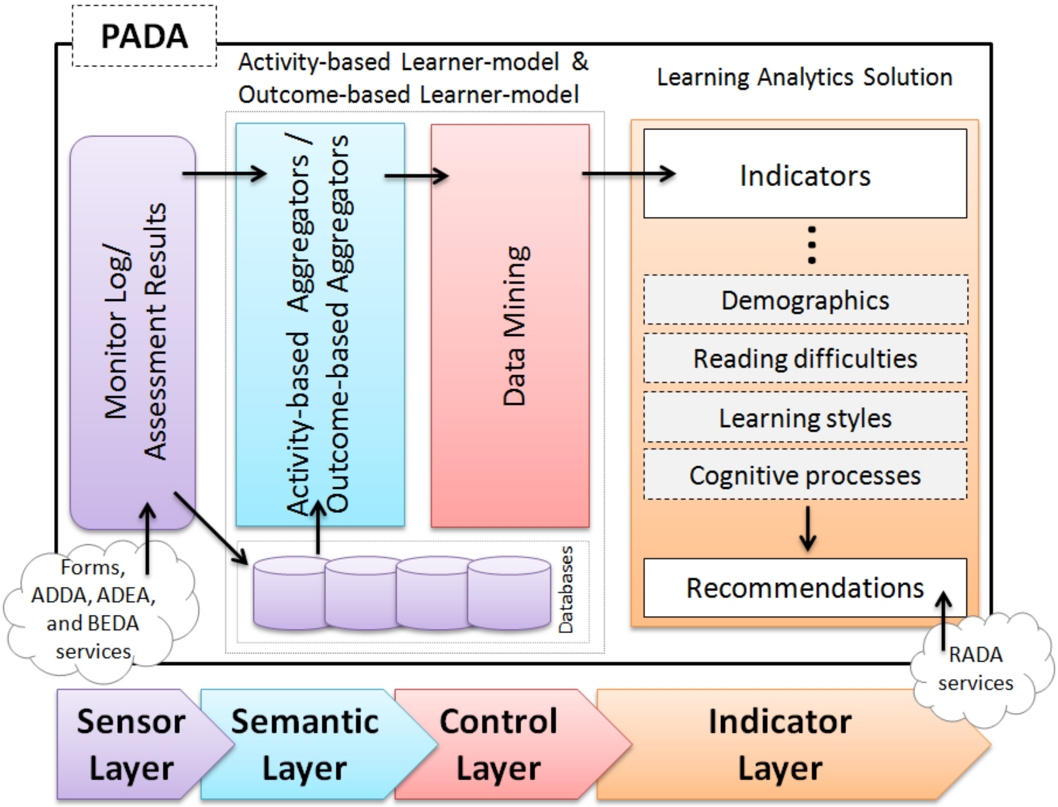


Figure 6-1. The activity-based learner-models technical framework adapted to PADA

6.2 PADA: Dashboard of Learning Analytics of Dyslexia in adults

Once the data detection and assessment of students is saved (see Chapter 4 and Chapter 5), learning analytics of the data collected can be produced. In this research work PADA tool is proposed to produce such learning analytics. PADA is a dashboard for visualizing and inspecting fragments of information from the learner model (Mejia & Fabregat, 2012) related to reading difficulties for university students (i.e., demographics, reading profile, learning styles, and cognitive traits). It generates visualizations for each of the demographics data forms, questionnaires (i.e., ADDA and ADEA) and cognitive assessment tasks (i.e., BEDA) presented in previous chapters. These visualizations seek to create awareness among students about their reading difficulties, learning style, and cognitive deficits in order to facilitate reflection and encourage self-regulated of their learning, especially where reading is involved.

6.2.1 Architecture and Implementation

As mentioned previously, the PADA architecture is based on the of the Activity-based Learner-models technical framework to have a flexible and extendable dashboard to open more fragments of the learner model if they are required later (Florian et al., 2011). Basically, the PADA components are: 1) the *databases*, which implement the sensor layer to collect data from the students and their activity and performance through forms (i.e., demographics), ADDA (i.e., reading profile), ADEA (i.e., learning styles) and BEDA (i.e., cognitive traits), 2) the *aggregators*, which implement the semantic layer to transform the data from the database according to the social plane (i.e., student, peers or class) and the social perspective (i.e., student, teacher or expert) required, 3) the *data mining*, which implement the control layer to process the aggregators using different rules and statistical analysis, 4) the *learning analytics*, which implement the indicator layer to display in the corresponding interface the visualizations (i.e., Overview, Reading Difficulties, Learning Styles, and Cognitive Processes), and 5) a *web server* that stores the implemented layers and allows communication between learners and PADA by means of a browser.

Three challenges were raised in Section 6.1 related with the particular implementation of Activity-based Learner-models in PADA:

- How to implement this technical framework in an independent educational software such as PADA?
- How can it include a new role of expert psychologist?
- How can be added an outcome-centered moderation?

To answer these challenges, Figure 6-2 summaries technology details to implement the four layers for PADA (answer to the first challenge). There are also details of aggregators' elements (to answer the second and the third challenge). The *sensor layer* uses PostgreSQL databases to save assessment results and monitor logs. The *semantic layer* is entirely implemented with the web object-oriented language PHP. In this layer a set of classes and functions are used to define aggregators. An aggregator function receives at least two parameters: a) the social plane, and b) the perspective. Inside the aggregator function a SQL query is built and launched. The SQL query changes depending on the value of parameters received. Thus, the same aggregator returns different semantic data. In PADA there are two kinds of aggregators. The outcome-based aggregators collect data of detection and assessment results from the database. The activity-based aggregators collect data from monitor logs from the database. The *control layer* holds several Javascripts based on the jQuery Javascript library. Scripts request particular aggregators. The request is an AJAX call to the server. Thus, data mining processes, codified with jQuery library and intensive AJAX call to the server, transform the information of the aggregators to send it to the *indicator layer*. A final processing is made in the indicator layer to produce adequate plots. These plots use new HTML 5 elements such as the <canvas> element. A particular library is used also, the jpPlot library. The final aspects of the interface are arranged using CSS. It is important to know that all selected technology is open source. In particular de jqPlot library was selected after testing it and other five libraries. The jqPlot library has functions to plot a wide range of charts, the aspect of plots is nice and adaptable, and finally the time of response is adequate.

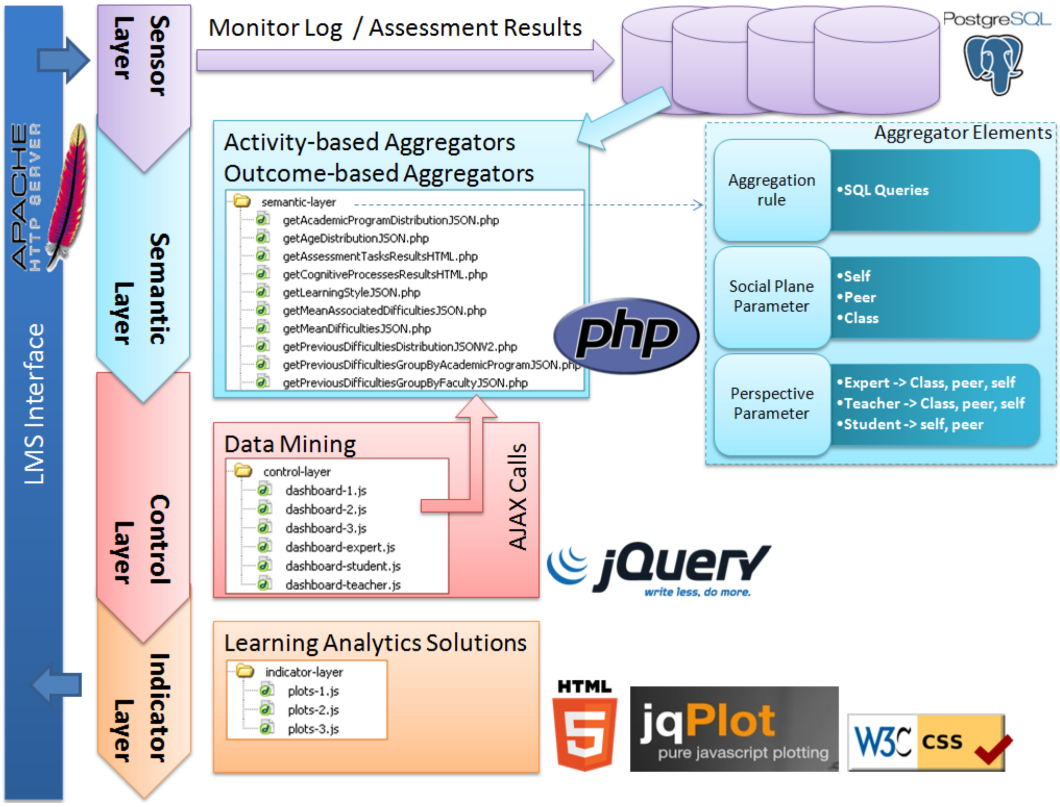


Figure 6-2. Architecture and technology behind PADA

To sum up the results of this architecture and their implementation are visualizations for different social planes (student, peers, and class) and social perspectives (student, teacher, and expert); although in this dissertation author only consider the student's perspective in the case study reported. Therefore, in this student's perspective, the visualizations that are shown are mostly for the student's social plane, although some of them include views of the peers and class planes in order to provide comparisons and generate reflection among students taking reference points. The social plane student shows visualizations of a single student (i.e. the student logged in PADA), the social plane peers shows visualizations of the entire class minus the student logged in PADA and the social plane class shows visualizations of the entire class.

6.2.2 Interfaces

The PADA interface was divided into four tabs depending on the learner submodel accessed: 1. demographics, 2. reading profile, 3. learning styles or 4. cognitive traits (see Section 3.3). These tabs allow students to explore different visual representations of their activity and performance and provide feedback to support them to recognize strengths and weakness in their reading competences. These tabs also provide some parallel views of an individual students, his/her peers, and all as a class, in order to identify the severity of their difficulties according to the results of other matched by age and academic level. The analyses are made according to guidelines and statistical analysis taking into account the criteria set for the construction of each of the data collection tools.

- **Overview** (see a in Figure 6-3) refers to personal details of the participant students (i.e. ages, genders, academic programs, etc.). The tab visualizes (1) the number of participant students, (2) the details of the student in session, (3) the time spent to complete the data collection tools (see b in Figure 6-3), (4) the age distributions, and (5) the number of student per academic program. Figure 6-3 shows results of the time spent to complete the data collection on a line chart; in this line student views the minimum time spent by a student, her/his time (see c in Figure 6-3), the average of her/his peers and class, as well as the maximum time spent by a student. The learning analytic present both textual and graphical visualizations.

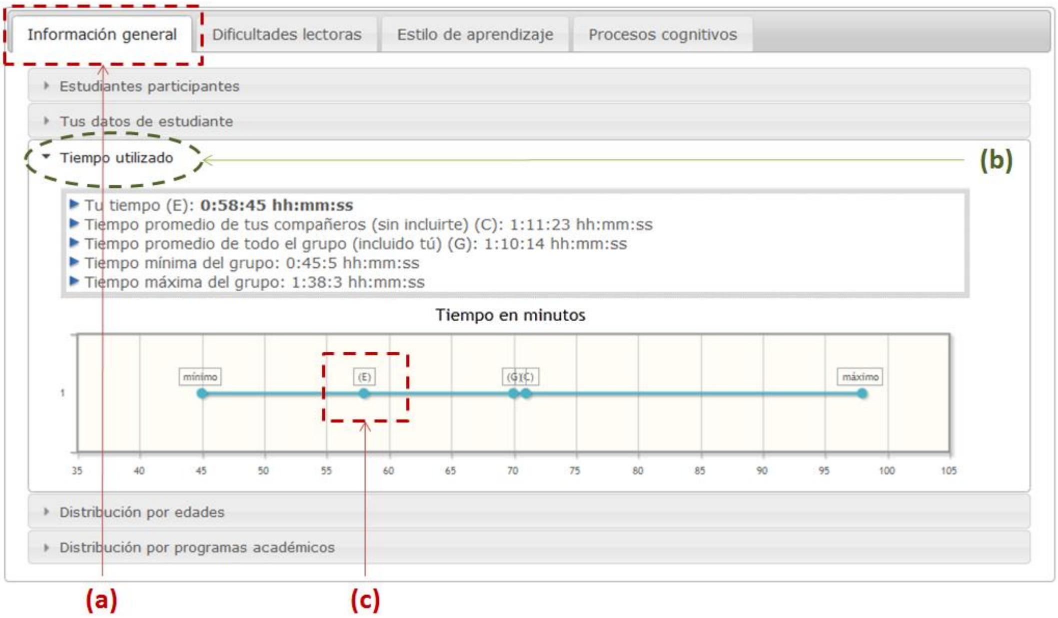


Figure 6-3. PADA interface: Tab of overview analytics

- **Reading difficulties** (see a in Figure 6-4) refers to reading profile of the participant students. The tab visualizes (1) the previous diagnosis of learning disabilities, (2) the number of learning difficulties in reading, writing and math reported by the students, (3) the number of associated difficulties with reading (i.e. language, memory, motivation, perception, attention, and spatial-temporal) reported by the students, and (4) the reading and writing habits reported by the students. Figure 6-4 (see b) shows results of the reading (left) and writing (right) habits by the single student while Figure 6-4 (see c) illustrates feedback provided to the student. Figure 6-5 (see a) displays results of the difficulties in reading, writing and math by the single student, peers and class while Figure 6-5 (see b) shows a summary by the single student. Figure 6-5 (see c) reports a summary of results of the associated difficulties with reading by the single student.
- **Learning styles** (see a in Figure 6-6) refers to ways in which participant students prefer to learn. The tab visualizes the major preferences of these students. Figure 6-6 (see b) shows result for a single student with learning style: active, sensory, visual and sequential. Figure 6-6 (see c) displays feedback provided to the student.

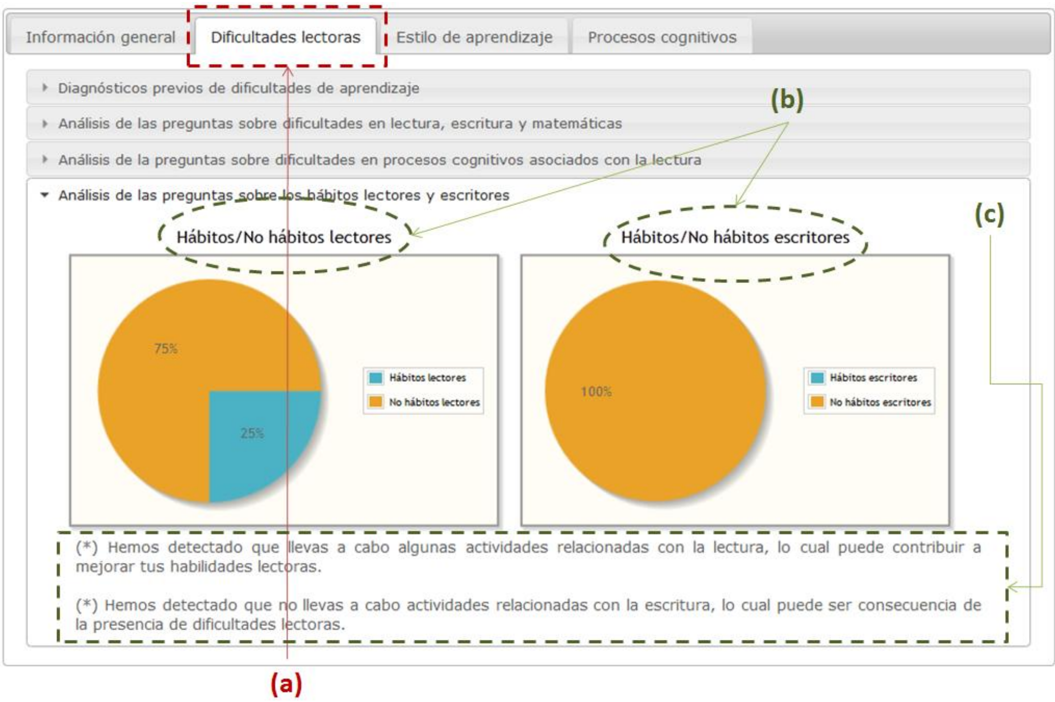


Figure 6-4. PADA interface: Tab of reading difficulties analytics

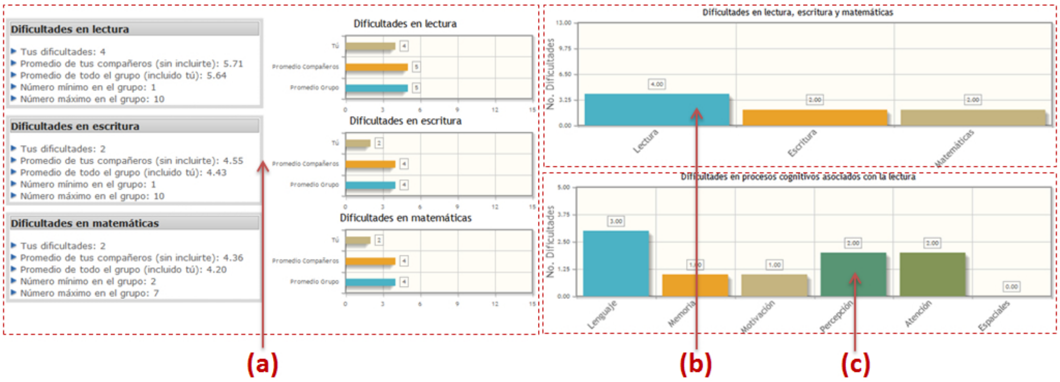


Figure 6-5. PADA interface: Analytics with summaries of reading and associated difficulties

- **Cognitive processes** (see Figure 6-7) refer to processes associated with reading that were assessed. The tab visualizes (a) the results for each assessment task, (b) the percentages of successes/errors for each assessment task, (c) the result for cognitive process, and (d) the percentages of success/errors for each cognitive process. Figure 6-7 (see a) shows results of the difficulties in the assessment task of phonological processing. Figure 6-7 (see b) illustrates results of successes/errors for the assessment task “Segmentation into Syllables” (Mejia, Díaz, Jiménez, et al., 2012). Figure 6-7 (see c) reports results for the cognitive processes by single student.

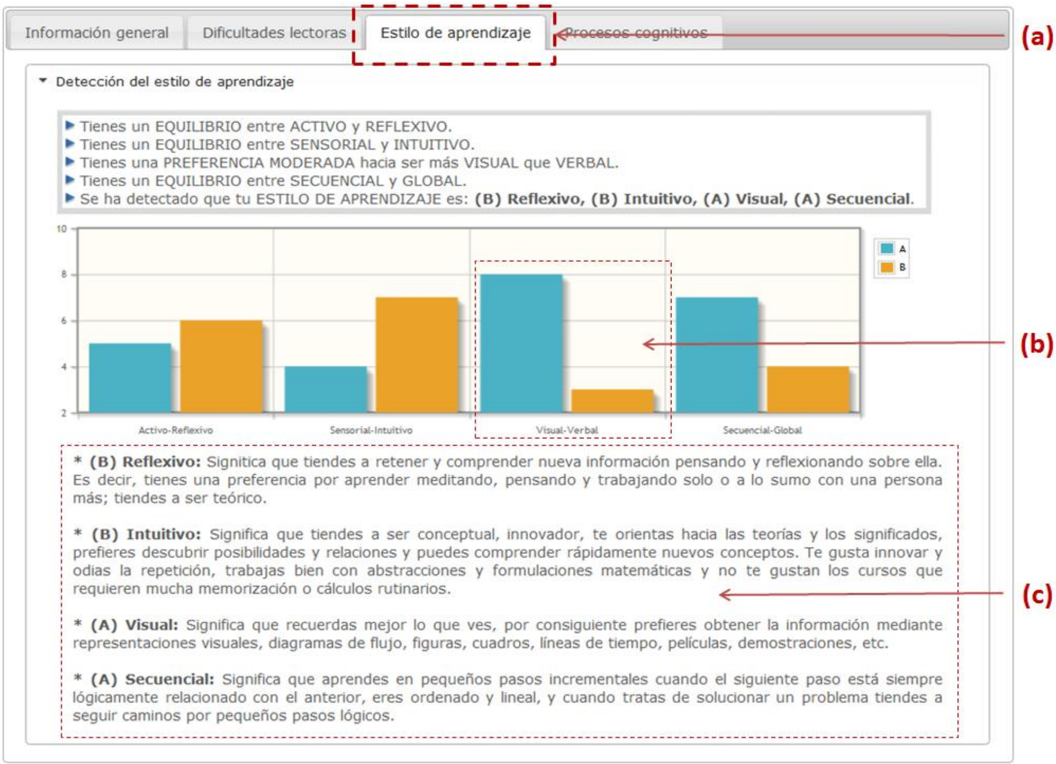


Figure 6-6. PADA interface: Tab of learning style analytics

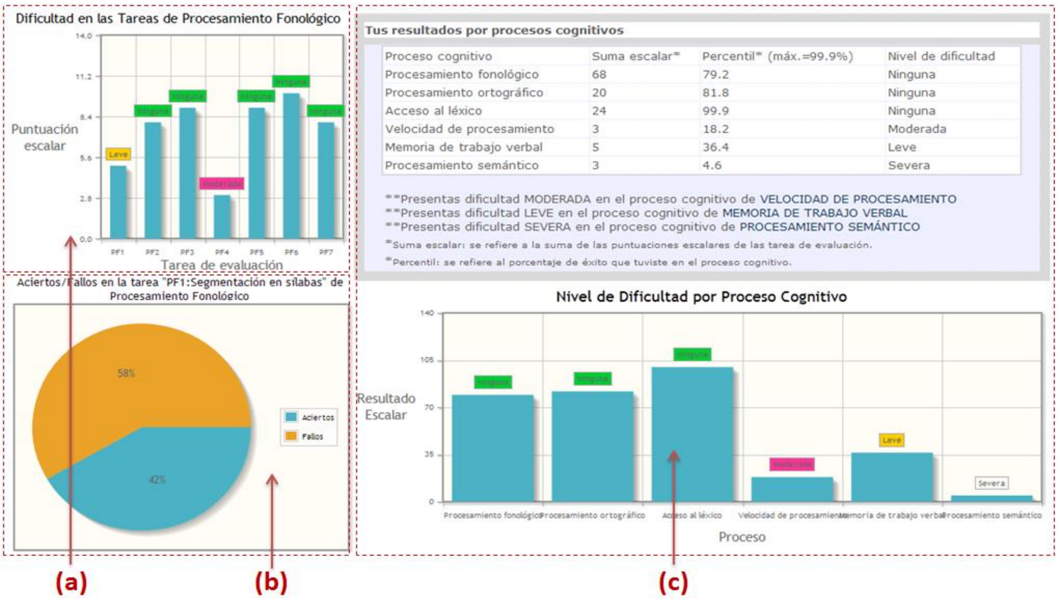


Figure 6-7. PADA interface: Tab of cognitive processes analytics

6.2.3 Case study

The concern is whether students would find PADA useful to detect their reading difficulties and their implications for learning and cognition. More specifically, this study was based on answering the following questions:

- Could students view their student model?
- Could students understand that model?
- Did students agree with the visualizations presented in that model?
- Were students aware on their difficulties, learning styles and cognitive deficits?
- Could PADA support students to perform self-regulated learning?
- Were learning analytics useful for students?

6.2.3.1 Method

6.2.3.1.1 Participants

Participants were 26 students (11 male and 15 female), with ages ranging from 21 to 53 years (M=27.538, SD=6.848) and coming from 15 classrooms of different programs and levels (undergraduate and graduate) at the University of Girona. All these students previously completed ADDA and they were selected because had a *Profile A*: students with symptoms of dyslexia (see Section 4.4.3). Eight students had a previous diagnosis of dyslexia, i.e., they had been formally diagnosed with dyslexia during their primary or secondary schooling, through an official psychoassessment procedure. Students were recruited by the coordinators of the faculties and/or schools through e-mail and website announcements. However, most dyslexic students were recruited in collaboration with the *Program to Support People with Disabilities of the University of Girona*. Students took part in an individual session that lasted an average of 60 minutes. Seven of them needed an average of two sessions to complete the tests without feeling tired.

6.2.3.1.2 Instruments

The case study was conducted in a computer lab using a Windows desktop computer equipped with a screen, a keyboard, a mouse, headphones, microphone, and Internet connection. Other software requirements were installing Java and an appropriate version of the Firefox web browser.

To carry out the case study all the web-based tools presented in previous sections were required (i.e., 1. Demographics data forms, 2. ADDA, 3. ADEA, and 4. BEDA). After all data were collected, PADA tool was enabled and became operational for participants. To gather participants' feedback about whether PADA could assist them in understanding their learner models and could be useful to identify reading difficulties, learning styles and cognitive deficits, author provided them with an online survey.

As shown in Table 6-1, the survey consisted of 37 statements as follows. One question to inquire whether participants have previous diagnosis of dyslexia (*'yes'* or *'no'*). Eight 5-point Likert scale questions to inquire about navigation, and understanding of the visualizations were presented in each tab of PADA (*'1 = never'* to *'5 = always'*). Nine 5-point Likert scale questions inquired about the agreement or disagreement with the contents of the learner model in term of reading difficulties, learning style and cognitive deficits detected (*'1 = strongly disagree'* to *'5 = strongly agree'*). Seven 5-point Likert questions inquired about the awareness and self-regulation that can support PADA (*'1 = never'* to *'5 = always'*). There were three open-end questions to clarify the moments reported by students regarding awareness of difficulties, learning styles and cognitive deficits. Four open-end questions accompanied each of the awareness questions to inquire about more visualizations which could improve the experience with PADA. Four

5-point Likert questions inquired about PADA's big-picture usefulness (*'1 = never'* to *'5 = always'*). One rank order scale question to inquire about the opinion on the type of recommendations that the participants would prefer to receive. Finally, one open-ended question gave the opportunity for additional comments.

Table 6-1. Overview of PADA survey case study

Descriptive information	
DES.1.	Have you been diagnosed with dyslexia?
Navigation	
A.1. to A.4.	Did you check graphical and textual visualizations in… Tab 1?, Tab 2?, Tab 3, Tab 4?
Understanding	
B.1. to B.4.	Was it easy for you to understand the meaning of the visualizations displayed on… Tab 1?, Tab 2?, Tab 3?, Tab 4?
Inspection	
C.1.	Do you agree with the visualizations about your reading difficulties?
C.2.	Do you agree with the visualizations about your associated difficulties (i.e., languages, memory, etc.)?
C.3.	Do you agree with the visualizations about your reading habits?
C.4.	Do you agree with the visualizations about your writing habits?
C.5.	Do you agree with the visualizations about your learning style?
C.6.	Do you agree with the visualizations about your successes/errors in each cognitive assessment task?
C.7.	Do you agree with the visualizations about your successes/errors in each cognitive process?
C.8.	Do you agree with the visualizations about your results in the cognitive assessment tasks?
C.9.	Do you agree with the visualizations about your cognitive deficits?
Awareness	
D.1.	Was it possible for you to be aware about your reading difficulties?
D.1.*	The former was possible by means of…
D.2.	Was it possible for you to be aware about your learning style?
D.2.*	The former was possible by means of…
D.3.	Was it possible for you to be aware about your cognitive deficits?
D.3.*	The former was possible by means of…
D.4.	Was it helpful for your awareness process to view your learning analytics versus the performance of others (i.e., "peers" and "class"?
D.5.	Did you learn more about your difficulties than you knew previously?
D.6. to D.9.	What other visualizations do you think could improve your experience in… Tab 1?, Tab 2?,Tab 3?, Tab 4?
Self-regulation	
E.1.	Do you think that PADA can help you in reflecting and making decisions to self-regulate your learning process?
Usefulness	
F.1.	Was it useful for you to check the visualizations in multiple views (i.e., graphical and textual)?
F.2.	Did the presented learning analytics provide feedback on your reading performance?
F.3.	Do you think PADA helps to recognize strengths and weaknesses in your reading process you could use to improve your academic performance?
F.4.	Did you find all the visualizations you expected?
Recommendations	
REC.1.	Finally, if you could have a recommender system in PADA, what kind of recommender do you prefer? '1 - advices recommended by dyslexia-affected peers', '2 - activities/tasks recommended by expert', '3 - exercises, games, and other resources recommended by experts'.
Comments	
COM.1.	Please, if you have more comments about your experience with PADA ...

Note. Tab 1=tab of overview; Tab 2=Tab of reading difficulties; Tab 3=Tab of learning styles; Tab 4=tab of cognitive processes.

6.2.3.1.3 Procedure

Prior to the case study, PADA was studied to evaluate the functionality and usability with a pilot group of students from the University of Girona. Once PADA was improved based on the findings of the pilot group, it was given to the participants of this case study. The present study focused on the use of PADA for visualizing and inspecting student models. Participants were given an explanation of the web-based tools so as they could familiarize themselves with them, before commencing their sessions. Once the participants started a session, firstly, they could register their personal details information. Then, they were asked to enter ADDA and fill in the self-report questionnaire in order to detect reading difficulties. Afterwards, they were asked to access ADEA to fill in the self-report questionnaire for detecting their learning styles. Subsequently, they completed all tasks of BEDA which evaluates their cognitive processes associated with reading. Thereafter, they were asked to enter PADA and navigate the entire tool. Finally, when participants had browsed through PADA, the teacher gave them access to the online survey.

During the process, participants were accompanied by one teacher with experience in using all tools. To complete this survey, they were left alone in order to not bias the responses. Approximately, this survey takes 10 to 20 minutes to complete.

6.2.3.2 Results

This study allows evaluating participants' opinions of the support for activity and performance analytics (i.e., visualizations) provided by PADA. These results presume to give a possible answer to the research questions defined for this study.

From the *navigation* category, the results indicated that all 26 participants navigated through the different tabs and visualizations presented in the graphical user interface of PADA. In terms of *understanding*, 84.6% of the participants always (53.8%) and almost always (30.8%) understood the meaning of the visualizations shown in the tab of overview (question B.1.). 96.1% of the participants always (53.8%) or almost always (42.3%) understood the visualizations in tab of reading difficulties (question B.2.). 80.8% of the participants always understood the visualizations in tab of learning styles (question B.3.), while the remaining 19.2% of them almost always understood. Regarding the tab of cognitive processes (question B.4.), 69.3% of participants always (30.8%) and almost always (38.5%) understood the visualizations presented, while 30.8% sometimes and 3.8% almost never understood them. A multivariate analysis of variance with the independent variable of dyslexia (dyslexic or possible-dyslexic, i.e., those with symptoms of dyslexia) and the four dependent variables of understanding visualizations (overview, reading difficulties, learning styles, cognitive processes) was statistically significant (Roy's largest root=1.01, $F(4, 21)=5.31$, $p=0.004$). However, a multivariate analysis of variance with the independent variable of gender (female or male) and the four dependent variables of understanding visualizations was not significant (Roy's largest root=0.33, $F(4, 21)=1.71$, $p=0.18$).

With regard to the remaining categories (i.e., inspection, awareness, self-regulation, and usefulness), it present the results considering separated groups of participants in students with diagnosis of dyslexia and students with symptoms of dyslexia (i.e., dyslexic and possible-dyslexic, respectively). This is because participants with previous diagnosis of dyslexia may be familiar with similar tools, since they could have received training, they could have a clear picture of their particular difficulties, and/or they could have adopted effective compensatory strategies to overcome their difficulties, which could provide us different perspectives on the visualizations of PADA.

In the *inspection* category, participants indicated being agreed or disagreed with the visualizations of the student model. As shown in Table 6-2, in general, participants strongly agreed or agreed with the visualizations presented (questions C.1. to C.9.), a small percentage of them were indifferent to these visualizations (questions C.2., C.3., C.4., C.6., C.7. and C.8.) and an insignificant percentage were disagreeing or strongly disagreeing with them. It is highlights that the visualizations of learning style (question C.5.), all participants strongly agreed or agreed with them.

Table 6-2. Results of inspection category

Question	Responses (n=26)					Possible-dyslexic (n=18)		Dyslexic (n=8)	
	Strongly disagree	Disagree	Indifferent	Agree	Strongly Agree	M	SD	M	SD
C.1.	0	2	0	12	12	4.44	0.784	4.00	0.926
C.2.	0	1	3	11	11	4.28	0.752	4.13	0.991
C.3.	0	0	3	14	9	4.22	0.732	4.25	0.463
C.4.	0	2	4	11	9	3.94	1.056	4.25	0.463
C.5.	0	0	0	9	17	4.78	0.428	4.38	0.518
C.6.	0	1	3	16	6	4.11	0.832	3.88	0.354
C.7.	0	2	3	13	8	4.11	1.023	3.88	0.354
C.8.	0	2	3	14	7	4.17	0.857	3.63	0.744
C.9.	1	1	0	17	7	4.28	0.752	3.63	1.061

According to the analysis of mean (M) and standard deviations (SD) in Table 6-2, the dyslexic participants not revealed significant differences in questions C.1. to C.7. compared to their peers with symptoms of dyslexia. However, in questions C.8. and C.9. some differences were showed. Table 6-3 summarizes these differences. Multivariate analyses of variance of the nine dependent variables of inspection (reading difficulties, associated difficulties, reading habits, writing habits, learning style, cognitive assessment task, cognitive process, results, and cognitive deficits) was insignificant for both the independent variable of dyslexia (Roy's largest root=1.03, $F(9, 15)=1.71$, $p=0.17$) and gender (Roy's largest root=0.76, $F(9, 15)=1.27$, $p=0.32$).

Table 6-3. C.8. and C.9 responses diagnosis*

	C.8.		C.9.	
	Possible-dyslexic (n=18)	Dyslexic (n=8)	Possible-dyslexic (n=18)	Dyslexic (n=8)
Strongly disagree	0	0	0	1 (12.5%)
Disagree	1 (5.5%)	1 (12.5%)	1 (5.5%)	0
Indifferent	2 (11.1%)	1 (12.5%)	0	0
Agree	8 (44.4%)	6 (75%)	10 (55.5%)	7 (87.5%)
Strongly agree	7 (39%)	0	7 (39%)	0

Table 6-4 shows the findings in the *awareness* category that participants could achieve by interacting with PADA. Although most participants always (42.3%) or almost always (26.9%) indicated that they were able to be aware of their reading difficulties (question D.1.), it is worth noting that 28% of them indicated that sometimes (19.2%), almost never (7.7%) or never (3.8%) achieved such awareness. Regarding the visualizations of learning style (question D.2.), author found that almost all participants achieved the awareness. For visualizations of cognitive processes (question D.3.), 77% of the participants indicated they achieved be aware of their cognitive deficits, while 23% indicated that they did it only sometimes (3.8%), almost never (11.5%) or never (7.7%).

Table 6-4. Results of awareness category

Question	Responses (n=26)					Possible-dyslexic (n=18)		Dyslexic (n=8)	
	Never	Almost never	Sometimes	Almost always	Always	M	SD	M	SD
D.1.	1 (3.8%)	2 (7.7%)	5 (19.2%)	7 (26.9%)	11 (42.3%)	4.00	1.237	3.88	0.991
D.2.	0	0	2 (7.7%)	5 (19.2%)	19 (73.1%)	4.72	0.575	4.50	0.756
D.3.	2 (7.7%)	3 (11.5%)	1 (3.8%)	12 (46.2%)	8 (30.8%)	3.78	1.263	3.88	1.246
D.4.	0	3 (11.5%)	6 (23.1%)	4 (15.4%)	13 (50%)	4.11	1.231	3.88	0.835
D.5.	0	2 (7.7%)	4 (15.4%)	12 (46.2%)	8 (30.8%)	4.22	0.808	3.50	0.926

Comparing possible-dyslexic and dyslexic students in Table 6-4, author did not find significant differences for these two groups in the aforementioned questions (D.1. to D.3.). However, analyzing questions about peer or group comparison (question D.4.) and increased knowledge of difficulties (question D.5.) revealed some differences. In question D.4. (possible-dyslexic M=4.11, SD=1.231; dyslexic M=3.88, SD=0.835) and question D.5. (possible-dyslexic M=4.22, SD=0.808; dyslexic M=3.50, SD=0.926). Therefore, it was presented cross-tabulation results between having or not a previous diagnosis and both questions (D.4. and D.5.) so as to understand better the distribution of responses in each case (see Table 6-5).

Table 6-5. D.4. and D.5. responses diagnosis*

	D.4.		D.5.	
	Possible-dyslexic (n=18)	Dyslexic (n=8)	Possible-dyslexic (n=18)	Dyslexic (n=8)
Never	0	0	0	0
Almost never	3 (16.7%)	0	1 (5.5%)	1 (12.5%)
Sometimes	3 (16.7%)	3 (37.5%)	1 (5.5%)	3 (37.5%)
Almost always	1 (5.5%)	3 (37.5.%)	9 (50%)	3 (37.5%)
Always	11 (61.1%)	2 (25%)	7 (39%)	1 (12.5%)

A multivariate analysis of variance with the independent variable of dyslexia (dyslexic or possible-dyslexic) and the five dependent variables of awareness (reading difficulties, learning styles, cognitive deficits, peer or group comparison, and increased knowledge) did not yield statistically significant results (Roy's largest root=0.40, F(5, 19)=1.52, p=0.23). Similarly, a multivariate analysis of variance with the independent variable of gender (female or male) and the five dependent variables of awareness was also not significant (Roy's largest root=0.10, F(5, 19)=0.39, p=0.84).

The comments in Table 6-6 illustrate some of the opinions given by participants for improving their experience with each tab of PADA (questions D.6. to D.9.). Several comments were repeated, and some participants included comments on performance and usability of PADA, which not been included in this table.

Table 6-6. Summary of highlighted student's comments regarding awareness category

1. Overview
I think that the overview tab was much appropriated.
The spent time comparison could have a "zoom option" to view better where I am located with regards to my group.
I found it hard to understand the distribution of academic programs analytic.
I would like viewing information about gender of my peers.
I would like viewing an analytic of the place of origin of my peers.
I think that the tab has more information than the one I would need to know.
2. Reading difficulties
I would like to find more details of my particular difficulties.
I think it is necessary to add the meaning of the difficulties associated with reading.
It would be interesting to know what difficulties I do not have.
I think a comparison chart with all difficulties you are measuring will be helpful.
I want to know how to deal with my particular difficulties.
I would like to know the causes for the difficulties presented.
It would be useful to know how these difficulties are manifest in "cognitive processes".
What learning methods could we use? and What teaching methods could teacher use?
3. Learning styles
I think that these analytics were much appropriated.
I would like to find more details of the presented classification.
It would be interesting some analytics by faculties and gender.
I think that could be presented a comparison between my analytics and my peers' analytics.
It is very interesting information that can be used by teachers to design activities and resources of their courses.
I want to know other learning methods that people with the same difficulties are using positively.
4. Cognitive processes
I think it is necessary to add the meaning of each task assessment and each cognitive process.
I would like to find more details about my cognitive deficits.
I think that a comparison between my analytics and my peers' analytics could be interesting.
It would be interesting to know how scalar scores were obtained, which define the presence or absence of cognitive deficits.
I would like advice on what I can do to improve the processes affected.
I would like to know the causes of my cognitive deficits.
It would be worth to add graphics that include the variable time, i.e. I think it is important to know how long it takes you to read/write something and compare this value with my peers'.

The *self-regulation* evaluation that can support PADA was represented in the E.1. question. It was found that 61.5% of the participants always (11.5%) or almost always (50%) took conscientious that PADA could encourage self-regulation in the learning process, 30.8% indicated that only sometimes could it, while 7.6% indicated that almost never or never could it. A univariate analysis of variance with the independent variable of dyslexia and the dependent variable of self-regulation was not significant ($F(1, 23)=0.03$, $p=0.85$) and neither were there any significant differences with respect to gender ($F(1, 23)=0.14$, $p=0.71$)

In relation to the *usefulness* of PADA (see Table 6-7), participants reacted positively to the idea of multiple views (question F.1.), with 88.5% always and 11.5% almost always useful as response. Also, they were positive about how easily they could recognize the strengths and weaknesses of their reading process using PADA (question F.2.), with 23.1% always, 50% almost always and 23.1% sometimes useful as response. But, they were not so positive about the use of PADA to improve their academic performance (question F.3.), since 23.1% of participants almost never found it useful. However, participants indicated that PADA showed the visualizations that they expected to find (question F.4.).

Table 6-7. Results of usefulness category

Question	Responses (n=26)					Possible-dyslexic (n=18)		Dyslexic (n=8)	
	Never	Almost never	Sometimes	Almost always	Always	M	SD	M	SD
F.1.	0	0	0	3 (11.5%)	23 (88.5%)	4.94	0.236	4.75	0.463
F.2.	1 (3.8%)	0	6 (23.1%)	13 (50%)	6 (23.1%)	3.94	1.056	3.75	0.463
F.3.	0	6 (23.1%)	5 (19.2%)	8 (30.8%)	7 (26.9%)	3.72	1.274	3.38	0.744
F.4.	0	0	5 (19.2%)	16 (61.5%)	5 (19.2%)	4.22	0.548	3.50	0.535

Comparing the responses of dyslexic participants and those with symptoms of dyslexia (possible-dyslexic), author only found a significant difference in question F.4. (possible-dyslexic M=4.22, SD=0.548; dyslexic M=3.50, SD=0.535). Table 6-8 presents the cross-tabulation results between these two groups of participants and question F.4. A multivariate analysis of variance with the independent variable of dyslexia (dyslexic or possible-dyslexic) and the four dependent variables of usefulness (multiple views, reading performance feedback, reading process evaluation, and expected visualizations) was statistically significant (Roy's largest root=0.58, F(4, 20)=2.87, p=0.05). However, a multivariate analysis of variance with the independent variable of gender (female or male) and the four dependent variables of usefulness was not significant (Roy's largest root=0.17, F(4, 20)=0.83, p=0.52).

Table 6-8. F.4. responses diagnosis*

	F.4.	
	Possible-dyslexic (n=18)	Dyslexic (n=8)
Never	0	0
Almost never	0	0
Sometimes	1 (5.5%)	4 (50%)
Almost always	12 (66.7%)	4 (50%)
Always	5 (27.8%)	0

Concerning the rank order question, participants organized three options of recommender systems from most to least important to them. In Table 6-9, the "votes" of participants for the three options were showed. Option R2 is the most preferred by participants (15 of 26; 57.7%). Option R3 is the second, which was selected by 7 participants (26.9%). While option R1 is the less preferred, since only 4 participants (15.4%) reported they preferred this option.

Table 6-9. Recommendation preferences

Order	Options		
	R1	R2	R3
1	4 (15.4%)	15 (57.7%)	7 (26.9%)
2	7 (26.9%)	10 (38.5%)	9 (34.6%)
3	15 (57.7%)	1 (3.8%)	10 (38.5%)

Finally, some additional comments made by participants suggest their interest in PADA and willingness to contribute to its improvement:

- "It is a very useful tool - it helped me to reflect on the difficulties I have; it was good to learn about my learning style to reinforce my strategies for studying. I think the cognitive processes analytics are fine, but I missed more feedback on them."

- "It is very gratifying to see the results both textual and visual, since the reports I used to receive they are all textual and also hard to understand."
- "It would be interesting to have available a tutorial explaining the issues addressed by PADA which includes: symptoms, causes and solutions, cognitive processes, and so on."
- "I would appreciate to see some recommendations for dealing with my difficulties and strengthening my abilities."
- "I never had the opportunity to know such information, and I think that can be very helpful to improve my studying habits. I also believe that this information can be very useful for our teachers."
- “I think PADA may show more information. I spent almost 2 hours completing questionnaires and doing exercises. I would like to see more details of what I did.”

6.2.3.3 Discussion

The main focus of this study was assessing the usefulness of PADA in term of assisting university students with dyslexia and/or reading difficulties to achieve awareness, so that, reflection and self-regulation could be facilitated during their learning process. Findings of previous studies of (Goldberg et al., 2003; Raskind et al., 1999; Reiff et al., 1994; Werner, 1993) revealed that awareness is a powerful predictor for their academic success. In this regard, a survey was created which explores PADA's aspects such as navigation, understanding, and inspection capabilities. In particular, the survey investigated awareness, as well as, support for reflection and self-regulation which PADA sought to provide. Finally, overall usefulness of PADA was assessed.

According to the *navigation* results, the PADA tool is found to be well implemented. Students reported viewing their entire learner model by browsing through all the tabs of PADA and checking different graphical and textual visualizations. They also commented that PADA adequately respond to their navigation pace, it was friendly and intuitive, and it graphical user interface was suitable.

On the other hand, although students reported that it was easy to *understand* the different visualizations displayed, they also commented that it took them quite some time, mainly those related to cognitive processes. It is believe this could be due to two factors (1) there are many visualizations in this tab which makes students take longer to understand, and (2) the cognitive process concept is new for students which makes it difficult for quick comprehension. Furthermore, multivariate analysis showed significant differences between dyslexics and students with symptoms of dyslexia. Surprisingly, dyslexic students found it a little more difficult to understand the meaning of the cognitive processes visualizations. It was expected that these students with previous diagnosis were more familiar with this concept. At this point, it is worth noting that dyslexia definitions and diagnostic criteria have changed since these students were first identified during childhood.

Regarding the *inspection*, overall, students were rather agreeing with the visualizations presented. This could indicate that PADA is reliable, though this claim may require further analysis of the system's confidence as presented by Bull & Pain (1995) and Mabbott & Bull (2006). However, it is worth noting that a slightly significant percentage of students were "indifferent" and "disagreed" with the visualizations of reading and writing habits. It is assuming that students who were "indifferent" might not have understood the visualizations presented, while students "agreed" or "disagreed" had understood the visualizations. Accordingly, it was expected that the inspection of the student model would lead to awareness and subsequent reflection and self-regulation. On the other hand, multivariate analyses were insignificant between dyslexics and students with symptoms of dyslexia, but analysis showed slight differences in visualization of cognitive processes. Some dyslexic students expected greater cognitive deficits than those presented in PADA.

In relation to *awareness*, although most students reported having reached awareness, a slight percentage reported not having succeeded with a few visualizations of reading difficulties and cognitive processes. On the one hand, it was assumed that the positive perceptions of most of the students are due to the novelty of incorporating the cognitive processes concept across students' learning process. On the other hand, it was observed that both dyslexics and students with symptoms of dyslexia require more feedback on the visualizations presented to increase their awareness. In order to understand better why the slight percentage of students did not increase their awareness, it was highlighted some of their comments: *"I need more feedback to understand the difficulties presented and be aware of them", "I've had dyslexia for years. So, I know what my particular reading difficulties are. Then, I didn't have an increased awareness", "I enjoyed the visualizations presented, but it's not clear the meaning of each cognitive processes", "I do not quite understand the percentages that it shows to me"*. In addition, from the comments it was identified that some dyslexic students did not increase their awareness because they already knew their particular difficulties since childhood. This would indicate that the visualizations of reading difficulties increase more awareness among students with symptoms of dyslexia. This was also supported by peer or group comparisons which are presented in these visualizations, as well as the acceptance of these students to increase knowledge of their difficulties.

Similarly, the results on *self-regulation* showed that PADA can provide successful mechanisms to encourage student independence in overcoming their difficulties during the learning process.

Although the results of *usefulness* category were generally positive, i.e., students were satisfied about multiple views, reading performance feedback, and expected visualizations, these results were not so positive in recognizing the strengths and weaknesses in reading. Again, it confirmed the need to include more feedback on the visualizations presented. Furthermore, multivariate analysis showed significant differences between dyslexics and students with symptoms of dyslexia, particularly because dyslexic students expected more visualizations of their model. Emerging research findings indicate relationships between emotional, notational, and social aspects of learning analytics. These aspects could be considered in the usefulness evaluation of PADA's visualizations. For example, studies of (Vatrapu, Reimann, Johnson, & Bull, 2013) show that the traffic lights representations followed by smile notations have high emotional activation in students, because of their general socio-cultural availability and quick comprehension. In (S. Bull & Kay, 2007), the notations and social aspects also are studied in order to increase the interest of the students in their learner models. Further, in (S. Bull & Britland, 2007) , authors note that release of model fragments to peers could help to find suitable collaborators peers with common difficulties. Additionally, facilitating collaboration between partners can improve understanding of themselves and each other by gaining information from their respective learner model. Here, it is worth noting that visualizations could play a role in guiding collaborative learning by amplifying certain kind of social interactions (Scheuer, Loll, Pinkwart, & McLaren, 2010; Suthers, Vatrapu, Medina, Joseph, & Dwyer, 2008).

Regarding students' gender, there were no significant differences between female and male students in any of the aspects evaluated (i.e., navigation, understanding, inspection, awareness, self-regulation, and usefulness). This is a topic of interest since previous studies have often reported a higher rate of difficulties for males than females (Allred, 1990; Newman et al., 1993; Snowling, 2000), as well as differences in the particular difficulties presented by males and females, and the specific assistance that they require (Heyman, Swain, & Gillman, 2004; Rojewski, 1999). For instance, regarding attitude to technology, males generally are performing better in learning conditions which included visual resources, while females perform better with the traditional text-based resources (Holzinger, Kickmeierrust, Wassertheurer, & Hessinger, 2009).

Finally, over 100 comments were made by students. It was surprising that students made comments as the open-ended question was not mandatory. They made comments to clarify some answers, they suggested more visualizations to improve their experience, and they made comments that contribute to the overall enrichment of PADA. All in all, based on the empirical case study results, it is believed that PADA was well received, and it could be used to facilitate the learning process of students with dyslexia and/or reading difficulties.

Nevertheless, the findings of this study need to be viewed in light of some limitations. First, PADA is a tool to visualize the presence of reading difficulties or subjective symptoms implying dyslexia, the learning styles, and the presence of cognitive deficits, as well as to provide feedback. However, this feedback is still limited, so this may lead to the creation of specific and necessary recommendations to support reflection and self-regulation of difficulties and learning process. In addition, the students also offered some suggestions for improvement of the dashboard with new functionalities such as extend visualizations, giving more detail feedback on, and creating a tutorial. Moreover, PADA displayed visualizations for each of the tools that collect data (namely demographic data forms, ADDA, ADEA, and BEDA), but it does not create aggregators that combine data between tools. Further research is proposed to analyze the influence between data collected in order to improve the assistance. Finally, future work includes the execution of additional experiments with more dyslexic students, so as to evaluate the feedback provided by them about the effectiveness of the dashboard compared with the feedback of students with symptoms of dyslexia (i.e. have a balanced group of dyslexic and participants with symptoms of dyslexia). It is also believed that using PADA in a LMS can be useful in terms of improving the student's academic performance in general and this need to empirically investigated.

6.3 RADA: Recommender of Activities for Dyslexia in Adults

As mentioned before, to support the reflection and self-regulation processes in the students with their reading difficulties and learning, the creation of recommendations (i.e., hints, feedback, scaffold guidance and/or advices) is necessary. Thus, once the learning analytics are built (see Section 6.2), the provision of recommendations that complement such analytics could be achieved. Taking into consideration students' suggestions in the case study of PADA (see Section 6.2.3), a recommender system of learning activities provided by expert psychologist could be implemented. Thus, in this dissertation a first scope of this recommender was implemented.

Basically, RADA consists of a repository (i.e., database) of specialized recommendations of learning activities and an adaptation engine with the rules that evaluate whether recommendations can be delivered when a student presents a deficit in cognitive processes. RADA helps to mitigate the cognitive deficits detected in the students in order to improve their academic performance. The recommendations were created in collaboration with expert researchers and practitioners in dyslexia from University of La Laguna (Spain) and University of Las Palmas de Gran Canaria (Spain).

As first approach, RADA contains 36 recommendations to support the 6 cognitive processes assessed, i.e., by the moment, the repository was implemented based on the tab of cognitive processes of PADA. RADA stores these recommendations in both audio and text, and they can be delivered to students through PADA depending on their obtained scores and the cognitive difficulty level (none, slight, moderate or severe) presented. Further research is necessary to considering the remaining tabs (i.e., overview, reading difficulties, and learning style) and their combinations.

These recommendations are provided as assistance for students so that they can decide when to practice and thus self-regulate their training on cognitive processes involved in reading. It is stated that the provided recommendations do not substitute an intervention program. Below, some examples of recommendations stored at RADA are:

- Example of recommendation for training *Phonological processing*:

  Construct familiar words from the first syllable of another word. For example: "casa" (ca-sa). The first syllable is "ca", so look for words that begin with "ca", such as: "camisa" (ca-mi-sa), "capa" (ca-pa). Do not forget that the exercise consists in finding words that begin with the same syllable, so that words like "carpeta" (car-pe-ta) would not be valid, since the first syllable of "carpeta" is "car".

- Example of recommendation for training *Orthographic processing*:

  When writing use spelling check programs, such as freeware programs or Microsoft Word if you have access to this. Notice the words that the editor marks as incorrect (which are underlined in red) and write them down in a notebook in order to create a list of words with which to practice.

- Example of recommendation for training *Lexical access:*

  Measure the time, i.e., write the time that takes you to read lists of words or paragraphs, so as to see how reading speed increase or decreases. In case of reeading wrongly you should begin form the start and measure the time again.

- Example of recommendation for training *Speed processing*:

  Use video games involving your quick reaction and action. For example, the game "Tetris" or games in which have time limits for completing a task.

- Example of recommendation for training *Working memory*:

  Say a word, then say that word again plus one more word, and so on. Keep adding new words to the list and repeat them from the first word in the same order until you do not remember any.

- Example of recommendation for training *Semantic processing*:

  While you are reading, try to mentally put titles to each read paragraph. This will help you to get an overview and easy to remember each paragraph you read. If you think that reaching the end you will not remember reading your titles or general ideas, then you can write them down in the margin of paragraphs or in a notebook.

6.3.1 Architecture and implementation

The main objective of RADA is to enable the creation and delivery of specialized recommendations of learning activities for university students with deficits in any cognitive processes (i.e., phonological processing, orthographic processing, working memory, lexical access, processing speed, and semantic processing).

The architecture of RADA is modular to facilitate interaction between the different modules in relation to the user who uses them. For each type of user a different interface is presented depending on the permissions and tasks that can be developed. In the architecture it is specified the behavior of the tool, summarizing both the components and the relationships. In Figure 6-8 the components comprising the architecture are shown: 1) the *expert module*, 2) the *teacher module*, 3) the *student module*, 4) a *web server* that stores the modules and allows communication between users and the repository by means of a browser and 5) a *database* where the data from the recommendations and scales can be stored.

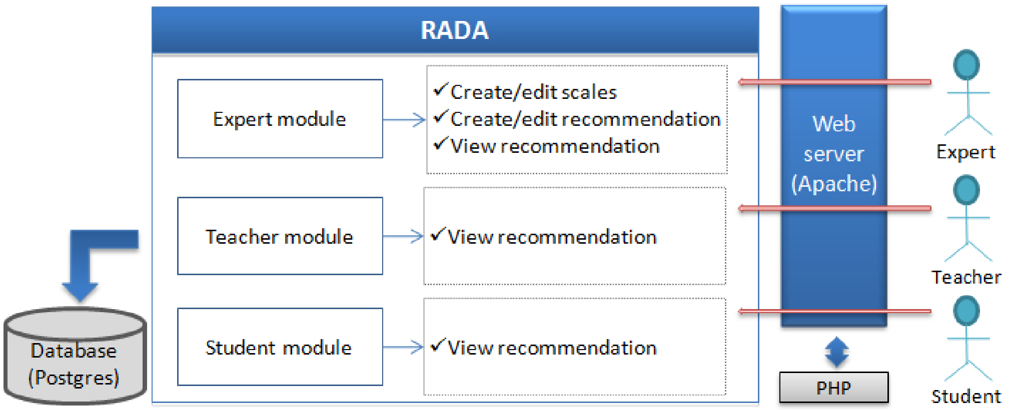


Figure 6-8. RADA's architecture

As shown in Figure 6-8, RADA can define three types of users: *Experts*, or users responsible for performing tasks related to the definition of the guidelines to present the recommendations (i.e., scales), the provision of recommendations, and the checking of the created recommendations; *Teachers*, or users responsible for viewing the recommendations given by experts for each student with cognitive deficits; and *Students*, or users that view their recommendations.

RADA was implemented with standard technology: Apache Web Server (version 2.0) which has support for PHP scripting language (version 5.2.6) and the relational database management Postgres (version 8.3.9), all installed on a Linux Operating System server (specifically Ubuntu 9.04, with kernel version 2.6.28).

During the implementation phase of the RADA, the different modules separately were tested. These tests revealed the need for changes in interface design and programming to achieve a better tool performance. The types of tests used were: connection to the database, requirements, inspection software/programming and functional testing of the different parts (such as adding/changing/deleting recommendations or adding/changing scales).

In next section, a case study with 20 students from the University of Girona and University of Cordoba is presented in order to test the functionality and usability of RADA. More than 5 students were asked to carry out this case study, because according to Nielsen (2000), Spool and Schroeder (2001), and Virzi (1992), the functionality and usability tests with at least 5 students provide the most information about the problems presented by the tools.

6.3.2 Case study

The aim of this case study was to evaluate the functionality of RADA and to check the comprehensibility of the recommendations, thus, two questions were drawn: Q1. Did you check recommendations (textual and auditory) when entering RADA? and Q2. Was it easy to understand the recommendations displayed in RADA?

6.3.2.1 Method

Ten students from the University of Girona (Spain) and 10 students from the University of Cordoba (Colombia) participated in the case study. For these samples both male and female students from engineering programs, aged between 22 and 27 (M=24.58, SD=2.193), were selected. Whether or not the student had dyslexia was not taken into account, because the aim of this case study was to evaluate the functionality of RADA and the comprehensibility of the recommendations.

This case study was carried out during the execution of the case study with students to test the functionality and the usability of the PIADA block (see Section 7.5.1). When students have finished completing their demographics, ADDA, ADEA, BEDA, and reviewing their learning analytics in PADA, they answered the two questions aforementioned (i.e., Q1 and Q2). The students chose the most appropriate response on a scale of 1-5 based on their perception.

6.3.2.2 *Results*

With regard to the first question, i.e. Q1, the results indicated that all 20 participants checked the different recommendations suggested by the experts. Furthermore, they confirmed they could both hear and read the recommendations.

Concerning the understanding of the recommendation displayed, i.e. Q2, 35% of participants always (30%) and almost always (5%) understood the recommendations presented, while 40% sometimes, 20% almost never and 5% never understood them.

6.3.2.3 *Discussion*

The case study allowed us verifies the functionality of RADA after students completed the information about demographics, self-questionnaires of ADDA and ADEA, as well as the tasks of BEDA.

However, the case study also shown that the students did not understand some of the recommendations well, which means that the recommendation have to be reviewed and restructured by the expert psychologists.

Thus, once the recommendations are reviewed, it is believed RADA is prepared to be used on a sample of university students with reading difficulties in order to analyze its usefulness in terms of enabling students to know about strategies they could follow to address their cognitive deficits. Furthermore, teachers may provide more appropriate learning resources for students who are affected.

Nevertheless, the findings of this study need to be viewed in light of some limitations. First, RADA is a tool to deliver recommendations, and it may deliver training activities (i.e., tasks, excercises, games, etc.) to overcome the deficits. Second, RADA deliver recommendations only for students with cognitive deficits, and it may deliver recommendations for all students with reading difficulties. Finally, RADA requires the execution of additional experiments, so as to evaluate the usability of the tool.

6.4 Summary

This chapter presented the definition of a dashboard of learning analytics of dyslexia and/or reading difficulties in adults, called PADA (acronym for the Spanish name *Panel de Analíticas de Aprendizaje de Dislexia en Adultos*), as well as a repository for storing and delivering of recommendations to overcome such difficulties, called RADA (acronym for the Spanish name *Recomendador de Actividades para la Dislexia en Adultos*). PADA is a software tool designed to facilitate the creation of descriptive learning analytics required for a better understanding of students about their learner model. Particularly, this novel tool generates automatic learning analytics from the detection and assessment tools presented previously in Chapter 4 and Chapter 5. RADA is a tool designed to store recommendations of learning activities to overcome cognitive deficits presented by students. The recommendations are created by experts and aimed at teachers and students. With PADA and RADA, experts, teachers and students are involved in a new approach support a better learning in higher education classes.

Through information visualization techniques, i.e. learning analytics, PADA shows students the knowledge in their learner models in order to help them to increase their awareness and to support reflection and self-regulation about their difficulties in reading.

PADA shows visualizations about demographics, reading profiles, learning styles, and cognitive traits of the students. Once these visualizations are presented, students can access specialized recommendations provided by RADA necessary to support the reflection and self-regulation processes.

PADA was tested in a case study with 26 students from the University of Girona, dyslexic and possible-dyslexic. The results show that PADA can assist students in creating awareness, and help them to understand their strengths and weaknesses associated with the reading tasks, as well as facilitate reflection and self-regulation in the learning process. Based on the results of this study it has been demonstrated that PADA is a usefulness tool. It was verified its functionality and navigability. Students were capable of understanding and inspecting their own student model through different visualizations. More interestingly, PADA can assist students in creating awareness, as well as facilitate reflection and self-regulation in the learning process.

On the other hand, RADA contains 36 recommendations to support the different cognitive processes were assessed. These recommendations were created in collaboration with expert researchers and practitioners in dyslexia. Examples of these recommendations were described.

The functionality of RADA and the comprehensibility of the recommendations were tested in a case study with 20 students from University of Girona and University of Cordoba. The results allowed to verify the functionality of RADA, but showed that some of the recommendations were difficult to understand.

In sum up, PADA and RADA are the first scope to provide a tool of assistance for university students affected with dyslexia and/or particular reading difficulties. PADA is based on the fundamentals of open user modeling and learning analytics. Particularly, its architecture is based on activity-based learner-models technical framework. PADA displayed visualizations of different tools previously implemented such as forms, ADDA, ADEA, and BEDA. Additionally, PADA displayed specialized recommendations extracted from RADA. Results of the case study shown that PADA is a usefulness tool, however, it is necessary to continue this work to study this usefulness of RADA as well as to test these tools with larger samples of dyslexics and students with symptoms of dyslexia.

Future research may provide a clearer picture of the learning analytics for awareness, reflection and self-regulation in the learning process among Spanish-speaking affected students. There is, of course, a need to replicate these findings and to validate them in other university contexts.

CHAPTER 7

INTEGRATION OF THE FRAMEWORK WITH A LEARNING MANAGEMENT SYSTEM

This chapter describes the integration of the proposed Framework presented in Chapter 3 (namely "Framework for Detection, Assessment and Assistance of University Students with Dyslexia and/or Reading Difficulties") with a Learning Management System (LMS). To carry out this integration, three components were developed, as follows:

- A ***Framework's Software Toolkit***, cluster of external software tools for retrieving and delivering the information processed in the Framework.
- An ***LMS's module***, through which it is accessed, displayed and used the information of the Framework.
- A communication bridge, based on ***web services*** technology, so as to transfer the information between the *Framework's Software Toolkit* and the *LMS's module*.

The integration enables the interaction between students with a LMS so as to provide them with a familiar environment that supports detection, assessment and assistance of reading difficulties related to dyslexia. The exemplary LMS used in this integration was **Moodle**, mainly because it is the LMS used at the University of Girona, as well as other universities that have contributed in the development of this research work.

This chapter is structured as follows: Section 7.1 shows a brief introduction and a research question concerning to the work presented in this chapter. Section 7.2 explains the *Framework's Software Toolkit*, and Section 7.3 explains the Moodle's used components. Section 7.4 presents details of the architecture designed for the integration process. Section 7.5 describes two conducted case studies to validate the integration. Participants in one case study were students, and in the other were teachers. This chapter ends in Section 7.6 with a summary of the chapter.

7.1 Introduction

Another novelty aspect of this dissertation is to consider into the context of a LMS the inclusion of students with dislexia and/or reading difficulties. As mentioned in Chapter 2, typically a LMS is able to manage characteristics of the students such as knowledge, interests, preferences, goals, background, among others. One specific objective of this dissertation is extending such scope to the characteristics of students with special needs such as dyslexia.

To achieve this objective, the integration of external tools developed for detection, assessment and assistance of university students and/or reading difficulties with a LMS is proposed. Initially, those tools were used independently of an LMS to deal with affected students. Some of them were used in higher education institutions, but not all teachers and experts manage to introduce them into their classrooms and consequently students with recognized or unrecognized reading difficulties are not treated appropriately.

Basically, the research question to be answered is: ***How detection, assessment and assistance can be provided to students in a LMS?*** To try giving an answer to this question, three components were designed and developed, namely:

(i). A *Framework's Software Toolkit*, cluster of external software tools for retrieving and delivering the information processed in the Framework. These tools were presented in previous chapters as follows: a set of forms to capture student demographics in Section 4.2, a self-report questionnaire to detect dyslexia in adults called ADDA in Section 4.4, a self-report questionnaire to detect learning styles called ADEA in Section 4.5, a assessment battery of dyslexia in adults called BEDA in Section 5.2, a dashboard of learning analytics of dyslexia in adults called PADA in Section 6.2, and a recommender of activities for dyslexia in adults called RADA in Section 6.3.

(ii). An *LMS's module* to interact with the tools of the Framework's Software Toolkit.

(iii). A communication bridge between the Framework's Software Toolkit and the LMS's module, which its architecture is based on *web services*. As first approach, the LMS used to implement the (ii) component was Moodle.

After presenting how the integration was achived by explaining each component, results of two conducted case studies are discussed.

7.2 The Framework's Software Toolkit

In this section the developed software tools that make up the proposed framework (see Chapter 3) are presented as a toolkit, as well as the processes that they carried out and designed databases (see Figure 7-1). The software tools are:

- The set of forms to capture student demographics.
- ADDA (acronym for Spanish name *Autocuestionario de Detección de Dislexia en Adultos*).
- ADEA (acronym for Spanish name *Autocuestionario de Detección del Estilo de Aprendizaje*).
- BEDA (acronym for the Spanish name *Batería de Evaluación de Dislexia en Adultos*).
- PADA (acronym for the Spanish name *Panel de Analíticas de Aprendizaje de Dislexia en Adultos*).
- RADA (acronym for the Spanish name *Recomendador de Actividades para la Dislexia en Adultos*).

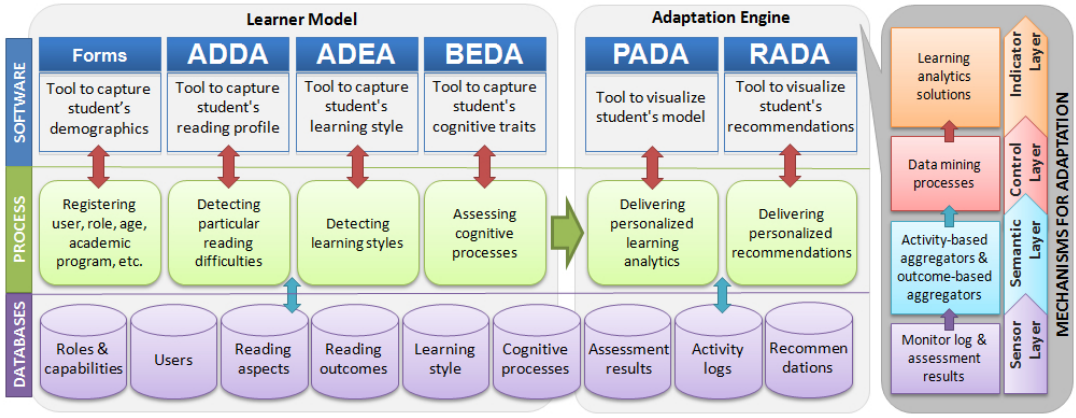


Figure 7-1. The framework's software toolkit

These tools are independent of any educational software system. This software toolkit is the materialisation of the main tools of the proposed framework in this dissertation, and it combines the **Learner Model** and the **Adaptation Engines** for "*Delivery personalized learning analytics*" and "*Delivery personalized recommendations*".

The *Framework's Software Toolkit,* as a set of tools, was built to perform a set of processes that aim to provide educational stakeholders with suitable support for:

- Registering users and including information about their role, age, gender, educational institution, faculty, academic program, etc. (Explained in Chapter 4).
- Detecting particular reading difficulties for identifying students' reading profile (Explained in Chapter 4).
- Detecting the learning style of students (Explained in Chapter 4).
- Assessing cognitive processes associated with reading in Spanish for identifying cognitive deficits (Explained in Chapter 5).
- Delivering personalized learning analytics for creating awareness and facilitating reflection and self-regulation during the learning process (Explained in Chapter 6).
- Delivering personalized recommendations for supporting the self-regulation of the students (Explained in Chapter 6).

Morever, these processes are based on the implementation of "mechanisms for adaptation", such as: monitor logs, activity-based and outcome-based aggregators, data mining, and learning analytics solutions (these mechanisms were described in Chapter 6).

7.3 The LMS Module

The exemplary LMS used in this dissertation was Moodle. This is an LMS with great pedagogical and technological flexibility and usability that is supported by a large community of developers and users around the world. Moodle has been developed as an open source educational application with a free software license, and is currently the LMS used at the University of Girona, as well as other universities that have contributed in the development of this research work. Particularly, Moodle is characterized by its simple interface, lightweight, and efficient, which can manage great amounts of educational resources, and that is easy to install. It is developed in PHP, it works with different database managers such as Postgres, MySQL, etc. Moreover, it can be installed in Linux or Windows operating systems and works with any web server that supports the appropriate version of PHP, although the most widely used web server is Apache.

A relevant characteristic of Moodle to this research work is its interoperability, by allowing the exchange of information with external software systems or tools. This can be achieved by the supported protocols in Moodle (such as SOAP and XML-RPC) for implementing the communication with a web service.

This feature of interoperability using web services facilitates the integration of the *Framework's Software Toolkit* proposed with this LMS. This will be further described in next Section 7.4.

Aditionally, Moodle is designed in a modular way, allowing new additions or modifications to be incorporated (without changing the source code) so as to facilitate its updating and growth. Thus, Moodle consists of "Modules" which provide users with different functionalities such as courses management, classes assignments, homework alerts, collaborative tools (e.g. forums, chat, etc.) management, quizzes assignment, among others. The stable builds of Moodle has some default modules for working, but more extensions (other modules) can be installed to deploy more functionalities.

Also in Moodle there are small modules called "blocks", which are considered "extras" that complement and support teachers and students to manage and perform activities in the courses respectively. Stable builds of Moodle already comes with several default *blocks* installed, although like the modules more extensions can be added. Some examples of these blocks are: a calendar, external RSS feeds, course description, a translator, etc.

In this research work a "block", named PIADA (acronym for the Spanish name *Plataforma de Intervención y Asistencia de Dislexia en Adultos*), which allow users to interact with the tools in the Framework's Software Toolkit was developed. To this end, PIADA was developed following the guidelines of Moodle.

PIADA's design involves two identified user's roles that can interact wih the tools in the *Framework's Software Toolkit*, namely:

- "Teacher", or users responsible for installing the block in their courses, review the learning analytics of the students enrolled in their courses, and viewing recommendations given by experts (e.g., educational psychologists) for each student with cognitive deficits; and
- "Student", or users who access the block and can view their reports.

Diagrams in Figure 7-2 and Figure 7-3 specify the behavior of PIADA using the Unified Modeling Language (UML). They have been organized into different functional groups for better interpretation. Thus, Figure 7-2 shows a Case Use diagram of the PIADA block with the actions that can be performed by each role (Teacher and Student), and Figure 7-3 shows the Activity diagram for PIADA. These diagrams show that the student is able to: register, view tools, access to tools, view progress notifications, and view results, while teacher is able to: view tools, access to tools, and view results.

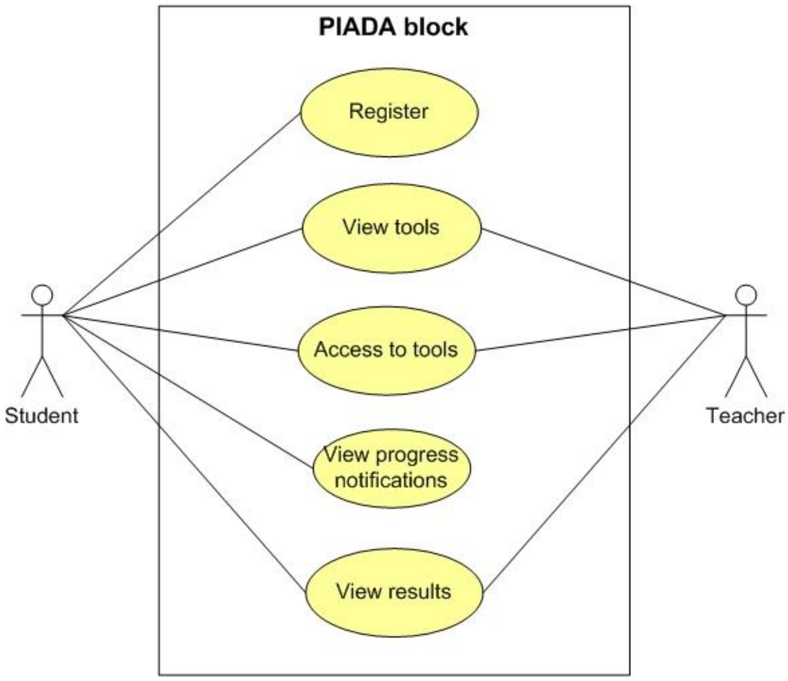


Figure 7-2. Use case diagram of the PIADA block

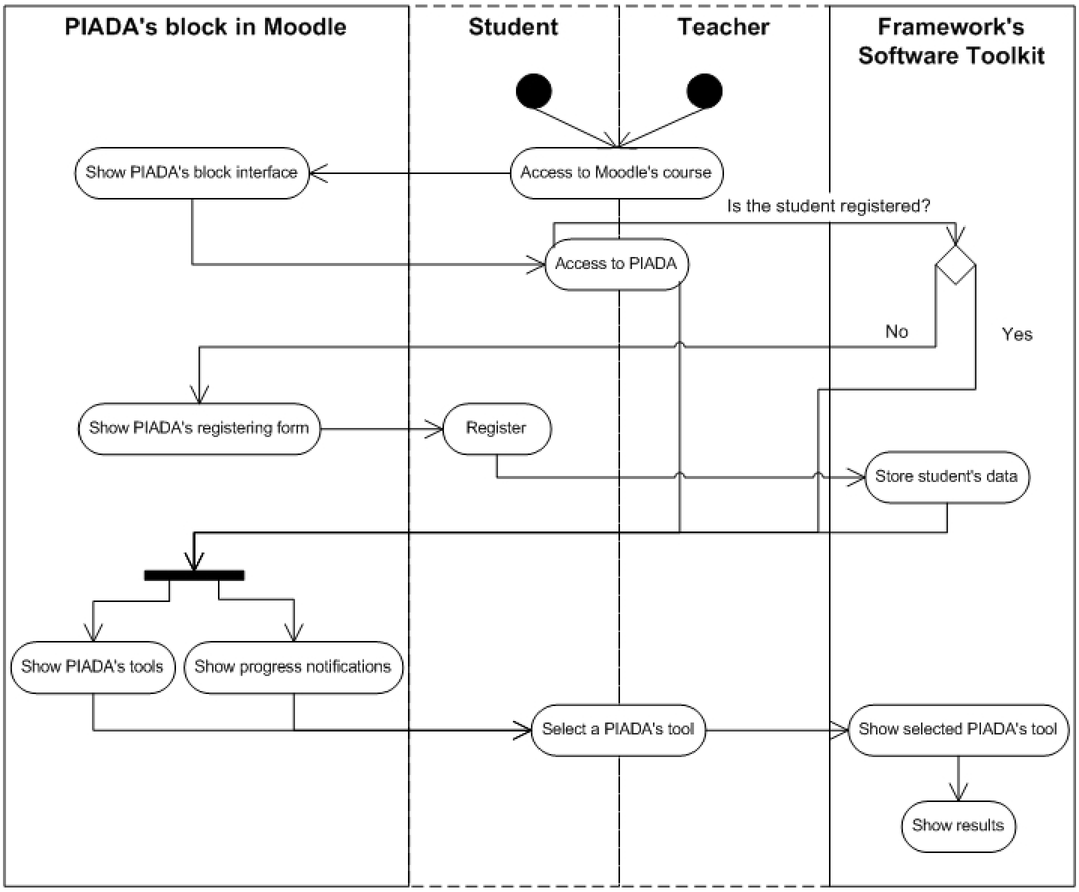


Figure 7-3. Activity diagram for PIADA

Thus, PIADA could be accessed by Students and Teachers as a complementary activity of a course that a teacher manages and in which students are enrolled. Table 7-1 show a summary of the requirements followed for the development of PIADA.

Table 7-1. Summary of requirements of the PIADA block in Moodle.

No.	Requirement
R1	The block should be able to register a new user in the Framework's Software Toolkit.
R2	The students should be able to access all tools of the Framework's Software Toolkit using the block.
R3	The students should be able to view progress notifications (i.e., percentages) of the detection and assessment tools (i.e., ADDA, ADEA and BEDA).
R4	The teachers should be able to view learning analytics and recommendatios (i.e., PADA and RADA) of students enrolled in the course.
R5	The block should be able to get the reading difficulties, learning styles, and cognitive deficits of a student.
R6	The teacher should be able to install the block in a course.
R7	The block should be able to install as a standard block of Moodle.
R8	The administrator should be able to update the block.
R9	The administrator should be able to unistall the block.

The development of the block was supported and performed using the modules creation wizard that Moodle offers. This wizard created a new folder within the Moodle blocks structure with the name "piada" to identify this new module. The creation of this folder, as shown in Figure 7-4, includes the automatic creation of an internal sub-folders structure and some necessary configuration files. The functionalities for interacting with the *Framework's Software Toolkit* within the block were developed using PHP and JavaScript.

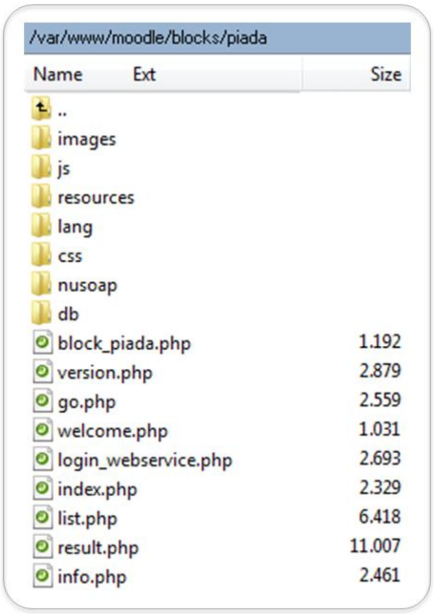


Figure 7-4. Folder structure of the PIADA block

The interfaces of the PIADA block were divided into two groups depending on the user's role who can access the tools (Student and Teacher). The group of interfaces for a Student allows accessing and visualizing the tools of the *Framework's software toolkit*, while the group of interfaces for a Teacher allows visualizing the learning analytics and recommendations for the students. Figure 7-5 depicts the user interface for accessing the PIADA block from a course in Moodle.

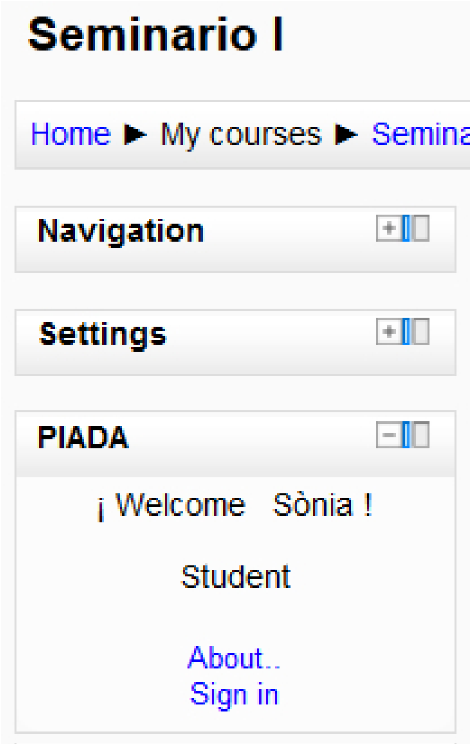


Figure 7-5. PIADA interface: Access from a course in Moodle

In the case of the Student role, once, a student accesses PIADA, a new browser window, divided into two sections, shows up. In the top of that window, icons for accessing each tool of the *Framework's software toolkit* from Moodle are displayed (see a in Figure 7-6). In the bottom of that window, a panel with notifications of the progress performed in the tools related with the Student Model (i.e. Forms, ADDA, ADEA and BEDA) is displayed, (see b in Figure 7-6).

Figure 7-6. PIADA interface: view of the students

In the case of the Teacher role, once a teacher accesses PIADA, a list with students enrolled in his/her course is displayed (see Figure 7-7). On the right side of that interface the teacher can enter to any of both: the analytics of learning (i.e., PADA) (see a in Figure 7-7) or the recommendations (i.e., RADA) (see b in Figure 7-7), and furthermore view the results of each student. These results will let the teacher to decide and deliver appropriated activities and resources to students regarding their needs.

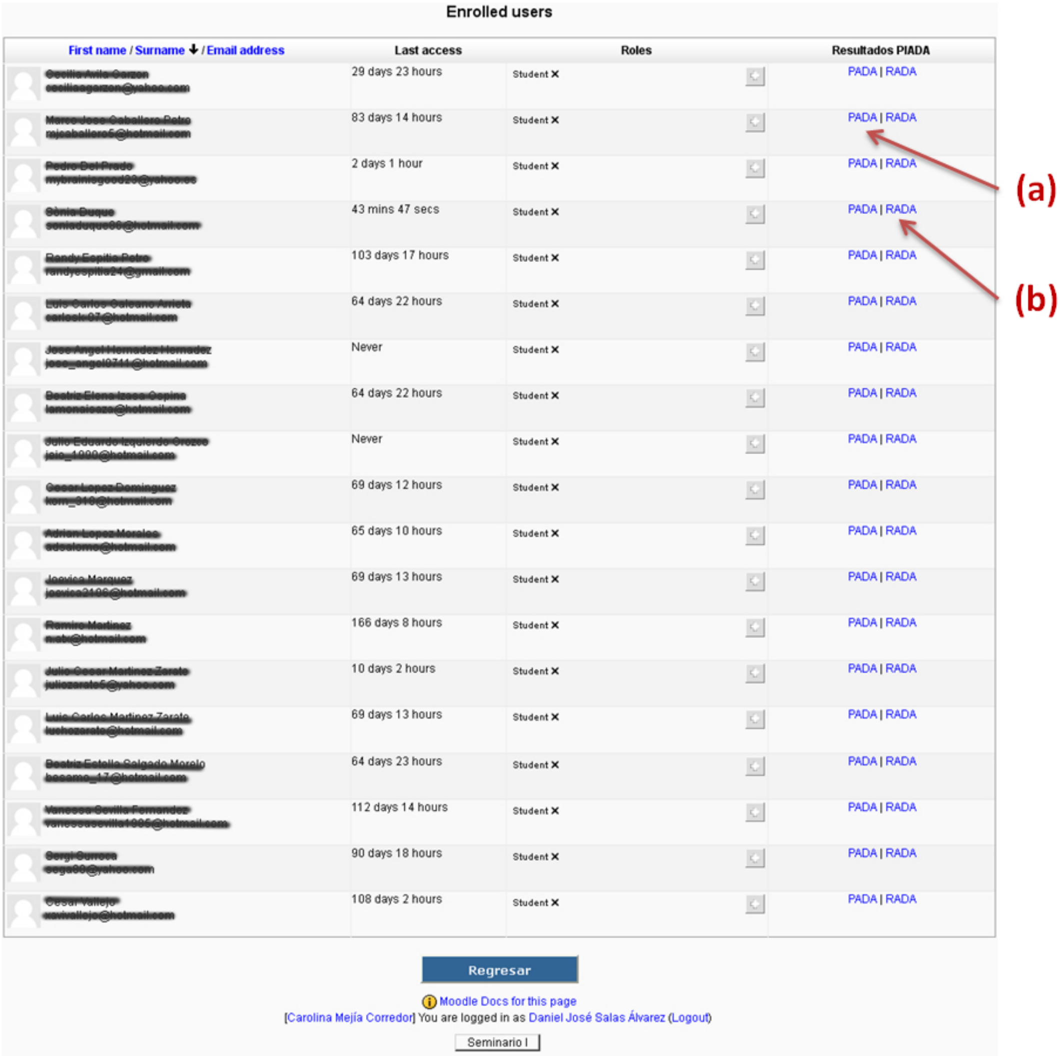


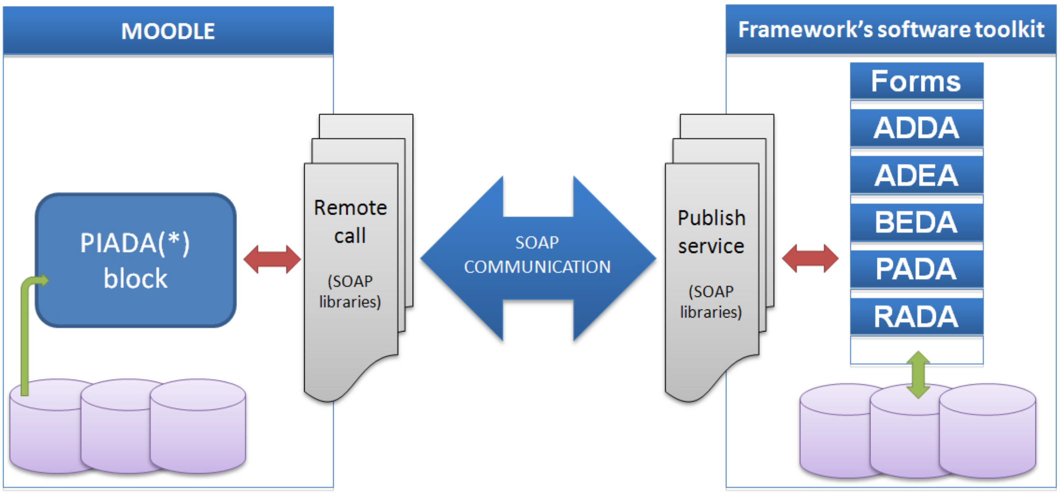
Figure 7-7. PIADA interface: view of the teachers

7.4 Integration Architecture based on Web Services

As presented in previous sections a block in Moodle, namely PIADA, was developed so as the *Framework's Software Toolkit* can be accessed and used by university teachers interested in detecting, assessing, and assisting students who may have reading difficulties and/or dyslexia. The capabilities of Moodle to support web services technologies were used to communicate Moodle and the *Framework's Software Toolkit* so as to achieve the proposed integration (see Figure 7-8).

The integration architecture is based on the communication between the LMS and the *Framework's Software Toolkit.* The communication protocol used in this architecture was SOAP[1]. This communication is achieved by developing a set of web services (published by the *Framework's Software Toolkit*) that allow PIADA in the LMS to retrieve data from and send data to the tools of the *Framework's Software Toolkit.*

[1] http://www.w3.org/TR/soap/



(*) PIADA, acronym for the Spanish name *Plataforma de Intervención y Asistencia de Dislexia en Adultos.*

Figure 7-8. Integration architecture of the framework's software toolkit with Moodle

In general, web services allow web-based systems to exchange data between them regardless of the programming language with which they were created, the operating system or platform where they run and the device from where they are accessed.

More precisely, in this research work data exchanging through web services is typically performed using XML for sending requests and responses, between a system that operates as a server (the *Framework's Software Toolkit*) and other system that operates as a client (PIADA) (see Figure 7-8). To achieve XML-based requests and responses the SOAP protocol was used. SOAP is a standardized messaging language defined by W3C[2] which is typically conveyed using HTTP and that relies on XML for its message format. Moreover, SOAP specifies all the necessary rules for locating web services, integrating web-based systems and managing communication between them. In Figure 7-9 how data exchange carried out through SOAP is represented.

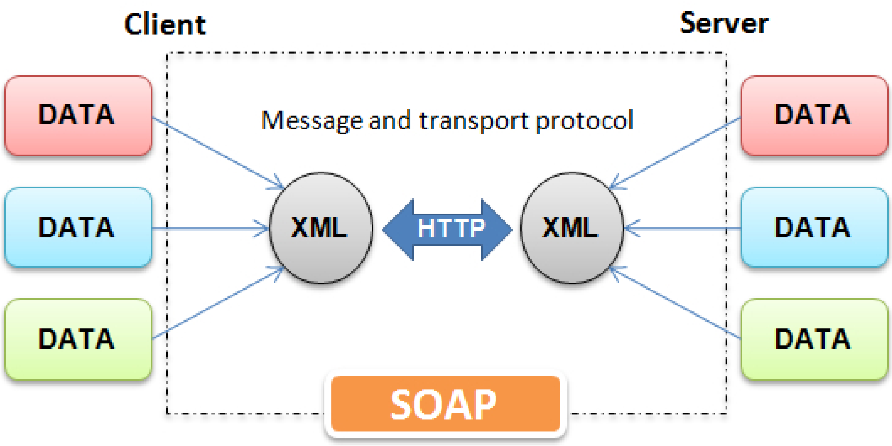


Figure 7-9. Representation of SOAP's data exchange

[2] http://www.w3.org/

The SOAP libraries (i.e. NuSOAP) used in the development of the integration allows exchanging data by *publishing services* in the *Framework's Software Toolkit,* and by using these services through *remote calls* made by PIADA (see Figure 7-8).

NuSOAP is a group of PHP classes that allow developers to create and use SOAP web services that can be used with Moodle aiming communication with other systems.

Different web services were built to achieve the proposed integration. Table 7-2 shows the Web Services created on the server side (*Framework's Software Toolkit*). First two columns in Table 7-2 show the Web Service's name and its descripcion, the last two columns show the input (resquests) paramenters needed by the Web Service and the output (responses) it returns to the client.

Table 7-2. Description of the functions created for the web services

Web service	Description	input parameters	output parameters
user_exist	Checks if a user exist in the databases of the framework's software toolkit	Request → username, moodle_id	Response → 0 (not exist) / 1(exist)
register_user	Registers a user in the databases of the framework's software toolkit	Request → id_user, username, password, id_user_type, name, lastname, birthday, sex, id_institution, id_aca_program, id_country, city, date, moodle_id	Response → 0 (unregistered) / 1 (registered)
login_user	Provides data for the login in the framework's software toolkit	Request → username	Response → username, password
get_id_user	Gets the user identifier in the databases of the framework's software toolkit	Request → username, moodle_id	Response → id_user
get_aca_levels	Gets academic levels recorded in the databases of the framework's software toolkit	Request → {}	Response → id_aca_level, description_aca_level
get_aca_programs	Gets academic programs recorded in the databases of the framework's software toolkit	Request → {}	Response → id_aca_program, description_aca_program
get_countries	Gets countries recorded in the databases of the framework's software toolkit	Request → {}	Response → id_country, description_country
get_url	Gets the url for access in the framework's software toolkit	Request → url	Response → url
get_last_moodle_id	Gets the last identifier of Moodle registered in the framework's software toolkit	Request → {}	Response →number (last moodle_id)
percentage_beda_tasks	Provides the total percentage made of BEDA's tasks.	Request → id_user	Response → percentage

percentage_phonological_awareness	Provides the total percentage of the cognitive process of phonological awareness of BEDA.	Request → id_user	Response → percentage
percentage_orthographic_processing	Provides the total percentage of the cognitive process of orthographic processing of BEDA.	Request → id_user	Response → percentage
percentage_lexical_access	Provides the total percentage of the cognitive process of lexical access of BEDA.	Request → id_user	Response → percentage
percentage_processing_speed	Provides the total percentage of the cognitive process of processing speed of BEDA.	Request → id_user	Response → percentage
percentage_working_memory	Provides the total percentage of the cognitive process of working memory of BEDA.	Request → id_user	Response → percentage
percentage_semantic_processing	Provides the total percentage of the cognitive process of semantic processing of BEDA.	Request → id_user	Response → percentage
adda_test_completed	Checks if a user completed the ADDA's test.	Request → id_user	Response → 0 (not completed) / 1 (completed)
adea_test_completed	Checks if a user completed the ADEA's test.	Request → id_user	Response → 0 (not completed) / 1 (completed)
cognitive_deficits_exist	Checks if a user has a cognitive deficit.	Request → id_user	Response → number (deficient cognitive processes)
get_reading_difficulties	Gets all reading difficulties of a user	Request → id_user	Response → {id_difficulty_1 to id_difficulty_n}
get_learning_style	Gets the learning style of a user	Request → id_user	Response → {id_processing, id_ perception, id_input, id_understanding }
get_cognitive_deficits	Gets all deficient cognitive processes of a user	Request → id_user	Response → {id_cognitive_process_1 to id_cognitive_process_n}

7.5 Case Studies

Two cases studies were performed to test the functionality and the usability of the PIADA block in order to have two different viewpoints. The first case study was carried out for students while the second one was for teachers.

7.5.1 Case study with students

7.5.1.1 Method

Ten students from the University of Girona (Spain) and 10 students from the University of Cordoba (Colombia) participated in the case study. For these samples both male and female students from engineering programs, aged between 22 and 27 (M=24.58, SD=2.193), were selected. Whether or not the student had dyslexia was not taken into account, because the aim of this case study was to assess the functionality and usability of the PIADA block.

During the case study, students were accompanied by a teacher experienced in managing Moodle and the PIADA block. When students have finished reviewing the block, the teacher asked them to fill an online survey and intended to evaluate the functionality and usability of the PIADA block.

As shown in Table 7-3, the survey used to gather student comments consisted of 15 evaluation questions. Eleven questions where the students chose the most appropriate response on a scale of 1-5 based on their perception. Three open-end questions to inquire why some previous answers, which are marked with an asterisk (*) in Table 7-3. In addition, at the end of the survey, one open-end question to include more comments if students wished.

Table 7-3. Overview of student's case study survey

No.	Question
Q1	Is the overall appearance of the elements of the PIADA block (images, background colors, etc.) suitable?
Q2	Was it easy to navigate through and locate the tools of the PIADA block in the graphical interface?
Q3	Did the PIADA block adequately respond to your navigation pace?
Q4	When you start the block, was it easy to understand the information displayed in each of the enable icons of the PIADA block menu (ie, personal details, ADDA, ADEA and BEDA)?
Q4*	The former was possible by means of…
Q5	When you completed all tests (ADDA, ADEA and BEDA), was it easy to understand the information displayed in the icons of the PIADA block menu (ie, reports, learning analytics and recommendations)?
Q5*	The former was possible by means of…
Q6	Was it easy to understand the notifications about ADDA, ADEA and BEDA?
Q6*	The former was possible by means of…
Q7	Do you think it is a good idea to integrate the Framework's software toolkit in a LMS as Moodle for detection, assessment and assistance for students with reading difficulties?
Q8	How satisfied are you with the integration of the Framework's Software Toolkit with Moodle?
Q9	In general, was the PIADA block intuitive (i.e., did it not require much effort and time to learn to handle it)?
Q10	Do you think it took a short time to navigate through the tools?
Q11	Please, if you have more comments about your experience with the PIADA block ...

7.5.1.2 Results

The students' answers showed that appearance and navigability of the PIADA block were satisfactory. Furthermore, it was very user friendly and intuitive: the students never had questions about how to access and use the block. Students also think it is a good idea to integrate the Framework's software toolkit with a LMS, and they were satisfied with the integration performed in Moodle. However, they indicated that navigate through all tools it took them a long time. The results obtained of the questions are presented in Table 7-4.

Table 7-4. Results of the survey filled in by students

Question	1		2		3		4		5	
	(worse)				(neutral)					(best)
	n	%	n	%	n	%	n	%	n	%
Q1	0	0%	0	0%	2	10%	6	30%	12	60%
Q2	0	0%	1	5%	2	10%	5	25%	12	60%
Q3	1	5%	1	5%	3	15%	7	35%	8	40%
Q4	0	0%	0	0%	3	15%	8	40%	9	45%
Q5	0	0%	1	5%	1	5%	8	40%	10	50%
Q6	0	0%	0	0%	5	25%	4	20%	11	55%
Q7	0	0%	0	0%	0	0%	7	35%	13	80%
Q8	0	0%	0	0%	2	10%	7	35%	11	55%
Q9	0	0%	0	0%	1	5%	8	40%	11	55%
Q10	2	10%	1	5%	3	15%	6	30%	8	40%

In terms of understanding of the information displayed in the icons of the PIADA block menu, students indicated that they achieved an easy comprenhesion of each tool, as well as progress notifications of them. Although several comments were repeated in Q11 (see Table 7-3), and some were not significant, it highlight: "*because there are a brief introduction of each tool*", "*because the information is accompanied by graphs and descriptive texts*", "*because the notifications show the progress percentages of each tool*". Finally, at the end of the survey, students gave opinions for improving the experience with the block; most of them to better understand the use of the different tools.

7.5.1.3 Discussion

The main focus of this case study was assessing the functionality and usability of the PIADA block of Moodle which supports university students with dyslexia and/or reading difficulties. General speaking, the results were very positive. In addition, the understanding of the contents of block was good, so that, the authors believed that this block could be used to facilitate the learning process of students with dyslexia and/or reading difficulties through a LMS. Although, further research should be carried out to explore the usability of the block with dyslexic students, and in others university contexts.

In addition, it is necessary to extend this case study to test the functionality of the *Framework's Software Toolkit* to be integrated in others LMS (e.g., dotLRN or ATutor), since this dissertation only considers the LMS "Moodle" to exemplify the integration.

Finally, it is worth noting that integration with Moodle required a great effort and time by the author and collaborators in the analysis and development of the block. Thus, it was necessary to study and understand Moodle's architecture for the development of new blocks, and it was necessary to learn to use the workspace within Moodle for development and management of style sheets. It was also important to have skills in developing Web service-oriented applications and implement these services in Moodle. It is believed that similar efforts will be required to integrate with other LMS.

7.5.2 Case Study with Teachers

7.5.2.1 Method

Two teachers from the University of Girona (Spain) and 2 teachers from the University of Cordoba (Colombia) participated in the case study. Teachers were from humanities and engineering programs with pedagogical experience between 5 and 16 years. The case study is based on interviews with participants, during which they reviewed the PIADA block and exposed their comments in order to evaluate its usability and usefulness. Three questions were answering during the interview:

1. Did you find it easy to navigate through and locate the PIADA block in Moodle?
2. Do you think it is a good idea to integrate the Framework's software toolkit in a LMS as Moodle for detection, assessment and assistance for students with reading difficulties?
3. Do you think that the PIADA block can help you in reflecting and making decisions to improve your teaching strategies?

7.5.2.2 Results

In term of usability, interviews with the teachers showed that the PIADA block is fairly easy to access and use. Additionally, as students, they think it is a good idea to intregrate the Framework's software toolkit with Moodle, although they expressed some drawbacks for use in their classes: "*it is quite difficult to promote the use of these tools due to our current academic load*", "*Moodle in the university is limited to share resources (i.e., documents, assignments, exercises, etc.)*", "*I think it will be difficult to promote these tools among students because they do not like to use them*".

In relation to the usefulness of the PIADA block, interviews showed that teachers need more time to understand the meaning of learning analytics and recommendations displayed (i.e., PADA and RADA). One of the engineering teacher said the recommendations were addressed to teacher of education and psychology faculty, and consequently they were hard to understand. Teachers also indicated that although they would need additional hours of work, they were willing to seek alternatives that would allow them to support students with difficulties.

7.5.2.3 Discussion

Similar to the student study, this case study assessed the usability of the PIADA block, and and further it assessed its usefulness from the teacher's perspective. The results were positive. And some teachers' opinions suggest a revision of the PIADA block in order to provide better services. These suggestions will be taken into suggesstion account for further versions of this block.

Findings of this study need to be viewed in light of some limitations. First, the PIADA block is a tool to access, visualize and use the Framework's Software Toolkit, although it has available information about reading difficulties, learning styles and cognitive deficits of the students, these are not used in the LMS to produce appropriate learning resources. Second, this research work only considered the evaluation of the functionality and usability of the block for students, it is necessary to continue this work to assess the usefulness and effectiveness of this block with larger groups of students. Third, there is, of course, a need to replicate the interviews with a large sample of teachers. Finally, future work has to include the execution of additional experiments with diagnosed dyslexic students. This is because dyslexic students may be familiar with similar tools, which could provided different perspectives on the use and usefulness of the block.

7.6 Summary

This chapter presented the integration of the *Framework's Software Toolkit*, which consist of the demographics data forms, ADDA, ADEA, BEDA, PADA and RADA, with the LMS Moodle. In order to achieve this integration a Moodle's module and a set of web services were implemented.

The Moodle's module allows users (students and teachers) to interact with the tools in the Framework's Software Toolkit. This module was called PIADA (acronym for the Spanish name *Plataforma de Intervención y Asistencia de Dislexia en Adultos*), and it was developed following the guidelines of Moodle.

The set of web services establish the communication to transfer the information the Framework's Software Toolkit and PIADA. To this end, the communication protocol used was SOAP which allows PIADA retrieve data from and send data to the tools of the *Framework's Software Toolkit.*

The idea with this integration is to enable the interaction between students with a LMS so as to provide them with a familiar environment that supports detection, assessment and assistance of reading difficulties related to dyslexia. Additionally, encouraging teachers to revise their teaching practices in order to adapt them to the needs of students with reading difficulties.

Two cases studies were performed to test the functionality and the usability of PIADA. The first case study was carried out with 20 students while the second one was with 4 teachers. Both samples from the University of Girona and the University of Cordoba (Colombia). Results in both case studies were very positive. Students and teachers were satisfied with the appearance and navigability of PIADA, they expressed that is a good idea to integrate the Framework's software toolkit with a LMS, and they were satisfied with the integration performed in Moodle. However, they suggested a revision of the PIADA's functionalities in order to provide better services.

CHAPTER 8

CONCLUSIONS AND FUTURE WORK

This chapter presents conclusions and some ideas that may be worth exploring for future research. First, a general summary of this research work is given together with the objectives achieved. Second, a revision of the research questions formulated in Chapter 1 so as to explain the achieved conclusions to the solutions developed and their evaluation. Third, possible directions for future works are presented. Fourth, the chapter present the author' publications and scientific collaboration. Finally, the projects where this dissertation has contributed are described.

8.1 General Summary

The main objective (OB) of this dissertation was to: ***Including students with dyslexia and/or reading difficulties in an e-learning process, so as to define methods and tools to detect, assess and assist them in overcoming their difficulties during their higher education***. Accordingly, the Spanish-speaking university students who have a previous diagnosis of dyslexia and/or are affected with reading difficulties which may be related to dyslexia are addressed. Thus, covering the first subordinate objective (OB.1.) (see Section 1.3), the solution presented in this dissertation was to define a ***Framework for Detection, Assessment and Assistance of University Students with Dyslexia and/or Reading Difficulties***. In addition, the integration of this framework with a LMS is considered.

To address these issues, a considerable theoretical preparation was required (see Chapter 2). First of all, a review of concepts related to Learning Management System (LMS) and Adaptive Hypermedia Systems (AHS), including learner modeling and adaptation processes. Moreover given the inclusive approach of this dissertation, topics related to achieve an e-Learning for All such as Learning Disabilities (LD) and dyslexia are studied. Secondly, since this research study was aimed at university students with dyslexia, their symptoms, compensatory strategies, cognitive processes, and assistance were also studied. Thirdly, a review of tools to detect dyslexia symptoms (i.e., reading difficulties) and compensatory strategies (e.g., learning styles), as well as tools to assess the cognitive process involved in reading in order to determine cognitive deficits was performed. Finally, assistance strategies that could be used with these students for personalization and improvement of their learning were also studied.

On the basis of these studies, the defined framework takes into account: (i) a ***learner model*** of students with dyslexia and/or reading difficulties, and (ii) a *set of* ***software tools*** to collect and store data into the learner model so as to detect and assess the profile of each student, which is covering the second, third and fourth subordinate objectives (OB.2., OB.3., and OB.4.) of this dissertation (see Section 1.3), (iii) a set of ***adaptation processes*** that provides personalized assistance to each student's profile through data visualization techniques and recommendations, covering the fifth subordinate objective (OB.5.)(see Section 1.3), and (iv) a set of ***web services*** to integrate the learner model, implemented software tools and adaptive components with a LMS so as to include affected students in an e-learning process, covering the sixth and last subordinate objective (OB.6.) of this dissertation (see Section 1.3).

8.2 Conclusions

Firsly, based on the review of the definitions presented in Chapter 2 of some relevant statements about LD, the author of this dissertation concludes (Mejia et al., 2010; Mejia & Fabregat, 2010): (a) LD are difficulties in the acquisition and use of listening, speech, reading, writing, reasoning or mathematical abilities, (b) LD are not problems of any of this types: sensory, physical, intellectual, attention, behavior, social interaction, mental retardation, emotional, socio-cultural deficiencies and higher intellectual skills, (c) LD generally emerge in childhood and are detected at school age, but can be generated later by factors such as educational, social, and emotional, and (d) LD may affect people throughout their entire lives. For this reason, LD can be categorized in: children with LD, adolescents with LD and adults with LD.

Second, taking into account the 10th revision of the International Classification of Diseases (ICD-10) and the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR) classification systems as well as a literature review conducted for the LD classification (see Chapter 2), it was concluded that there are very similar approaches, thereby, it is used the following classification of LD in this dissertation (Mejia et al., 2010; Mejia & Fabregat, 2010): *Dyslexia* or difficulties with basic reading skills and reading comprehension, *Dysorthographia* or difficulties with poor performace in spelling, *Dysgraphia or* difficulties with written expression, and *Dyscalculia* or difficulties with calculations and mathematical reasoning.

Third, the author is focused on *university students* with dyslexia, a population that has been studied very little. University students with this type of disability may experience difficulties during their academic careers, since reading is the basis of most, if not all, formal educational processes and has significant importance in many learning domains. Furthermore, a literature review shows that poor readers are also less successful in writing tasks than their peers. Thus, in accordance with common practice, dyslexia entails not only reading difficulties. It is commonly associated to disorders of writing and spelling skills, i.e. dysgraphia and dysorthographia respectively.

Fourth, it is also concluded that dyslexia is related to difficulties in speech, working memory, attention and spatial organization, the development of compensatory strategies, and deficits in cognitive processes involved in reading. Furthermore, it is noted that technologies could help affected students in developing skills and enhancing their learning performance, consequently, there is a notable challenge with regards to using technology that support these students, and thus, facilitate their learning process and assistance by supporting materials and activities that are not necessarily provided during school hours due to busy learning schedule to be followed.

Fifth, the author concludes stating that not all students whose performance is affected by dyslexia are diagnosed and/or assisted before starting their studies at university; therefore, there are many students with symptoms of dyslexia or reading difficulties who have not been diagnosed with an official psychoassessment procedure. Consequently, a considerable number of students enter university without having reading skills expected, and would require support to cope with high reading demands.

Sixth, along this dissertation the author uses the description "dyslexia and/or reading difficulties" because in this research work, dyslexia is analyzed independently of reading difficulties. Thus, students with previous diagnosis of dyslexia were considered in the study, as well as students with reading difficulties detected with the tools proposed in this dissertation. Consequently, either of the two cases could be given at the same time (dyslexia and reading difficulties) or independently (dyslexia or reading difficulties).

It is concluded then, that the higher educational institutions are in clear need of specific resources to detect students with or without a previous diagnosis of dyslexia that still show reading difficulties, and to provide assistance to them. In this sense, methods and tools to detect, assess and assisst Spanish university students with dyslexia and/or reading difficulties are needed and therefore were proposed in this research work.

Regarding to the first research question (RQ1) addressed in this dissertation "***How can university students with dyslexia and/or reading difficulties be detected?***"*:*

- The author concludes stating that there are three parallel ways in which the detection could be made. One way is the *detection of demographics*, i.e., the personal details of the affected students such as age, gender, and academic level, etc. The second way is the *detection of reading profile*, i.e., the individual weaknesses (or difficulties) of the affected students. The other way is the *detection of learning styles*, i.e., the strengths (or preferences) of these affected students.
- In Chapter 2 a characterization of students with LD and particularly, those who present dyslexia was presented. Here, it is stated that aspects such as school life, family history, current reading-writing difficulties (e.g., reading disorders related to vocabulary, reading comprehension, oral reading fluency, writing, and spelling), associated difficulties (e.g., speech, working memory, attention, and spatial organization), as well as reading and writing habits are important to consider in the detection. Additionally, in this chapter was highlighted the usefulness of self-report questionnaires for detecting students who may have dyslexia because they have been proven to be valid and reliable tools for collecting information about personal history and current difficulties of these students.
- Therefore, in Chapter 3, the author of this dissertation proposed a self-report questionnaire to detect dyslexia in adults, called **ADDA** (acronym for the Spanish name *Autocuestionario de Detección de Dislexia en Adultos)* (Mejia, Giménez de la Peña, et al., 2012, 2013). This self-report allows detection of reading difficulties and provide feedback to students based on two profiles, namely: students reporting current difficulties (Profile A), and normal readers (Profile B), i.e., students with and without symptoms of dyslexia respectively. In Chapter 4 a complete description of ADDA was presented. And, in Appendix A and B, the items that comprise ADDA, in its first and second version, are shown.

- According to the results presented in Chapter 4, ADDA gather the advantages of self-reports. It is easy to administer and short time taken, what makes it a suitable tool for detecting university students with reading difficulties from fairly large samples with low cost. It is also worth noting that the responses to ADDA have revealed a number of students with subjective symptoms that have not received any assistance. Then, ADDA may play an important role in detecting students that could greatly benefit from advice and training.
- On the other hand, along this research work has been pointed that despite reading difficulties, many dyslexic students could develop compensatory strategies to help them succeed in their studies and get into university. In this sense, in Chapter 2 several studies that have demonstrated the relevance of detecting the learning style of these students in order to help them to identify and develop the most effective compensatory strategies they could use to learn were presented.
- Thus, in Chapter 3, the author of this dissertation proposed to adopt the **Felder-Silverman's Index of Learning Styles (ILS)** (Felder & Silverman, 2002), a self-report questionnaire to detect the learning styles of students with dyslexia and/or reading difficulties, which for practical purposes was called **ADEA** (acronym for the Spanish name *Autocuestionario de Detección del Estilo de Aprendizaje*). As was presented in Chapter 3 and Chapter 4, this self-report combines learning styles of four dimensions (i.e., processing, perception, input, and understanding) to define the learning styles of a particular student. In Chapter 4 a complete description of ADEA was presented. And, in Appendix C, the items that comprise ADDA (i.e., the ILS) are shown.
- In Chapter 4, the results after applying ADEA to a sample of students shown that the most of them possess *Active*, *Sensitive*, *Visual*, and *Sequential* learning styles. And no differences were found between the dyslexics and possible-dyslexics (i.e., students with symptoms of dyslexia) in this tendency. Moreover, the results also shown that students were satisfied with the learning styles presented in the ADEA report. Hence, ADEA can be used to make students and teachers aware of the students' learning styles. Accordingly, students with dyslexia and/or reading difficulties could better understand the ways in which they learn, understand their strengths and weaknesses, and develop appropiate strategies to learn. In addition, teachers could be motivated to extend their teaching strategies or materials if they do not support different learning styles.
- To implement ADDA, in Chapter 4 was presented a software tool, called **detectLD**, devoted to the delivery and review of this kind of self-reports (Mejia, Clara, et al., 2011). Furthermore, due to the scope of this tool to embed different self-reports, it was also used to implement ADEA.

With regard to second research question (RQ2) addressed in this dissertation "***How can cognitive traits of the students with dyslexia and/or reading difficulties be assessed in order to inquire which cognitive processes related to reading are failing?***":

- The author of this dissertation have argued for the importance of assessing cognitive processes associated with reading that can be altered in university students with dyslexia and/or reading difficulties, considering that reading is a complex activity consisting of different cognitive processes, ranging from visual perception of letters to obtain the overall meaning of the text. Thus, identification of which specific processes are failing on a student during reading activity let understand how the student can be assisted. Consequently, in Chapter 2, it is also argued that the cognitive processes that are considered essential for success in reading activity and should be assessed are: *phonological processing, orthographic processing, working memory, lexical access, processing speed,* and *semantic processing*.

- Furthermore, in Chapter 2, a review of the tools used to identify LD, and particulary dyslexia (Mejia et al., 2010), showed that cognitive processes can be assessed by using tests – also referred to as instruments, batteries or tasks – that access and retrieves information about each of cognitive processes. This review also showed that only DN-CAS (Tellado et al., 2007) and SICOLE (Jiménez et al., 2002) batteries which are targeted to children and the UGA (Díaz, 2007) targeted to adults offer specific tasks aiming to assess some of the processes mentioned above. However, there is not yet a tool that evaluates all cognitive processes related to reading in Spanish-speaking university students.
- Then, in Chapter 3, the author of this dissertation proposed an automated battery for the assessment of cognitive processes involved in reading, called **BEDA** (acronym for the Spanish name *Batería de Evaluación de Dislexia en Adu*ltos) (Díaz et al., 2013; Mejia, Díaz, et al., 2011; Mejia, Díaz, Jiménez, et al., 2012). Thus, this battery allows identify specific processes are failing on students and provide feedback according to their cognitive traits.
- As show in Chapter 5, BEDA has a modular design to facilitate communication between the modules and interaction between users (i.e., students, teachers, and experts). It consists of eight modules: six for the assessment of each cognitive process involved, one for the analysis of results, and one for administration purposes. Moreover, BEDA is supported by a multimodal architecture that allows students to communicate with the assessment modules through different modes (visual, auditory, and speech) according to the specific objective of each assessment task in the different modules.
- With respect to the validity of BEDA, worth mentioning that it is valid in terms of content, since the tasks and items were made in collaboration with psychologist and pedagogues experts in Dyslexia from the Research Group on Learning Disabilities, Psycholinguistics and New Technologies (DEA&NT) at the University of La Laguna. Thus, the author of this dissertation jointly with these experts carried out a review of the tasks and bibliography about the contents of each assessment module (see Chapter 5). Furthermore, the content validity implies judgments that involve both the appearance of the items as the cognitive processes involved in answering these items. The opinions and suggestions of the experts were taken into account from the early stages of development of BEDA to completion. In Appendix D, the items that comprise BEDA are shown.
- On the other hand, in Chapter 5 is argued a first scope of standardization of BEDA so it can check the student's performance level in different cognitive processes and provide a preliminary feedback and recommendation to students. Additionally, statistical analyses were performed in order to debug of the BEDA's items. Thus, successes and errors, missing cases, as well as difficulty indexes, discrimination indexes, and correlations of the items with the tasks were calculated. Consequently, the author of this dissertation proposes to discard some

BEDA's items due to they are not discriminating. In Appendix E, the items that author propose as definitive are shown.

In relation to the third research question (RQ3) addressed in this dissertation "***How can students with dyslexia and/or reading difficulties be assisted?***":

- Studies have shown that detection, assessment and assistance supported by technologies tend to increase motivation of students affected with dyslexia (see Chapter 2). In addition, it is stated that technologies help promoting university students reflection on their learning (skills, difficulties, preferences, misconceptions, etc.). Thereby, there is notable challenge with regards to using technology that support these students, and thus, facilitate their learning process and assistance by supporting materials and activities that are not necessarily provided during school hours due to busy learning schedule to be followed.
- Furthermore, in Chapter 2, it is argued that the students' awareness of their weaknesses and strengths, as well as ability to make decisions and self-regulate their learning, are powerful predictors for their academic success. Accordingly, it is concluded that opening the learner model to the students has been a successful strategy to promote awareness-raising, which leads to reflection on learning, and facilitates self-regulation, thereby the learning process is supported.
- In this sense, one of the emerging visualization techniques and potential impact to open the learner model are the learning analytics. Then, in Chapter 3, the author of this dissertation proposed a dashboard for visualizing and inspecting the reading difficulties and their characteristics, called PADA (acronym for the Spanish name *Panel de Analíticas de Aprendizaje de Dislexia en Adultos*). As show in Chapter 6, PADA is a web-based tool designed to facilitate the creation of descriptive visualizations required for a better understanding of students about their learner model. Through information visualization techniques, PADA shows students the knowledge in their learner models in order to help them to increase their awareness and to support reflection and self-regulation about their difficulties in reading. PADA provides different learning analytics on reading performance of students, so that they can self-identify their particular strengths and weaknesses and self-regulate their learning.
- In addition, according to literature presented in Chapter 2, it was concluded that the hints, feedback and advice could help affected students to facilitate and develop self-regulation that will allow the independence of their difficulties. Thus, in Chapter 3, the author of this dissertation proposed a repository for storing and delivering of recommendations to overcome such difficulties, called RADA (acronym for the Spanish name *Recomendador de Actividades para la Dislexia en Adultos*). Consequently, as show in Chapter 6, once the PADA's visualizations are presented, students can access RADA and view a set of recommendations that have been designed in collaboration with psychologist and pedagogues experts in Dyslexia according to the cognitive deficits presented.
- Based on the results of a case study to test the usefulness of PADA. It was concluded that PADA can assist students in creating awareness, and help them to understand their strengths and weaknesses associated with the reading tasks, as well as facilitate reflection and self-regulation in the learning process. It was verified its functionality and navigability. Students were capable of

understanding and inspecting their own learner model through different visualizations. Additionally, students were awareness about their reading difficulties, learning styles and cognitive deficits, as well as reflect and think how to self-regulate their learning process.

Concerning to the last research question (RQ4) addressed in this dissertation "***How can the detection, assessment and assistance of university students with dyslexia and/or reading difficulties be provided in a LMS?***"

- In order to integrate the previous tools for detection, assessment and assistance of students with dyslexia and/or reading difficulties with a LMS (see Chapter 4, Chapter 5, and Chapter 6), an architecture based on web services was proposed. In Chapter 3, it is stated that this integration, besides these tools can be used independently from an LMS, it enables working within a specific LMS, so as to achieve interoperability of the tools in an e-learning process.
- As shown in Chapter 7, the exemplary LMS used in this dissertation was Moodle. This is an LMS with great pedagogical and technological flexibility and usability that is supported by a large community of developers and users around the world. It is an open source educational application, and is currently the LMS used at the University of Girona, as well as other universities that have contributed in the development of this research work.
- To this end, a module named PIADA (acronym for the *Spanish name Plataforma de Intervención y Asistencia de Dislexia en Adultos*), which allow students to interact with the tools in the framework was developed. Thus, teachers can install this block in their courses, review the learning analytics of the students enrolled in their courses, and viewing recommendations given by experts for each student with cognitive deficits; and students can access each of the detection and assessment tools as well as assistance tools through Moodle.
- According to the results presented in Chapter 7, both students and teachers were satisfied with the integration performed in Moodle. Additionally, teachers indicated that although they would need additional hours of work, they were willing to seek alternatives that would allow them to support students with difficulties.
- From these findings it is expected that this integration provides students a familiar environment that supports detection, assessment and assistance of reading difficulties related to dyslexia, as well as encourages teachers to revise their teaching practices in order to adapt them to the needs of students with reading difficulties.

Finally, it is worth noting that the success of this research work was due to collaboration of an interdisciplinary group of researchers and practicioners from different universities in Spain and internationally.

8.3 Future Work

This section concludes the dissertation with the vision for future research. There are several issues that have been left as future work throughout this dissertation. The next paragraphs present these issues.

Regarding the ADDA self-report questionnaire (see Appendix A), it is necessary to continue this research study to consider its validity as a predicting tool using specific standard tests (e.g., performance on a battery of cognitive tasks), as well as to analyze its effectiveness with large samples of university students with dyslexia. Moreover, it is recommended to study the influence of each section of ADDA for defining the profiles (i.e., Profile A or Profile B). Although the profile currently relies on the analysis of questions in Section 3 (i.e., Current reading-writing difficulties); further analysis can be carried out on other sections to improve the definition of this profile. Future research may provide a clearer picture of the distribution of reading difficulties among Spanish-speaking university students. There is, of course, a need to replicate these findings and to validate them in other university contexts.

Furthermore, ADDA might also consider motivational and affective aspects, which could be used as criteria to adjust more the reading profiles found and facilitate the creation of personalized recommendations from the experts. In this research work, a second version of ADDA was proposed (see Appendix B), which consider these two aspects as well as the restructuration of some sections and questions based on the findings of the case study presented in Section 4.4. However, this second version has not been tested with university students in order to do reliability and correlation analysis. Future research poses conducting cases studies at the University of Girona, the University of La Laguna and the University of Las Palmas Gran Canaria in order to test this second version and create a standardized procedure.

In relation to ADEA, a case study with 36 students from the University of Girona (Spain) and the University of Cordoba (Colombia) identified the most preferred learning styles of the students (dyslexics and possible-dyslexics), and also found that all students were satisfied with the learning style detected. However, further research could identify detailed patterns about the preferences of students with dyslexia and/or reading difficulties. Thus, more analysis can be made with the collected students sample as well as analyze the effectiveness of ADEA with larger samples.

In this dissertation an exploratory case study that let managing and evaluates BEDA with students of the University of Girona was done. However, the idea is to convert BEDA on a psychometric test standardized consisting of items, selected and organized in tasks, which measure cognitive processes involved in dyslexia in adults. Accordingly, at present more case studies are being conducted at the University of La Laguna and the University of Las Palmas Gran Canaria in order to create a more refined standardized procedure than achieved in this dissertation.

Moreover, for proper refined standardized procedure it is important to consider the fluency, a variable that is essential to the proper development of reading (it is collected from measuring response time and execution time of some tasks). Although in this dissertation the response and execution times were recovered, these were not considered in the analysis of exploratory case study to calculate the preliminary standards. Future work includes the consideration of these times in the standardized procedure.

In order to support some tasks in BEDA, which require the use of the voice to answer them, a prototype of voice recognition system was implemented in this dissertation.

Although the prototype uses a corpus trained with Spanish-language voices[1], it still shows high error rates, forcing experts to review these tasks. This means that the system requires further research and development as future work.

Another interesting observation relates to the interpretation of the reports. Currently, students see the reports once ADDA, ADEA or BEDA is completed, however, they must know how to understand these reports. It is therefore essential that the student knows what it means and involves reading, as well as dyslexia symptoms, preferred learning styles and the importance of certain cognitive processes involved in reading compared to other processes, that besides from being facilitators they are not essential for reading to be developed. Thus, in the near future, a tutorial that explains all these issues and theoretical foundations must be created and enabled for teachers and students.

Regarding PADA, future work includes the execution of additional experiments with more dyslexic students, so as to evaluate the feedback provided by them about the effectiveness of the dashboard compared with the feedback of students with symptoms of dyslexia (i.e. have a balanced group of dyslexic and possible-dyslexic participants).

Moreover, PADA displayed visualizations for each of the tools that collect data (namely demographic data forms, ADDA, ADEA, and BEDA), but it does not create aggregators that combine data between tools. Further research is proposed to analyze the influence between data collected in order to improve the assistance.

In this dissertation it is proposed a first approach of a recommender system fed by experts (i.e., educational psychologists) for teachers and students. Thus, a repository for storing and delivering specialized recommendations that help to mitigate the cognitive deficits, called RADA, was designed and developed. However, extensions to add the recommender system are being designed and their development and tests are still waiting. In addition, further research is necessary to consider the remaining collected information (i.e., demographics, reading profile, and learning styles) as well as the influence among collected data in order to improve the assistance of the recommendations.

It is clearly important to establish university programs to provide advice and support to students with dyslexia and/or reading difficulties. In this research work, it was designed and built effective tools to detect, assess and assisst these students, which were integrated in a LMS. However, it is necessary to continue this research work and use additional tools to provide appropriate learning resources and aids. Future research may provide adapted resources and services through an LMS as well as incorporate different data models (e.g. learning flow, assessment and contents) that can be processed and inferred so as to deliver educational information tailored to the students' needs.

Although participants were balanced bilinguals (i.e., Catalan and Spanish speakers), further research should be carried out to explore the influence of bilingualism on the development of reading-writing skills, specifically in those cases with difficulties.

Moreover, it is proposed as future work the design and development of accessibility testing scenarios in order to verify the easiness of the solutions presented in this dissertation to meet the users' access needs.

[1] http://sourceforge.net/projects/cmusphinx/?source=navbar

In addition, the students and teachers also offered some suggestions for improvement of the proposed tools with new functionalities such as extending visualizations, giving more detail feedback, and recommendations.

8.4 Publications and Scientific Collaborations

8.4.1 Journal papers

Mejía, C., Florian, B., Vatrapu, R., Bull, S., Fabregat, R. (2013). A novel web-based approach for visualization and inspection of reading difficulties on university students. Computers & Education (Impact Factor: 2.621). Submitted.

Mejía, C., Giménez, A., Fabregat, R. (2013). Evidence for Reading Disabilities in Spanish University Students – Applying ADDA. The Scientific World Journal (Impact Factor: 1.730). Submitted

Mejía, C., Díaz, A., Jiménez, J., Fabregat, R. (2012). BEDA: a computarized assessment battery for dyslexia in adults. Journal of Procedia-Social and Behavioral Sciencies, Volume 46, Pages 1795–1800. Published by Elsevier Ltd., doi: 10.1016/j.sbspro.2012.05.381. Presented at the 4th World Conference on Educational Sciences (WCES 2011), Barcelona (Spain). Published.

8.4.2 Book chapters

Díaz, A., Jiménez, J., Mejía, C., Fabregat, R. (2013). Estandarización de la Batería de Evaluación de la Dislexia en Adultos (BEDA). In M. del C. Pérez Fuentes & M. del M. Molero Jurado (Eds.), Variables Psicológicas y Educativas para la Intervención en el Ámbito Escolar. Presented at III Congreso Internacional de Convivencia Escolar: Contextos Sicológicos y Educativos (Asociación., pp. 191–194). GEU Editorial. Published.

Mejía, C., Díaz, A., Jiménez, J., Fabregat, R. (2011). Considering Cognitive Traits of University Students with Dyslexia in the Context of a Learning Management System. In D.D. Schmorrow and C.M. Fidopiastis (Eds.), Foundations of Augmented Cognition - Directing the Future of Adaptive systems, Lecture Notes in Computer Science, Volume 6780/2011, Pages 432-441. Published by Springer, doi: 10.1007/978-3-642-21852-1_50, presented at 14th International Conference on Human-Computer Interaction (HCII 2011). Orlando, Florida, USA. Published.

Baldiris, S., Fabregat, R., Mejía, C., Gómez, S. (2009), Adaptation Decisions and Profiles Interchange among Open Learning Management Systems based on Agent Negotiations and Machine Learning Techniques, In J. Jacko (Ed.), Human-Computer Interaction. Interacting in Various Application Domains, Lecture Notes in Computer Science (Vol. 5613, pp. 12-20). Springer Berlin / Heidelberg. doi:10.1007/978-3-642-02583-9_2. San Diego, California, USA. Published.

8.4.3 Conference papers

Mejía, C., Bull, S., Vatrapu, R., Florian, B., Fabregat, R. (2012). PADA: a Dashboard of Learning Analytics for University Students with Dyslexia. Proceedings of the Last ScandLE Seminar in Copenhagen. Published.

Mejía, C., Díaz, A., Florian, B., Fabregat, R. (2012). El uso de las TICs en la construcción de analíticas de aprendizaje para fomentar la autorregulación en estudiantes universitarios con dislexia. Proceedings of Congreso Internacional EDUTEC 2012, Canarias en tres continentes digitales: educación, TIC, NET-Coaching. Published.

Mejía, C., Giménez, A., Fabregat, R. (2012). ATLAS versión 2: una experiencia en la Universitat de Girona. Proceedings of the XXVIII Congreso Internacional AELFA: Asociación Española de Logopedia, Foniatría y Audiología. Published.

Mejía, C., Fabregat, R. (2012). Framework for Intervention and Assistance in University Students with Dyslexia. In Bob Werner (Eds). Proceedings of the 12th IEEE International Conference on Advanced Learning Technologies (ICALT 2012), Volume 2012, pp. 342-343. Rome, Italy. DOI: 10.1109/ICALT.2012.170. Published.

Mejía, C., Clara, J., Fabregat, R. (2011). detectLD: Detecting University Students with Learning Disabilities in Reading and Writing in the Spanish Language. In T. Bastiaens & M. Ebner (Eds.), Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2011, EdiTLib Digital Library, Volume 2011, Issue 1, pp. 1122-1131, Chesapeake, VA: AACE. (ED-MEDIA 2011), Lisboa, Portugal. Published.

Gelvez, L., Mejía, C., Peña, C.I., Fabregat, R. (2010). Metodología de Gestión de Proyectos aplicada al Desarrollo de Objetos de Aprendizaje. In J. Sánchez, Congreso Iberoamericano de Informática Educativa (Vol. 1, pp. 690-697). Santiago de Chile, Chile. Published.

Mejía, C., Fabregat, R., Marzo, J.L. (2010). Including Student's Learning Difficulties in the User Model of a Learning Management System. XXXVI Conferencia Latinoamericana de Informática (CLEI 2010) (pp. 845-858). Asunción, Paraguay. Published.

Mejía, C., Fabregat, R. (2010). Towards a Learning Management System that Supports Learning Difficulties of the Students, In P. Rodriguez (Ed.), XI Simposio Nacional de Tecnologías de la Información y las Comunicaciones en la Educación (ADIE), SINTICE 2010 (pp. 37-44). Ibergarceta Publicaciones , S.L. Valencia, Spain. Published.

Gelvez, L., Mejía, C., Peña, C.I., Fabregat, R. (2010). MetOA: Metodología de Gestión de Proyectos aplicada al Desarrollo de Objetos de Aprendizaje. II Congreso Internacional en Ambientes Virtuales de Aprendizajes Accesibles y Adaptativos: Hacia un Sistema Inclusivo y Adaptativo (CAVA3 2010). Cartagena, Colombia. Published.

Gómez, S., Mejía, C., Huerva, D., Fabregat, R. (2009), Context-Aware Adaptation Process to Build Units of Learning Based on IMS-LD Standard, International Conference on Education and New Learning Technologies (EDULEARN 2009) Conference (pp. 5743-5754). Barcelona, Spain. Published.

Gómez, S., Huerva, D., Mejía, C., Baldiris, S., Fabregat, R. (2009), Designing Context-Aware Adaptive Units of Learning Based on IMS-LD Standard, EAEEIE Annual Conference, 2009 (pp. 1-6). Valencia, Spain: IEEE. doi:10.1109/EAEEIE.2009.5335463, Valencia, Spain. Published.

Mejía, C., Baldiris, S., Gómez, S., Fabregat, R. (2009), Personalization of E-Learning Platforms Based On an Adaptation Process Supported on IMS-LIP and IMS-LD. In I. Gibson, R. Weber, K. McFerrin, R. Carlsen, & D. A. Willis (Eds.), Society for Information

Technology & Teacher Education International Conference 2009 (pp. 2882-2887). Charleston, SC, USA: AACE. Published.

Huerva, D., Fabregat, R., Mejía, C., Gómez, S. (2009). Arquitectura basada en Agentes Inteligentes y Servicios Web para la Adaptación de Contenidos Educativos en Plataformas e-Learning. XIII Congreso Internacional de Informática en la Educación (InforEdu 2009). La Habana, Cuba. Published.

Mejía, C., Mancera, L., Gómez, S., Baldiris, S., Fabregat, R. (2008). Supporting Competence upon dotLRN throught Personalization. 7th OpenACS / .LRN conference (pp. 104-110). Valencia, Spain. Published.

Peña, C., Gómez, S., Mejía, C., Fabregat, R. (2008). Competence Formation through Learning Objects in a Multiagent Virtual Educational Environment. Web Intelligence and Intelligent Agent Technology, 2008. WI-IAT '08. IEEE/WIC/ACM International Conference on (Vol. 3, pp. 343-347). Ieee. doi:10.1109/WIIAT.2008.400. Sydney Australia. Published.

Mejía, C., Baldiris, S., Gómez, S., Fabregat, R. (2008). Adaptation Process to Deliver Content based on User Learning Styles. In L. Gómez Chova, D. Martí Belenguer & I. Candel Torres (Eds.), International Conference of Education, Research and Innovation (ICERI 2008) (pp. 5091-5100). International Association of Technology, Education and Development (IATED). Madrid, Spain. Published.

Peña, C., Gomez, S., Mejia, C., Fabregat, R. (2008). The PROSPETIC Project: A Pioneer Latin-American Initiative for Higher Education support using Information and Communication Technologies. In L. Gómez Chova, D. Martí Belenguer & I. Candel Torres (Eds.), International Conference of Education, Research and Innovation (ICERI 2008) (pp. 2851-2860). International Association of Technology, Education and Development (IATED). Madrid, Spain. Published.

Peña, C., Mejía, C., Gomez, S., Fabregat, R. (2008). Learning Objects Production for Competence Formation by Adaptive Virtual Educational Environments. In B. Chang & H.-J. So (Eds.), Workshop Proceedings: Supplementary Proceedings of the 16th International Conference on Computers in Education (pp. 40-47). Taipei, Taiwan. Cognitive Aspects in Intelligent and Adaptive Web-based Educational Systems (CIAWES 2008). Published.

8.4.4 Guides & reports

Díaz, A., Mejía, C., Jiménez, J., Fabregat, R. (2012). Manual de uso e instrucciones de la batería de evaluación de dislexia en adultos (BEDA). Universitat de Girona (27 p.), unpublished, Girona (Spain).

Mejía, C., Díaz, A., Jiménez, J., Fabregat, R. (2012). Manual de instalación de la Batería de Evaluación de Dislexia en Adultos (BEDA). Universitat de Girona (5 p.), unpublished, Girona (Spain).

8.4.5 Final thesis reports

Co-director of the bachelor's degree project: "Integration of a framework for intervention and assistance of students with reading difficulties with the e-learning platform

MOODLE", developed by Marco Caballero, Randy Espitia, Julio Martinez. This project was part of a collaborative work initiative between University of Girona (Spain) and University of Córdoba (Colombia), 2013.

Co-director of the bachelor's degree project: "Design and implementation of a system for detection of students with learning disabilities in reading and identification of cognitive processes deficient", developed by Jonathan Clara. University of Girona, Spain, 2011.

8.4.6 Invited talks

Mejía, C., Fabregat, R. (2011). Framework per a personalitzar la intervenció i assistència per a estudiants amb dislèxia a través d'un sistema de gestió de l'aprenentatge. In FEDER project reports – Clúster TIC MEDIA de Girona, presented at Jornades de Creació d'Objectes d'Aprenentatge Adaptatius: l'Ajuntament de Girona. Girona, Spain.

Gómez, S., Mejía, C. (2009). Construcción de Unidades de Aprendizaje Adaptativas basada en el Contexto de Acceso. I Congreso Internacional de Ambientes Virtuales de Aprendizaje Adaptativos y Accesibles - Competencias para Todos (CAVA3 2009). Montería, Colombia.

Mejía, C., Gómez, S., Huerva, D., Fabregat, R. (2008). Adaptation Process in E-Learning Platforms. BCDS International Workshop. Girona, Spain.

8.4.7 Scientific collaborations

Collaborative work initiative for the development of the Dashboard of Learning Analytics of Dyslexia in adults (PADA *Panel de Analíticas de Aprendizaje de Dislexia en Adultos*). Participating entities: Communications and Distributed Systems (BCDS) from the University of Girona (Spain), the Computational Social Science Laboratory (CSSL) from the Copenhagen Business School (Denmark), the Open Learner Modelling Research Group from the University of Birmingham (UK), and the Department of Education at the University of La Palmas de Gran Canaria (Spain). 2013.

Collaborative work initiative for the development of the Assessment Battery of Dyslexia in Adults (BEDA, *Batería de Evaluación de Dislexia en Adultos).* Participating entities: Communications and Distributed Systems (BCDS) from the University of Girona (Spain), and the Research Group on Learning Disabilities, Psycholinguistics and New Technologies (DEA&NT) from University of La Laguna (Spain). 2012.

Collaborative work initiative for the development of the Self-report Questionnaire to Detect Dyslexia in Adults (ADDA, *Autocuestionario de Detección de Dislexia en Adultos*). Participating entities: Communications and Distributed Systems (BCDS) from the University of Girona (Spain), and the Department of Psychology from University of Malaga (Spain). 2011.

8.5 Projects

ALTERNATIVE e-ACCESS (Supporting Teachers Training for an Inclusive Vocational Education), Organismo Autónomo Programas Educativos Europeos – Leonardo da Vici –. Duration, since: 2012 Until: 2014.

ARreLS (Augmented Reality in Adaptive Learning Management Systems for ALL), Ministerio de Economia y Competitividad (TIN2011-23930). Duration, since: 2011 Until: 2013.

ALTER-NATIVA (Referentes curriculares con incorporación tecnológica para facultades de educación en las áreas de lenguaje, matemáticas y ciencias, para atender poblaciones en contextos de diversidad), European Commission, ALFA III Programme. Duration, since: 2011 Until: 2013.

A2UN@ (Accessibility and Adaptation for ALL in Higher Education), Ministerio de Educación y Ciencia ([TIN2008-06862-C04-02/TSI]). Duration, since: 2009 Until: 2011.

ProSPETIC (Soporte al Proceso Educativo UIS Mediante Tecnologías de Información y Comunicación), Universidad Industrial de Santander. Duration, since: 2005 Until: 2010.

AdaptaPlan (Adaptación basada en aprendizaje, modelado y planificación para tareas complejas orientadas al usuario), Ministerio de Educación y Ciencia (MEC). Duration, since: 2005 Until: 2008.

APPENDIX A

ADDA ITEMS – FIRST VERSION

The following self-report questionnaire contains a list of statements (in Spanish language) that ask students about their experience with reading.

> ***Por favor responda todas las afirmaciones con la respuesta que crea es más cercana a su experiencia. No hay respuestas buenas o malas.***

#…… Programa académico.. Edad……….…… Genero M F

Sección 1. Señala la respuesta que más se aproxime a su experiencia durante la etapa escolar.

1. ¿Le gustaba ir al colegio? .... a) SI b) NO
2. ¿Era un buen estudiante? .... a) SI b) NO
3. ¿A qué edad cree que leía y escribía correctamente? .... a) 6-7 b) 8 c) 9 d) más tarde
4. ¿Qué asignatura le resultaba más difícil? .... a) Matemáticas b) Lengua y literatura castellana c) Historia d) Inglés
5. ¿Recibió clases particulares? .... a) Un curso b) Dos cursos c) Cada curso d) NO
6. ¿Cuántos idiomas puede hablar sin dificultad? .... a) 1 b) 2 c) 3 d) más
7. ¿Cuál considera que es su primera lengua? .... a) Catalán b) Castellano c) Inglés d) Otro
8. ¿Ha tratado de aprender otros idiomas? .... a) SI b) NO
9. ¿Le ha sido fácil aprender otros idiomas? .... a) SI b) NO

Sección 2. Respecto a dificultades en el aprendizaje, señale la respuesta que crea más adecuada en su caso.

10. ¿Ha acudido a consulta alguna vez por problemas de lectura ó aprendizaje? .... a) SI b) NO
11. ¿Ha sido evaluado con anterioridad por dificultades en la lectura ó aprendizaje?.................. a) SI b) NO
12. Ha sido diagnosticado de............. a) Dislexia b) Disgrafía/Disortografía c)Discalculia d) Ninguna
13. ¿Ha seguido alguna vez tratamiento por alguna de las dificultades anteriores? .... a) SI b) NO
14. ¿Durante cuánto tiempo (en años) ha seguido tratamiento por estas dificultades? .... a) 1 b) 2 c) 3 d) más años
15. ¿Considera que actualmente tiene dificultades al leer ó escribir? .... a) SI b) NO

Section 3. Más detalladamente, ¿considera que tiene dificultades en alguno de los siguientes aspectos?

16. Omite y/o confunde letras al leer. .... a) SI b) NO
17. Omite y/o confunde palabras al leer. .... a) SI b) NO
18. No comprende bien lo que lee. .... a) SI b) NO
19. Le cuesta extraer la idea principal de un texto con una sola lectura. .... a) SI b) NO
20. Tiene que leer despacio para no tener confusiones. .... a) SI b) NO
21. Suele necesitar volver atrás en el texto. .... a) SI b) NO
22. Le resulta difícil leer en voz alta. .... a) SI b) NO
23. Le ayuda a comprender un texto que otra persona se lo lea. .... a) SI b) NO
24. Tiene dificultad para concentrarse cuando lee. .... a) SI b) NO
25. Necesita revisar su ortografía constantemente. .... a) SI b) NO
26. Omite y/o confunde letras al escribir. .... a) SI b) NO
27. Omite y/o confunde palabras al escribir. .... a) SI b) NO
28. Comete faltas de ortografía. .... a) SI b) NO
29. Confunde el orden de los números. .... a) SI b) NO
30. Altera el orden de las palabras al escribir. .... a) SI b) NO

31. Le cuesta utilizar los signos de puntuación.	a) SI	b) NO
32. Le cuesta escribir de forma fluida y exacta.	a) SI	b) NO
33. Le resulta difícil expresar una idea por escrito.	a) SI	b) NO
34. Tiene dificultad para organizar un trabajo por escrito.	a) SI	b) NO
35. Le cuesta diferenciar entre nombres, verbos, adjetivos o adverbios al escribir.	a) SI	b) NO
36. Suele utilizar oraciones complejas o subordinadas (con más de dos verbos) al escribir.	a) SI	b) NO
37. Tiene una escritura difícil de leer o ilegible (mala letra).	a) SI	b) NO
38. Suele mezclar letras minúsculas con mayúsculas de forma aleatoria.	a) SI	b) NO
39. Le cuesta encontrar la palabra correcta.	a) SI	b) NO
40. Le cuesta adquirir nuevo vocabulario.	a) SI	b) NO
41. Pronuncia mal o usa palabras equivocadas.	a) SI	b) NO

Seccion 4. Por favor, señale si encuentra difícil realizar alguna de las siguientes actividades.

42. Tiene dificultad para escuchar y escribir al mismo tiempo.	a) SI	b) NO
43. Tiene dificultad diferenciando automáticamente la derecha de la izquierda.	a) SI	b) NO
44. Recordar lo que ha leído.	a) SI	b) NO
45. Dar información por escrito.	a) SI	b) NO
46. Exponer sus ideas.	a) SI	b) NO
47. Tomar notas.	a) SI	b) NO
48. Recordar el nombre de las personas.	a) SI	b) NO
49. Recoger mensajes telefónicos.	a) SI	b) NO
50. Recordar instrucciones o información nueva.	a) SI	b) NO
51. Usar un diccionario.	a) SI	b) NO
52. Usar mapas.	a) SI	b) NO
53. Controlar el tiempo.	a) SI	b) NO
54. Organizarse y establecer el orden de prioridad temporal.	a) SI	b) NO
55. Usar un ordenador.	a) SI	b) NO

Section 5. Respecto a su familia, señale la respuesta más adecuada.

56. Indique otros familiares con dificultades semejantes a las suyas.........	a) Padres	b) Abuelos	c) Hermanos	d) Ninguno
57. Alguien de su familia ha sido diagnosticado de....	a) Dislexia	b) Disgrafía/Disortografía	c)Discalculia	d) Ninguna

Section 6. Respecto a sus hábitos de lectura, señale la respuesta que mejor describa su experiencia.

58. ¿Le gusta leer?	a) SI	b) NO		
59. ¿Lee habitualmente?	a) SI	b) NO		
60. ¿Qué tipo de literatura lee?	a) Novela	b) Ensayo	c) Ciencia ficción	d) Poesía
61. ¿Qué tipo de prensa ó periódico lee?	a) Gratuita	b) Deportiva	c) Nacional	d) Internacional
62. ¿Lee la prensa escrita?	a) Todos los días	b) 3-4 veces semana	c) Fin de semana	d) Nunca
63. ¿Utiliza Internet para documentarse y leer?	a) SI	b) NO		
64. ¿Lee la prensa en Internet?	a) Todos los días	b) 3-4 veces semana	c) Fin de semana	d) Nunca

Section 7. Respecto a sus hábitos de escritura, señale la respuesta que mejor describa su experiencia.

65. ¿Le gusta escribir?	a) SI	b) NO
66. ¿Escribe habitualmente?	a) SI	b) NO
67. ¿Prefiere escribir a mano antes que usar el ordenador?	a) SI	b) NO

APPENDIX B

ADDA ITEMS – SECOND VERSION

The following self-report questionnaire contains a list of statements (in Spanish language) that ask students about their experience with reading.

> ***Por favor responda todas las afirmaciones con la respuesta que crea es más cercana a su experiencia. Cuando la pregunta se señala con (*) puede responder en más de una opción. No hay respuestas buenas o malas.***

#...… Academic program.. Age.…..… Gender M F

SECCION I: INFORMACIÓN GENERAL. Respecto a dificultades en el aprendizaje, señale la respuesta que crea más adecuada en su caso.

1. ¿Ha acudido a consulta alguna vez por problemas de lectura ó aprendizaje? a) SI b) NO
2. ¿Ha sido evaluado con anterioridad por dificultades en la lectura ó aprendizaje? a) SI b) NO
3. Ha sido diagnosticado de (*) a) Dislexia b) Disgrafía c) Disortografía d)Discalculia e) Disfasia f) Ninguna g) Otras ¿cuáles?____________________________________
4. ¿Ha seguido alguna vez tratamiento por dificultades en lectura y/o escritura (es decir, por dislexia, disgrafía y/o disortografía)? a) SI b) NO
5. ¿Durante cuánto tiempo (en años) ha seguido tratamiento por dificultades en lectura y/o escritura? a) 1 b) 2 c) 3 d) más años
6. ¿Considera que actualmente tiene dificultades al leer ó escribir? a) SI b) NO

(*) Indica que puede seleccionar más de una respuesta.

SECCIÓN II: VIDA ESCOLAR. Señale la respuesta que más se aproxime a su experiencia durante la etapa escolar.

7. ¿Le gustaba ir al colegio? .... a) SI b) NO
8. ¿Acudía al colegio regularmente? .... a) SI b) NO
9. ¿Solía repetir los cursos escolares? .... a) SI b) NO
10. ¿Tuvo problemas a la hora de aprender a leer y escribir? .... a) SI b) NO
11. ¿A qué edad cree que leía y escribía correctamente? .. a) 6 b)7 c) 8 d) 9 e) 10 f) más tarde
12. ¿Solía presentar dificultad con las asignaturas relacionados con la lectura? .... a) SI b) NO
13. ¿Solía presentar dificultad con las asignaturas no relacionados con la lectura? .... a) SI b) NO
14. ¿Recibió algún tipo de apoyo extra en el colegio? .... a) SI b) NO
15. ¿Recibió clases particulares? .... a) Un curso b) Dos cursos c) Cada curso d) NO
16. ¿Cuántos idiomas puede hablar sin dificultad? .... a) 1 b) 2 c) 3 d) más
17. ¿Cuál considera que es su primera lengua? .... a) Catalán b) Castellano c) Gallego d) Euskera …....................... e) Inglés f) Francés d) Otro, ¿Cuál?____________
18. ¿Ha tratado de aprender otros idiomas? .... a) SI b) NO
19. ¿Le ha sido fácil aprender otros idiomas? .... a) SI b) NO

SECCION III: HISTORIAL MÉDICO Y FAMILIAR. Respecto a su historial médico, señale la respuesta más adecuada.

20. Indique si ha presentado problemas de (*) ....a) Oído b) Visión c) Motores d) Lenguaje ....e) Ninguno f) Otros, ¿Cuáles?______________________
21. Indique si ha presentado problemas graves (*) ... a) Respiratorios b) Neurológicos c) Nacimiento ....d) Ninguno e) Otros, ¿Cuáles?______________________

(*) Indica que puede seleccionar más de una respuesta.

Respecto a su historial familiar, señale la respuesta más adecuada.

22. Indique otros familiares con dificultades semejantes a las suyas (*) ... a) Padre b) Madre b) Abuelos .... c) Hermanos d) Tios f) Hijos g) Ninguno h) No lo sé
23. Alguien de su familia ha sido diagnosticado de (*) .... a) Dislexia b) Disgrafía c) Disortografía d)Discalculia e) Disfasia f) Ninguna g) Otras ¿cuáles?_____________________ h) No lo sé

(*) Indica que puede seleccionar más de una respuesta.

SECCION IV: DIFICULTADES EN LECTURA, ESCRITURA Y MATEMÁTICAS. ¿Considera que tiene dificultades en alguno de los siguientes aspectos relacionados con la LECTURA?

24. Omite y/o confunde letras al leer. .... a) SI b) NO
25. Omite y/o confunde palabras al leer. .... a) SI b) NO
26. No comprende bien lo que lee. .... a) SI b) NO
27. Le cuesta extraer la idea principal de un texto con una sola lectura. .... a) SI b) NO
28. Tiene que leer despacio para no tener confusiones. .... a) SI b) NO
19. Suele necesitar volver atrás en el texto. .... a) SI b) NO
30. Le ayuda a comprender un texto que otra persona se lo lea. .... a) SI b) NO
31. Tiene dificultad para concentrarse cuando lee. .... a) SI b) NO
32. Le resulta difícil leer en voz alta. .... a) SI b) NO
33. Le cuesta adquirir nuevo vocabulario. .... a) SI b) NO

¿Considera que tiene dificultades en alguno de los siguientes aspectos relacionados con la ESCRITURA?

34. Omite y/o confunde letras al escribir. .... a) SI b) NO
35. Omite y/o confunde palabras al escribir. .... a) SI b) NO
36. Altera el orden de las palabras al escribir. .... a) SI b) NO
37. Tiene bastantes faltas de ortografía. .... a) SI b) NO
38. Le cuesta utilizar los signos de puntuación. .... a) SI b) NO
39. Suele mezclar letras minúsculas con mayúsculas de forma aleatoria. .... a) SI b) NO
40. Le cuesta escribir de forma fluida y exacta. .... a) SI b) NO
41. Le resulta difícil expresar una idea por escrito. .... a) SI b) NO
42. Tiene dificultad para planificar un trabajo por escrito. .... a) SI b) NO
43. Tiene dificultad para organizar un trabajo por escrito. .... a) SI b) NO
44. Le cuesta diferenciar entre nombres, verbos, adjetivos o adverbios al escribir. .... a) SI b) NO
45. Tiene dificultad en el uso de flexiones: singular-plural, tiempos verbales, masculino-femenino…………... a) SI b) NO
46. Tiene una escritura difícil de leer o ilegible (mala letra). .... a) SI b) NO

¿Considera que tiene dificultades en alguno de los siguientes aspectos relacionados con las MATEMÁTICAS?

47. Omiten y/o confunde los números al escribirlos. .... a) SI b) NO
48. Confunde los signos matemáticos (suma, resta, multiplicación, etc.). .... a) SI b) NO
49. Se le dificulta memorizar las tablas de multiplicar. .... a) SI b) NO
50. Tiene dificultades para resolver operaciones amplias. .... a) SI b) NO
51. Le cuesta terminar de resolver las operaciones. .... a) SI b) NO
52. Le resulta difícil entender los enunciados matemáticos. .... a) SI b) NO
53. Le resulta difícil entender la relación de variables que muestran las gráficas........................... a) SI b) NO
54. Le cuesta asimilar la cantidad de vocabulario matemático. .... a) SI b) NO
55. Tiene dificultades en el rendimiento en general en las matemáticas. .... a) SI b) NO

SECCION V: PROCESOS COGNITIVOS. LENGUAJE. Seleccione la respuesta que crea más adecuada.

56. Le resulta difícil expresarse en forma oral. ….. a) SI b) NO
57. A menudo le cuesta comprender lo que le dicen. .... a) SI b) NO
58. Le cuesta encontrar la palabra correcta al hablar. .... a) SI b) NO
59. Pronuncia mal o usa palabras equivocadas. .... a) SI b) NO
60. Le cuesta pronunciar algunos fonemas (sonidos del habla). .... a) SI b) NO

MEMORIA. Seleccione la respuesta que crea más adecuada.

61. Le resulta difícil recordar hechos o acontecimientos pasados. ….. a) SI b) NO
62. A veces pierde el hilo de la conversación. ….. a) SI b) NO
63. Olvida cosas como citas, fechas importantes o números de teléfono. …................................... a) SI b) NO
64. A veces olvida palabras frecuentes o los nombres de personas conocidas. …........................... a) SI b) NO
65. Le cuesta llevar sus cuentas bancarias o seguir el argumento de una película.......................... a) SI b) NO

MOTIVACIÓN. Seleccione la respuesta que crea más adecuada.

66. Le resultan indiferentes los temas que estudia. …... a) SI b) NO
67. A veces le cuesta encontrar motivos para estudiar. …... a) SI b) NO
68. Le cuesta comenzar a leer un texto relacionado con sus estudios. …... a) SI b) NO
69. Suele pensar que sería mejor abandonar los estudios. …... a) SI b) NO
70. Suele ser indiferente a las noticias o informaciones novedosas relacionadas con sus estudios. …............. a) SI b) NO

PERCEPCIÓN. Seleccione la respuesta que crea más adecuada.

71. Le resulta difícil distinguir algunos fonemas (sonidos del habla). …...................................... a) SI b) NO
72. A veces le cuesta diferenciar cuando le dicen unas palabras de otras................................. a) SI b) NO
73. Le resulta difícil distinguir algunas grafías (letras). …... a) SI b) NO
74. Algunas veces tengo dificultades para percibir estímulos visuales. .... a) SI b) NO
75. Algunas veces tengo dificultades para percibir estímulos auditivos …................................. a) SI b) NO

ATENCIÓN. Seleccione la respuesta que crea más adecuada.

76. Tiene dificultad para escuchar y escribir al mismo tiempo. …... a) SI b) NO
77. Le cuesta mantener la atención durante un tiempo prolongado. ….. a) SI b) NO
78. Le cuesta tener la activación suficiente para iniciar las tareas académicas. …......................... a) SI b) NO
79. Suele perder el hilo cuando se le realiza una explicación. ….. a) SI b) NO
80. Tiene dificultad para atender a los detalles. ….. a) SI b) NO

ESPACIAL. Indique si le resulta difícil alguna de las siguientes actividades.

81. Usar un diccionario. …... a) SI b) NO
82. Usar mapas. ….. a) SI b) NO
83. Controlar el tiempo. …... a) SI b) NO
84. Organizarse y establecer el orden de prioridad temporal. …... a) SI b) NO

BLOQUE VI: AFECTIVO. Señala la respuesta que crea más adecuada.

85. Le resulta embarazoso leer en voz alta delante de alguien conocido. …................................... a) SI b) NO
86. Suele recordar momentos escolares negativos relacionados con la lectura. .... a) SI b) NO
87. Siente que es incapaz de leer adecuadamente. …... a) SI b) NO
88. Alguna vez se ha sentido mal por su forma de leer. …... a) SI b) NO
89. Alguna vez se ha sentido inferior a los demás por su forma de leer. …..................................... a) SI b) NO

BLOQUE VII: HÁBITOS LECTORES. Respecto a sus hábitos de lectura, señale la respuesta que mejor describa su experiencia.

90. ¿Le gusta leer? .... a) SI b) NO
91. ¿Cuántos libros suele leer al año?. …....... .... a) 0 b) 1 c) 2 d) 3 e) más
92. ¿Qué tipo de literatura lee? ... a) Novela b) Ensayo c) Ciencia ficción e) Poesía f) Otros, ¿Cuáles?
93. ¿Qué tipo de prensa ó periódico lee? … a) Gratuita b) Deportiva c) Nacional d) Internacional
94. ¿Lee la prensa ó periódico? ....a) Todos los días b) 3-4 veces semana c) Fin de semana d) Nunca
95. ¿Lee la prensa en Internet? .... a) Todos los días b) 3-4 veces semana c) Fin de semana d) Nunca
96. Suele ver películas subtituladas. .... a) SI b) NO
97. Suele ampliar la información buscando en fuentes escritas (internet, enciclopedias, diccionarios, ……...a) SI b) NO

Respecto a sus hábitos de escritura, señale la respuesta que mejor describa su experiencia.

98. ¿Le gusta escribir? .... a) SI b) NO
99. ¿Escribe habitualmente? .... a) SI b) NO
100. ¿Prefiere escribir a mano antes que usar el ordenador? …... a) SI b) NO

APPENDIX C

FELDER-SILVERMAN'S INDEX OF LEARNING STYLES

The following self-report questionnaire contains a list of statements (in Spanish language) that ask students about their learning styles.

> ***Por favor responda todas las afirmaciones con la respuesta que crea es más cercana a su experiencia. Si tanto "a" como "b" le parecen respuestas correctas, elija la que se aplicaría más frecuentemente.***

1. Entiendo las cosas mejor después de…
(a) probarlas.
(b) pensar en ellas.

2. Me gustaría que me consideraran…
(a) realista.
(b) innovador/a.

3. Cuando pienso en lo que hice antes de ayer, suelo hacerlo como si viera…
(a) una foto.
(b) palabras.

4. tengo tendencia a…
(a) entender los detalles de un tema pero me pierdo en la estructura global.
(b) entender la estructura global, pero me pierdo en los detalles.

5. Cuando estoy aprendiendo algo nuevo, me ayuda…
(a) hablar del tema.
(b) pensar en el tema.

6. Si fuera profesor, preferiría enseñar un curso sobre…
(a) hechos y situaciones de la vida real.
(b) ideas y teorías.

7. Prefiero obtener información nueva a partir de…
(a) fotografías, diagramas, gráficas o mapas.
(b) instrucciones escritas o información verbal.

8. Una vez entiendo…
(a) todas las partes, entiendo el conjunto.
(b) el conjunto, entiendo cómo encajan las partes.

9. Cuando trabajo en un grupo de estudio con materias difíciles, prefiero…
(a) participar contribuyendo con ideas.
(b) no participar y solo escuchar.

10. Encuentro más fácil…
(a) aprender hechos.
(b) aprender conceptos.

11. De un libro con muchas fotos y mapas, prefiero…
(a) mirar las fotos y los mapas detenidamente.
(b) centrarme en el texto escrito.

12. Cuando resuelvo problemas de matemáticas…
(a) suelo trabajar a mi aire hasta obtener la solución paso a paso.
(b) con frecuencia suelo mirar las soluciones y luego ensayar para comprender los pasos para llegar a ella.

13. En las clases que he recibido…
(a) Normalmente llegué a conocer a muchos de los estudiantes.
(b) Raramente llegué a conocer a muchos de los estudiantes.

14. Cuando no leo ciencia-ficción, prefiero…
(a) algo que me enseñe nuevos hechos o me diga cómo hacer algo.
(b) algo que me proporcione nuevas ideas sobre las que pensar.

15. Me gustan los profesores que…
(a) usan muchos diagramas en la pizarra.
(b) pasan mucho tiempo explicando.

16. Cuando analizo una historia o una novela…
(a) pienso en los incidentes y trato de interconectarlos para comprender los temas.
(b) solo se cuáles son los temas cuando termino de leer y, entonces, tengo que retroceder y encontrar los incidentes que los demuestran.

17. Cuando abordo un problema prefiero…
(a) empezar inmediatamente a trabajar en la solución.
(b) tratar primero de entender totalmente el problema.

18. Prefiero la idea de…
(a) certeza.
(b) teoría.

19. Recuerdo mejor…
(a) lo que veo.
(b) lo que oigo.

20. Para mi es más importante que un profesor…
(a) distribuya el material en etapas secuencialmente claras.
(b) me proporcione una imagen general y relacione el material con otros temas.

21. Prefiero estudiar…
(a) en un grupo de estudio.
(b) solo.

22. Me gustaría más que me consideraran…
(a) cuidadoso con los detalles de mi trabajo.
(b) creativo respecto a la manera de hacer mi trabajo.

23. Cuando me indican cómo llegar a un nuevo lugar, prefiero…
(a) un mapa.
(b) instrucciones escritas.

24. Aprendo…
(a) a velocidad casi regular. Si estudio mucho, lo conseguiré.
(b) a saltos. Estoy totalmente confuso/a y de repente se enciende la luz.

25. Prefiero primero…
(a) probar las cosas.
(b) pensar sobre cómo voy a hacerlas.

26. Cuando leo por entretenimiento, me gustan los escritores que…
(a) dicen claramente lo que quieren decir.
(b) dicen las cosas de forma interesante y creativa.

27. Cuando veo un diagrama o dibujo, en clase, suelo recordar mejor…
(a) el dibujo.
(b) lo que dijo el profesor sobre él.

28. Cuando se considera un cuerpo de información, prefiero…
(a) centrarme en los detalles y perder el esquema total.
(b) tratar de entender el esquema total antes de entrar en los detalles.

29. Recuerdo más fácilmente…
(a) algo que he hecho.
(b) algo sobre lo que he pensado mucho.

30. Cuando tengo que realizar una tarea, prefiero…
(a) dominar una forma de hacerla.
(b) proponer nuevas formas de hacerla.

31. Cuando me muestran datos, prefiero…
(a) mapas o gráficos.
(b) texto resumiendo los resultados.

32. Cuando escribo un trabajo, me gusta más…
(a) trabajar (pensar o escribir sobre el inicio) en el comienzo del trabajo y continuar hacia adelante progresivamente.
(b) trabajar (pensar o escribir sobre las diferentes partes) en las diferentes partes del trabajo y después ordenarlas.

33. Cuando tengo que trabajar en un proyecto en grupo, primero quiero…
(a) tratar de pensar en él con los demás miembros del grupo aportando ideas.
(b) tratar de pensar en él individualmente y luego reunirme con el resto del grupo para comparar ideas.

34. Considero un gran cumplido llamar a alguien…
(a) sensitivo.
(b) imaginativo.

35. Cuando conozco gente en una fiesta, suelo recordar mejor…
(a) a quién se parecían.
(b) lo que decían de ellos mismos.

36. Cuando aprendo un nuevo tema, prefiero…
(a) centrarme en dicho tema, aprender sobre él todo lo que pueda.
(b) tratar de realizar conexiones entre este tema y otros temas relacionados.

37. Prefiero que me consideren…
(a) extrovertido.
(b) reservado.

38. Prefiero cursos que enfatizan…
(a) material concreto (hechos, datos).
(b) material abstracto (conceptos, teorías).

39. Para entretenerme, prefiero…
(a) ver televisión.
(b) leer un libro.

40. Algunos profesores comienzan sus clases con un esquema de lo que se dará. Estos esquemas son…
(a) a veces útiles para mí.
(b) muy útiles para mí.

41. La idea de hacer trabajo en grupo, con una calificación única para todo el grupo…
(a) me parece buena.
(b) no me parece buena.

42. Cuando estoy haciendo cálculos largos…
(a) suelo repetir todos los pasos que he dado y revisar mi trabajo con mucho cuidado.
(b) encuentro cansado tener que revisar mi trabajo, he de esforzarme para hacerlo.

43. Suelo recordar lugares en los que he estado…
(a) con facilidad y con bastante precisión.
(b) con dificultad y sin mucho detalle.

44. Cuando estoy resolviendo problemas en grupo, me gustaría más…
(a) pensar en los pasos del proceso de solución.
(b) pensar en las posibles consecuencias o aplicaciones de la solución en un rango grande de áreas. NO

APPENDIX D

BEDA ITEMS

In this appendix the BEDA's items are presented. These items are group by cognitive processes, and they were provided to Spanish-speaking university student. Thus, they are presented in Spanish language as follows:

Procesamiento fonológico / Phonological processing

Tarea 1: Segmentación en sílabas

id	texto
1	Popularidad
2	Concentración
3	Horrible
4	Carruaje
5	Variabilidad
6	Carnicería
7	Compasión
8	Antropología
9	Rinoceronte
10	Armonía
11	Responsabilidad
12	Maquinaria

Tarea 2: Número de sílabas

id	Texto
1	Multiplicación
2	Científico
3	Educación
4	Sobresaliente
5	Compañía
6	Marea
7	Realidad
8	Pingüino
9	Fiabilidad
10	Importancia
11	Transatlántico
12	Murciélago

Tarea 3: Segmentación por fonemas

id	Texto
1	Salto
2	Van
3	Chal
4	Clavel
5	Grapa
6	Calvo
7	Chino
8	Bis
9	Carpa
10	Global
11	Pradera

id	Texto
12	Barco

Tarea 4: Rima general

id	texto
3	Día
4	Don
5	Más
6	Bar

Tarea 5: Rima Específica

id	texto
	PAN
1	son
2	van
3	con
	SON
4	ron
5	las
6	dos
6	don
7	sol
	PLAN
9	fan
10	van
11	bar
12	sal
13	mas
	DOS
14	los
15	adiós
16	col
17	vas
18	don

Tarea 6: Localización fonémica

id	texto
1	Fan/Fin
2	Cal/Col
3	Pan/San
4	Copa/Lopa
5	Lad/Lod
6	Yul/Yus
7	Par/Pan
8	Dan/Tan
9	Don/Den
10	Den/Des
11	Carta/Marta
12	Pulga/Purga
13	Manta/Monta
14	Mareo/Marea
15	Patata/Patada

Tarea 7: Omisión de fonemas

id	Texto
1	Di Ponmocher, ahora dila sin decir /pon/.
2	Di Airden, ahora dila sin decir /air/.

3	Di Bantoren, ahora dila sin decir /to/.
4	Di Translirtel, ahora dila sin decir /lir/.
5	Di Monsusme, ahora dila sin decir /sus/.
6	Di Tarin, ahora dila sin decir /rin/.
7	Di Bim, ahora dila sin decir /b/.
8	Di Pol, ahora dila sin decir /l/.
9	Di Raf, ahora dila sin decir /r/.
10	Di Plin, ahora dila sin decir /l/.
11	Di Trel, ahora dila sin decir /r/.
12	Di Brel, ahora dila sin decir /l/.
13	Di Vunlip, ahora dila sin decir /v/.
14	Di Admes, ahora dila sin decir /d/.
15	Di Balti, ahora dila sin decir /t/.
16	Di Cilbet, ahora dila sin decir /t/.

<u>Procesamiento ortográfico / Orthographic processing</u>

Tarea 8: Elección homófono/pseudohomófono

id	Texto
1	Boske;Bosque
2	Abeja;Aveja
3	Lavabo;Labavo
4	Tiza;Tisa
5	Ombligo;Hombligo
6	Sesta;Cesta
7	Comenzar;Comensar
8	Vola;Bola
9	Merluza;Merlusa
10	Maceta;Maseta
11	Save;Sabe
12	Villansico;Villancico
13	Provocar;Probocar

Tarea 9: Elección ortográfica

id	texto
1	Hojear;Ojear
2	Cien;Sien
3	Tasa;Taza
4	Ola;Hola
5	Bote;Vote
6	Seta;Zeta
7	Vello;Bello
8	Cazo;Caso
9	Hay;Ay
10	Tuvo;Tubo
11	Orca;Horca
12	Sabia;Savia
13	Coser;Cocer
14	Haya;Halla
15	Varón;Barón
16	Vaya;Valla
17	Errar;Herrar
18	Hora;Ora

<u>Acceso al léxico / Lexical access</u>

Tarea 10: Lectura de palabras

id	texto
1	Arroz
2	Bodas
3	Cama
4	Comer
5	Gato
6	Ojo
7	Patio
8	Plato
9	Árbol
10	Cine
11	Fuego
12	Grasa
13	Huevos
14	Jugar
15	Largo
16	Leche
17	Abastecernos
18	Adelante
19	Amarilla
20	Apellidos
21	Camisetas
22	Divertirnos
23	Habitación
24	Plasmado
25	Ascenso
26	Bolígrafo
27	Descalzo
28	Funcionar
29	Lágrimas
30	Meridiano
31	Nochebuena
32	Servicios

Tarea 11: Lectura de pseudopalabras

id	texto
1	Redas
2	Nate
3	Proce
4	Pona
5	Esco
6	Sunos
7	Alnes
8	Seron
9	Indos
10	Delce
11	Lasda
12	Losmo
13	Vendor
14	Golmar
15	Noslla
16	Troros
17	Genmor
18	Palchos
19	Polton
20	Ritgo

id	texto
21	Tesgro
22	Dulle
23	Brufas
24	Lartia
25	Pomacos
26	Sucires
27	Jomanto
28	Delnico
29	Bocueto
30	Protuto
31	Socanos
32	Codidas
33	Setudad
34	Unsiles
35	Inbiles
36	Portuto
37	Renpertal
38	Talgunbros
39	Linsosrial
40	Mestruyen
41	Biocamcir
42	Barcurcaz
43	Puertindor
44	Benmacer
45	Choflegio
46	Berciclas
47	Dosglubis
48	Dengelio

Velocidad de procesamiento / Processing speed

Tarea 12: Velocidad visual

id	texto
1	poi7
2	dgru
3	c69g
4	yjft
5	zxcv
6	gtyu
7	hklo
8	lij7
9	9pok
10	uyvw
11	tf1l
12	r48b
13	e3fz
14	qad9
15	qwer
16	qasd
17	2szc
18	es4d
19	zxcv
20	69pq
21	tyfg
22	poiu
23	klji

id	texto
24	mnhg
25	uyv5
26	lkji
27	8brf
28	3efc
29	bght
30	drg6
31	1j7i
32	g69b
33	t7fz
34	89bw
35	xcvb

Memoria de trabajo / Working memory

Tarea 13: Codificación ortográfica expresiva

id	texto
1	Plin
2	Tarin
3	Ponmocher
4	Trel
5	Airden
6	Blin
7	Treles
8	Vunlip
9	Barten
10	Cilbet
11	Bantoren
12	Monsusme
13	Clina
14	Mero
15	Liposos
16	Pros
17	Criola
18	Tiernel

Procesamiento semantic / Semantic processing

Tarea 14: Primera lectura

id	texto
1	¿Qué nombre reciben las hipótesis sobre el surgimiento de vida en la Tierra?
2	¿Cuál de la hipótesis sobre el surgimiento de la vida tiene mayor apoyo por parte de los científicos?
3	¿En qué se diferencian fundamentalmente las hipótesis sobre el surgimiento de la vida?
4	¿Hace cuánto se estima que comenzó la vida en la Tierra?
5	¿Cuándo comenzó la vida en la Tierra?
6	¿Qué fue lo que proporcionaron las primeras lluvias que suministró el caldo de cultivo para el surgimiento de la vida?
7	¿Qué ayudó a desencadenar las reacciones químicas produciendo moléculas más complejas?
8	¿Qué propiedades podría tener "el replicador"?
9	¿Qué molécula ha reemplazado al replicador?
10	¿Qué tienen en común todas las formas de vida?

Tarea 15: Segunda lectura

id	texto
1	¿Qué es la lingüística?
2	¿En qué se diferencia la lingüística teórica de la aplicada?

3	¿Qué les facilitó a los neogramáticos el conocimiento del sanscrito?
4	La distinción entre lengua (el sistema) y habla (el uso) y la definición de signo lingüístico (significado y significante) han sido fundamentales para:
5	¿Qué idea es la fundamental del generativismo?
6	Desde el generativismo la perspectiva lingüística es considerada como:
7	¿Qué escuela lingüística toma fuerza a finales del siglo XX?
8	¿Qué idea fundamental defiende la escuela funcionalista?
9	La figura más relevante dentro de la escuela funcionalista es:
10	Las escuelas que configuran el panorama actual de la lingüística son:

APPENDIX E

BEDA ITEMS AFTER DEBUGGING

In this appendix the BEDA's items after debugging are presented. These items are group by cognitive processes. They are presented in Spanish language as follows:

Procesamiento fonológico / Phonological processing

Tarea 1: Segmentación en sílabas

id	texto
1	Popularidad
2	Concentración
3	Horrible
4	Carruaje
5	Variabilidad
6	Carnicería
7	Compasión
8	Antropología
9	Rinoceronte
10	Armonía
11	Responsabilidad
12	Maquinaria

Tarea 2: Número de sílabas

id	Texto
1	Multiplicación
2	Científico
3	Educación
4	Sobresaliente
5	Compañía
6	Marea
7	Pingüino
8	Fiabilidad
9	Importancia
10	Transatlántico
11	Murciélago

Tarea 3: Segmentación por fonemas

id	Texto
1	Salto
2	Van
3	Chal
4	Clavel
5	Grapa
6	Calvo
7	Chino
8	Bis
9	Carpa
10	Global
11	Pradera
12	Barco

Tarea 4: Rima general

id	texto
3	Día
4	Don
5	Más
6	Bar

Tarea 5: Rima Específica

id	texto
	PAN
1	son
2	con
	SON
3	dos
4	don
5	sol
	PLAN
6	van
	DOS
7	don

Tarea 6: Localización fonémica

id	texto
1	Fan/Fin
2	Cal/Col
3	Pan/San
4	Lad/Lod
5	Yul/Yus
6	Dan/Tan
7	Don/Den
8	Pulga/Purga
9	Mareo/Marea
10	Patata/Patada

Tarea 7: Omisión de fonemas

id	Texto
1	Di Ponmocher, ahora dila sin decir /pon/.
2	Di Airden, ahora dila sin decir /air/.
3	Di Bantoren, ahora dila sin decir /to/.
4	Di Translirtel, ahora dila sin decir /lir/.
5	Di Monsusme, ahora dila sin decir /sus/.
6	Di Tarin, ahora dila sin decir /rin/.
7	Di Bim, ahora dila sin decir /b/.
8	Di Pol, ahora dila sin decir /l/.
9	Di Raf, ahora dila sin decir /r/.
10	Di Plin, ahora dila sin decir /l/.
11	Di Trel, ahora dila sin decir /r/.
12	Di Brel, ahora dila sin decir /l/.
13	Di Vunlip, ahora dila sin decir /v/.
14	Di Admes, ahora dila sin decir /d/.
15	Di Balti, ahora dila sin decir /t/.
16	Di Cilbet, ahora dila sin decir /t/.

Procesamiento ortográfico / Orthographic processing

Tarea 8: Elección homófono/pseudohomófono

id	Texto

1	Abeja;Aveja
2	Lavabo;Labavo
3	Tiza;Tisa
4	Ombligo;Hombligo
5	Merluza;Merlusa
6	Villansico;Villancico
7	Provocar;Probocar

Tarea 9: Elección ortográfica

id	texto
1	Hojear;Ojear
2	Tasa;Taza
3	Bote;Vote
4	Vello;Bello
5	Cazo;Caso
6	Tuvo;Tubo
7	Orca;Horca
8	Sabia;Savia
9	Haya;Halla
10	Varón;Barón
11	Vaya;Valla
12	Errar;Herrar

Acceso al léxico / Lexical access

Tarea 10: Lectura de palabras

id	texto
1	Gato
2	Huevos
3	Abastecernos
4	Camisetas
5	Ascenso
6	Meridiano
7	Servicios

Tarea 11: Lectura de pseudopalabras

id	texto
1	Esco
2	Alnes
3	Indos
4	Delce
5	Lasda
6	Losmo
7	Troros
8	Polton
9	Ritgo
10	Tesgro
11	Dulle
12	Lartia
13	Pomacos
14	Bocueto
15	Unsiles
16	Portuto
17	Linsosrial
18	Mestruyen
19	Biocamcir
20	Barcurcaz

id	texto
21	Puertindor
22	Benmacer
23	Choflegio
24	Dosglubis
25	Dengelio

Velocidad de procesamiento / Processing speed

Tarea 12: Velocidad visual

id	texto
1	c69g
2	yjft
3	zxcv
4	hklo
5	lij7
6	9pok
7	uyvw
8	r48b
9	e3fz
10	2szc
11	es4d
12	zxcv
13	69pq
14	tyfg
15	poiu
16	klji
17	mnhg
18	uyv5
19	lkji
20	8brf
21	3efc
22	bght
23	drg6
24	1j7i
25	g69b
26	t7fz
27	xcvb

Memoria de trabajo / Working memory

Tarea 13: Codificación ortográfica expresiva

id	texto
1	Plin
2	Tarin
3	Ponmocher
4	Trel
5	Airden
6	Blin
7	Treles
8	Vunlip
9	Cilbet
10	Bantoren
11	Monsusme
12	Clina
13	Liposos
14	Pros

15	Criola
16	Tiernel

<u>Procesamiento semantic / Semantic processing</u>

Tarea 14: Primera lectura

id	texto
1	¿Qué nombre reciben las hipótesis sobre el surgimiento de vida en la Tierra?
2	¿Cuál de la hipótesis sobre el surgimiento de la vida tiene mayor apoyo por parte de los científicos?
3	¿En qué se diferencian fundamentalmente las hipótesis sobre el surgimiento de la vida?
4	¿Hace cuánto se estima que comenzó la vida en la Tierra?
5	¿Cuándo comenzó la vida en la Tierra?
6	¿Qué fue lo que proporcionaron las primeras lluvias que suministró el caldo de cultivo para el surgimiento de la vida?
7	¿Qué ayudó a desencadenar las reacciones químicas produciendo moléculas más complejas?
8	¿Qué propiedades podría tener "el replicador"?
9	¿Qué molécula ha reemplazado al replicador?
10	¿Qué tienen en común todas las formas de vida?

Tarea 15: Segunda lectura

id	texto
1	¿Qué es la lingüística?
2	¿En qué se diferencia la lingüística teórica de la aplicada?
3	¿Qué les facilitó a los neogramáticos el conocimiento del sanscrito?
4	La distinción entre lengua (el sistema) y habla (el uso) y la definición de signo lingüístico (significado y significante) han sido fundamentales para:
5	¿Qué idea es la fundamental del generativismo?
6	Desde el generativismo la perspectiva lingüística es considerada como:
7	¿Qué escuela lingüística toma fuerza a finales del siglo XX?
8	¿Qué idea fundamental defiende la escuela funcionalista?
9	La figura más relevante dentro de la escuela funcionalista es:
10	Las escuelas que configuran el panorama actual de la lingüística son:

REFERENCES

Ahissar, M. (2007). Dyslexia and the anchoring-deficit hypothesis. *Trends in cognitive sciences*, *11*(11), 458–465. doi:10.1016/j.tics.2007.08.015

Alfonseca, E., Carro, R. M., Martín, E., Ortigosa, A., & Paredes, P. (2006). The impact of learning styles on student grouping for collaborative learning: a case study. *User Modeling and User-Adapted Interaction*, *16*(3-4), 377–401. doi:10.1007/s11257-006-9012-7

Allinson, C., & Hayes, J. (1996). The Cognitive Style Index. *Journal of Management Studies*, *33*, 119–135. doi:10.1111/j.1467-6486.1996.tb00801.x

Allor, J. H., Fuchs, D., & Mathes, P. G. (2001). Do students with and without lexical retrieval weaknesses respond differently to instruction? *Journal of Learning Disabilities*, *34*(3), 264–275. doi:10.1177/002221940103400306

Allred, R. A. (1990). Gender differences in spelling achievement in Grades 1 through 6. *The Journal of Educational Research*, *83*(4), 187–193.

Alty, J. (2002). Dual Coding Theory and Education: Some Media Experiments to Examine the Effects of Different Media on Learning. *ED- MEDIA 2002: World conference on educational multimedia, hypermedia & telecommunications* (pp. 42–47). Denver, Colorado, USA.

Alvarado, D. G., Ruef, M. L., & Schrank, F. A. (2005). *Comprehensive Manual. Woodcock-Muñoz Language Survey-Revised*. Itasca, IL: The Riverside Publishing Company.

American Psychiatric Association. (2000). *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision (DSM-IV-TR)* (pp. 1–992). Washington, DC.

Anstey, E. (1990). *Dominó D-48*. Madrid: TEA Ediciones, S. A.

Apter, M. J. (2001). *Motivational styles in everyday life: a guide to reversal theory*. Washington DC.

Arroyo, I., & Woolf, B. P. (2005). Inferring learning and attitudes from a Bayesian Network of log file data. In C.-K. Looi, G. McCalla, B. Bredeweg, & J. Breuker (Eds.), *12th International Conference on Artificial Intelligence in Education - AIED'2005* (pp. 33–40). Amsterdam, The Netherlands.

Arteaga, C., Fabregat, R., Eyzaguirre, J., & Mérida, D. (2004). Adaptive Support for Collaborative and Individual Learning (ASCIL): Integrating AHA ! and CLAROLINE. *The Netherlands, Springer, LNCS*, 23–26.

Arteaga, C., Fabregat, R., & Mérida, D. (2006). Implementación del ambiente de aprendizaje ASCIL usando MOODLE. *SIIE*, *2*, 1–8.

Artigas, J. (1999). Fifteen basic questions about dyslexia. *First International Cogress on Neuropsychology in Internet*.

Ayres, R. (2002). Learner attitudes towards the use of CALL. *Computer Assisted Language Learning*, 241–249.

Bacca, J., Baldiris, S., Fabregat, R., & Avila, C. (2013). A Case-based Reasoning Approach to Validate Grammatical Gender and Number Agreement in Spanish language. *International Journal of Interactive Multimedia and Artificial Intelligence*, *2*(1), 73–81. doi:10.9781/ijimai.2013.2110

Bacca, J., Baldiris, S., Fabregat, R., Guevara, J. C., & Calderon, D. I. (2012). A Case-based Reasoning Approach to Support Teaching of Spanish as a Second Language in Indigenous Communities from Latin America. *13th Ibero-American Conference*. Cartagena, Colombia.

Baddeley, A. D. (1981). The concept of working memory: A view of its current state and probable future development. *Cognition*, *10*, 17–23.

Bajraktarevic, N., Hall, W., & Fullick, P. (2003). Incorporating learning styles in hypermedia environment: Empirical evaluation,. *Fourteenth Conference on Hypertext and Hypermedia*. Nottingham.

Bakalov, F., Hsiao, I.-H., Brusilovsky, P., & Koenig-Ries, B. (2011). Visualizing Student Models for Social Learning with Parallel Introspective Views. *Workshop on Visual Interfaces to the Social Semantic Web, ACM IUI 2011*. Palo Alto, USA.

Baldiris, S. (2012). *Supporting Competence Development Processes on Open Learning Systems through Personalization (Ph.D. Thesis)*. University of Girona, Girona, Spain.

Baldiris, S., Fabregat, R., Mancera, L., Ávila, C., Bacca, J., Hernández, J., & Carlos, J. (2011). Atendiendo la Diversidad en Contextos Virtuales de Aprendizaje. *New Trends in Engineering Education, II International Conference on Engineering and Computer Education - ICECE '2011* (pp. 32–38).

Baldiris, S., Fabregat, R., Mejia, C., & Gómez, S. (2009). Adaptation Decisions and Profiles Exchange among Open Learning Management Systems Based on Agent Negotiations and Machine Learning Techniques. In J. Jacko (Ed.), *Human-Computer Interaction. Interacting in Various Application Domains, Lecture Notes in Computer Science* (Vol. 5613, pp. 12–20). Springer Berlin / Heidelberg. doi:10.1007/978-3-642-02583-9_2

Barca, A., & Porto, A. (1998). Dificultades de aprendizaje: categorías y clasificación, factores, evaluación y procesos de intervención psicopedagógica. *Dificultades de Aprendizaje*. Madrid.

Barker, T. A., & Torgesen, J. K. (1995). An evaluation of computer-assisted instruction in phonological awareness with below average readers. *Journal of Educational Computing Research*, *13*(1), 89–103. doi:10.2190/TH3M-BTP7-JEJ5-JFNJ

Bar-Shalom, E. G., Crain, S., & Shankweiler, D. (1993). A comparison of comprehension and production in good and poor readers. *Applied PsychoLinguistics*, 197–227.

Bassi, C. (2010, September). Fracaso escolar por trastornos del aprendizaje. *DISLEXIA JAÉN - Asociación Dislexia Jaén y otras Dificultades de Aprendizaje (ASDIJA)*, 1. Retrieved from http://www.dislexiajaen.es/

Baumel, J. (2008). Dyslexia: An overview. *GreatSchools*. Retrieved from http://www.greatschools.org/special-education/LD-ADHD/dyslexia-overview.gs?content=525

Beacham, N., Szumko, J., & Alty, J. (2003). *An initial study of computer-based media effects on learners who have dyslexia. The Media Effects on Dyslexic Individuals in Academia (MEDIA) Project .* (p. 50). Loughborough.

Beatty, P., & Davis, W. (2007). *Evaluating Discrepancies in Print Reading Disability Statistics through Cognitive Interviews. National Center for Health Statistics. U.S. Census Bureau. Washington, D.C.* (p. 19). Washington.

Bekebrede, J., Van Der Leij, A., Plakas, A., Share, D. L., & Morfidi, E. (2010). Dutch Dyslexia in Adulthood: Core Features and Variety. *Scientific Studies of Reading*, *14*(2), 183–210. doi:10.1080/10888430903117500

Bender, V. N. (1987). Secondary personality and behavioral problems in adolescents with learning disabilities. *Journal of Learning Disabilities*, *20*(5), 280–285.

Ben-Dror, L., Pollatsek, A., & Scarpati, S. (1991). Word identification in isolation and in context by college dyslexic students. *Brain and Language*, *40*(1), 471–490. doi:10.1016/0093-934X(91)90144-P

Benktzon, M. (1993). Designing for our future selves: the Swedish experience. *Applied Ergonomics*, *24*(1), 19–27.

Bennett, G., Seashore, G., & Wesman, A. (2000). *DAT-5, Test de Aptitudes Diferenciales*. Madrid: TEA Ediciones, S. A.

Berninger, V. W. (1996). *Reading And Writing Acquisition: A Developmental Neuropsychological Perspective* (p. 240). Westview Press.

Berninger, V. W., Nielsen, K. H., Abbott, R. D., Wijsman, E., & Raskind, W. (2008). Writing Problems in Developmental Dyslexia: Under-Recognized and Under-Treated. *Journal of School Psychology*, *46*(1), 1–20. doi:10.1016/j.jsp.2006.11.008

Berninger, V. W., Winn, W., Stock, P., Abbott, R. D., Eschen, K., Lin, S.-J., Garcia, N., et al. (2008). Tier 3 specialized writing instruction for students with dyslexia. *Reading and Writing*, *21*(1), 95–129. doi:10.1007/s11145-007-9066-x

Birch, S., & Chase, C. (2004). Visual and language processing deficits in compensated and uncompensated college students with dyslexia. *Journal of Learning Disabilities*, *37*(5), 389–410. doi:10.1177/00222194040370050301

Birkett-Cattell, H. (1989). *The 16PF: Personality in depth*. Champaign, IL: Institute for Personality and Ability Testing.

Bjork, E., Ottosson, S., & Thorsteinsdottir, S. (2008). E-Learning For All. *E-Learning: 21st Century Issues and Challenges* (pp. 49–70).

Blanco-Fernandez, Y. (2005). AVATAR: a multi-agent TV recommender system using MHP applications. *The 2005 IEEE International Conference on e-Technology, e-Commerce and e-Service (EEE '05)* (pp. 660–665).

Blinkhorn, S. F. (1999). *GMA: evaluación de grado medio y alto: manual*. Madrid: TEA Ediciones, S. A.

Booth, J. R., Perfetti, C. A., MacWhinney, B., & Hunt, S. B. (2000). The association of rapid temporal perception with orthographic and phonological processing in reading impaired children and adults, *4*, 101–132.

Borkowski, J., Weyhing, R., & Carr, M. (1988). Effects of attribu- tional retraining on strategy-based reading comprehension in learning-disabled students. *Journal of Educational Psychology*, *80*(1), 46–53.

Bra, P. De, & Stash, N. (2002). AHA ! Adaptive Hypermedia for All. *SANE 2002 Conference* (pp. 411–412).

Brown, E., Stewart, C., & Brailsford, T. (2006). Adapting for visual and verbal learning styles in AEH Queen Mary University of London. *Sixth International Conference on Advanced Learning Technologies* (pp. 1145–1146).

Brown, J. I., Fishco, V. V., & Hanna, G. (1993). *The Nelson-Denny reading test*. Itasca, IL: The Riverside Publishing Company.

Bruck, M. (1990). Word-recognition skills of adults with childhood diagnoses of dyslexia. *Developmental Psychology - DEVELOP PSYCHOL*, *26*(3), 439–454. doi:10.1037//0012-1649.26.3.439

Bruck, M. (1992). Persistence of Dyslexics ' Phonological Awareness Deficits. *Developmental Psychology*, *28*(5), 874–886. doi:10.1037/0012-1649.28.5.874

Bruck, M. (1993a). Word recognition and component phonological processing skills of adults with childhood diagnosis of dyslexia. *Special Issue Phonological processes and learning disability*, *13*(3), 258–268. doi:10.1006/drev.1993.1012

Bruck, M. (1993b). Component Spelling Skills of College Students with Childhood Diagnoses of Dyslexia. *Learning Disability Quarterly*, *16*(3), 171–184.

Brünken, R., Steinbacher, S., Plass, J. L., & Leutner, D. (2002). Assessment of cognitive load in multimedia learning using dual-task methodology. *Experimental Psychology*, *49*, 109–119.

Brusilovsky, P. (1996). Methods and techniques of adaptive hypermedia. *User Modeling and User-Adapted Interaction*, *6*(2-3), 87–129. doi:10.1007/BF00143964

Brusilovsky, P., & Millán, E. (2007). User Models for Adaptive Hypermedia and Adaptive Educational Systems. *The Adaptive Web*, *LNCS 4321*, 3 – 53.

Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children's mathematics ability: inhibition, switching, and working memory. *Developmental Neuropsychology*, *19*, 273–293.

Bull, S. (2004). Supporting Learning with Open Learner Models. *4th Hellenic Conference with International Participation: Information and Communication Technologies in Education*. Athens.

Bull, S., & Britland, M. (2007). Group Interaction Prompted by a Simple Assessed Open Learner Model that can be Optionally Released to Peers. *PING Workshop, User Modeling 2007*.

Bull, S., Brna, P., La, L., & Pain, H. (1995). Extending the Scope of the Student Model. *User Modeling and User Adapted Interaction*, *5*(1), 45–65.

Bull, S., Jackson, T. J., & Lancaster, M. J. (2010). Students ' interest in their misconceptions in first year electrical circuits and mathematics courses. *International Journal of Electrical Engineering Education*, *47*(3), 307–318.

Bull, S., & Kay, J. (2007). Student Models that Invite the Learner In: The SMILI Open Learner Modelling Framework. *International Journal of Artificial Intelligence in Education*, *17*(2), 89–120.

Bull, S., & Kay, J. (2008). Metacognition and Open Learner Models. In I. Roll & V. Aleven (Eds.), *Workshop on Metacognition and Self-Regulated Learning in Educational Technologies, International Conference on Intelligent Tutoring Systems* (pp. 7–20).

Bull, S., & Kay, J. (2010). Open Learner Models. In R. Nkambou, J. Bordeau, & R. Miziguchi (Eds.), *Advances in Intelligent Tutoring Systems* (pp. 318–338). Springer-Verlag, Berlin Heidelberg.

Bull, S., Mcevoy, A. T., & Reid, E. (2003). Learner Models to Promote Reflection in Combined Desktop PC / Mobile Intelligent Learning Environments. In S. Bull, P. Brna, & V. Dimitrova (Eds.), *Workshop on Learner Modelling for Reflection, International Conference on Artificial Intelligence in Education* (Vol. 5, pp. 199–208).

Bull, Susan, & Nghiem, T. (2002). Helping Learners to Understand Themselves with a Learner Model Open to Students , Peers and Instructors. *Workshop on Individual and Group Modelling Methods that Help Learners Understand Themselves, International Conference on Intelligent Tutoring Systems* (pp. 5–13).

Bull, Susan, & Pain, H. (1995). " Did I say what I think I said , and do you agree with me ?": Inspecting and Questioning the Student Model. In J. Greer (Ed.), *Artificial Intelligence in*

Education (pp. 501–508). Association for the Advancement of Computing in Education (AACE).

Bull, Susan, Wasson, B., Kickmeier-Rust, M., Johnson, M. D., Moe, E., Hansen, C., Meissl-Egghart, G., et al. (2012). Assessing English as a Second Language: From Classroom Data to a Competence-Based Open Learner Model. *International Conference on Computers in Education*.

Burke, J., & Ryan, J. (2004). Teaching and learning practices for students with disabilities: Staff development training program and information guide. *A University of Ballarat Equity Initiative Program Project*.

Callens, M., Tops, W., & Brysbaert, M. (2012). Cognitive profile of students who enter higher education with an indication of dyslexia. *PloS one*, *7*(6), e38081. doi:10.1371/journal.pone.0038081

Campbell, J. P., & Oblinger, D. G. (2007). *Academic Analytics* (p. 24).

Capuano, N., Marsella, N., & Salerno, S. (2000). ABITS: An Agent Based Intelligent Tutoring System for Distance Learning, Montreal. *ITS 2000*. Canada: Springer-Verlag.

Carmona, C., Castillo, G., & Millán, E. (2007). Discovering Student Preferences in ELearning. *International Workshop on Applying Data Mining in e-Learning*.

Carver, C. A., Howard, R. A., & Lane, W. D. (1999). Addressing Different Learning Styles Through Course Hypermedia. *IEEE Transactions on Education*, *42*(1), 33–38.

Cattell, R. B., & Cattell, A. K. (1994). *Tests de Factor «g», Escalas 2 y 3*. Madrid: TEA Ediciones, S. A.

Coffield, F., Moseley, D., Hall, E., & Ecclestone, K. (2004). *Should we be using learning styles? What research has to say to practice* (p. 84). London.

Collins, A., & Brown, J. S. (1988). The Computer as a Tool for Learning Through Reflection. *Learning Issues for Intelligent Tutoring Systems* (pp. 1 – 18). New York: Springer-Verlag.

Coltheart, M., & Rastle, K. (1994). Serial processing in reading aloud: Evidence for dual-route models of reading. *Journal of Experimental Psychology. Human Perception & Performan*, *20*(6), 1197–1211.

Conati, C., Larkin, J., & VanLehn, K. (1997). A Computer Framework to Support Self-explanation. , IOS Press (). In B. du Bolay & R. Mizoguchi (Eds.), *8th World Conference on Artificial Intelligence in Education AIED'97, Knowledge and Media in Learning Systems* (pp. 279–286).

Conati, C., & Maclaren, H. (2005). Data-Driven Refinement of a Probabilistic Model of User Affect. *10th International Conference UM'05. Lecture Notes in Computer Science* (Vol. 3538, pp. 40–49). Springer-Verlag.

Cook, R., & Kay, J. (1994). The justified user model : a viewable , explained user model *. *Fourth International Conference on User Modeling* (pp. 145–150).

Cooper, R. (2006). Making Learning Styles Meaningful. *The journal of PATOSS*, *19*(1), 58–62.

Corbett, A. T., & Bhatnagar, A. (1997). Student Modeling in the ACT Programming Tutor: Adjusting a Procedural Learning Model Model with Declarative Knowledge. In A. Jameson, C. Paris, & C. Tasso (Eds.), *User Modeling* (pp. 243–254). New York: Springer.

Corley, M. A., & Taymans, J. M. (2007). Adults with Learning Disabilities - A Review of the Literature. *Review of Adult Learning and Literacy- A Project of the National Center for the Study of Adult Learning and Literacy* (pp. 44–83). Lawrence Erlbaum Associates.

Cortada de Kohan, N. (2003). *BAIRES. Test de Aptitud Verbal*. Madrid: TEA Ediciones, S. A.

Cousins, C., & Duhl, L. (1983). Health Technology Case Study 25: Technology and Learning Disabilities. *Crongress of the United States, Office of Technology Assessment*, (December).

Critchley, M. (1970). *The dyslexic child* (p. 137). Illinois: Springfield, III.: Charles C. Thomas.

Cuetos, F. (2002). *PROESC, Evaluacion de los Procesos de Escritura* (pp. 1–36). Madrid: TEA Ediciones, S. A.

Cuetos, F., & Valle, F. (1988). Modelos de lecturya y dislexia. *Infancia y Aprendizaje*, *44*, 3–19.

Curry, L. (1987). *Integrating Concepts of Cognitive Or Learning Style: A Review with Attention to Psychometric Standards* (p. 92). Learning Styles Network.

D'Angiulli, A., & Siegel, L. S. (2004). Schooling, socioeconomic context and literacy development. *Educational Psychology*.

Davis, R. (1992a). 37 Common Characteristics of Dyslexia. *Davis Dyslexia Association International*. Retrieved from http://www.dyslexia.com/library/symptoms.htm

Davis, R. (1992b). 37 Common Characteristics of Dyslexia. *Davis Dyslexia Association International*.

De Bra, P. (1999). Design issues in adaptive web-site development. *2nd Workshop on Adaptive Systems and User Modelling on the WWW* (pp. 29–39).

De la Cruz, M. V. (1999). *ECL. Evaluación de la comprensión lectora*. Madrid: TEA Ediciones, S. A.

De Vega, M., Carreiras, M., Gutiérrez, M., & Alonso, M. L. (1990). *Lectura y comprensión: Una perspectiva cognitiva* (p. 272). Madrid: Alianza editorial.

Decker, S. N. (1989). Cognitive processing rates among disabled and normal reading young adults: A nine year follow-up study. *Reading and Writing*, *2*, 123–134.

Decker, S. N., Vogler, G. P., & Defries, J. C. (1989). Validity of self-reported reading disability by parents of reading-disabled and control children. *Reading and Writing*, *1*(4), 327–331. doi:10.1007/BF00386265

DeFries, J. C., & Baker, L. A. (1983). Colorado family reading study: Longitudinal analyses. *Annals of Dyslexia*, *33*(1), 153–162.

DeFries, J. C., & Gillis, J. J. (1993). Genetics of reading disability. In R. Plomin & G. McClearn (Eds.), *Nature, nurture and psychology* (pp. 121–145). Washington: DC: APA Press.

Démonet, J.-F., Taylor, M. J., & Chaix, Y. (2004). Developmental dyslexia. *The Lancet*, *363*, 1451–1460.

Díaz, A. (2007). *Perfiles cognitivos y académicos en adolescentes con dificultades de aprendizaje con y sin trastorno por déficit de atención asociado a hiperactividad (Ph.D. Thesis)*. Universidad de la Laguna, La Laguna, Spain.

Díaz, A., Jiménez, J. E., Mejia, C., & Fabregat, R. (2013). Estandarización de la Batería de Evaluación de la Dislexia en Adultos (BEDA). In M. del C. Pérez Fuentes & M. del M. Molero Jurado (Eds.), *Variables Psicológicas y Educativas para la Intervención en el Ámbito Escolar. Presented at III Congreso Internacional de Convivencia Escolar: Contextos Sicológicos y Educativos* (Asociación., pp. 191–194). GEU Editorial.

Díaz, A., Mejia, C., Jiménez, J. E., & Fabregat, R. (2012). *Manual de uso e instrucciones de la batería de evaluación de dislexia en adultos (BEDA)* (pp. 1–27). Girona, Spain.

Dillenbourg, P., & Jermann, P. (2010). Technology for classroom orchestration. *New Science of Learning*, 525–552.

Donald Norris, L. B., Leonard, J., Pugliese, L., & Lefrere, P. (2008). Action Analytics: Measuring and Improving Performance That Matters in Higher. *Educause Review*, *43*(1).

Donnelly, R., & Mcsweeney, F. (2008). *Applied E-Learning and E-Teaching in Higher Education*. (R. Donnelly & F. McSweeney, Eds.) (p. 440). New York, USA: IGI Global. doi:10.4018/978-1-59904-814-7

Ducarne de Ribaucourt, E. (1977). *AFASIA: Test para el examen de la afasia: pruebas clínicas*. Madrid: TEA Ediciones, S. A.

Dunn, L. M., & Dunn, D. M. (2007). *Peabody Picture Vocabulary Test, Fourth Edition (PPVT™-4)*. Pearson Education, Inc.

Dunn, R., Dunn, K., & Price, G. A. (1985). *The learning style inventory*. Lawrence, KS: Price Systems.

Duval, E. (2011). Attention Please! Learning Analytics for Visualization and Recommendation. *LAK11: 1st International Conference on Learning Analytics and Knowledge* (pp. 9–17).

Echeita, G. (2007). *Educación para la inclusión o educación sin exclusiones* (p. 178). Madrid: Ediciones Narcea (2nd ed.).

Eden, G. F., Jones, K. M., Cappell, K., Gareau, L., Wood, F. B., Zeffiro, T. A., Dietz, N. A. E., et al. (2004). Neural Changes following Remediation in Adult Developmental Dyslexia 4000 Reservoir Road. *Neuron*, *44*(3), 411–422. doi:10.1016/j.neuron.2004.10.019

Eisenson, J. (1954). *Examining for aphasia: A manual for the examination of apha sia and related disturbances*. New York: Psychological Corporation.

Elias, T. (2011). *Learning Analytics : Definitions , Processes and Potential* (p. 23).

Elliot, C. D. (1990). *Differential Abilities Scale (DAS)*. San Antonio, Tx: Psychological Corporation.

Engeström, Y. (1987). Learning by expanding: An activity-theoretical approach to developmental research. *Orienta-Konsultit Oy*.

Engeström, Y. (1999). Expansive Visibilization of Work: An Activity-Theoretical Perspective. *Computer Supported Cooperative Work*, *8*(1), 63–93.

Engeström, Y. (2000). Activity Theory as a Framework for Analyzing and Redesigning Work. *Ergonomics*, *43*(7), 960–974.

Entwistle, N., McCune, V., & Walker, P. (2001). Conceptions, styles and approaches within higher education: analytic abstractions and everyday experience. In R. J. Sternberg & L.-F. Zhang (Eds.), *Perspectives on thinking, learning and cognitive styles* (London.). Lawrence Erlbaum Associates, Inc.

Farmer, M., & Klein, R. (1995). The evidence for a temporal processing deficit linked to dyslexia: a review. *Psychonomic Bulletin and Review 2*, 460–493.

Fawcett, A. J., & Nicolson, R. I. (1994). Naming speed in children with dyslexia. *Journal of Learning Disabilities*, *27*, 641–646.

Fawcett, A.J., Pickering, S., Nicolson, R. I. (1993). Development of the DEST test for early screening dyslexia. In S. F. Wright & R. Groner (Eds.), *Facets of dyslexia and its remediation*. Amsterdam: Elsevier Science Publishers BV.

Fayol, M. (1995). A propos de la compréhension. *Regards sur la lecture et ses apprentissages, ONL 96*, 85–102.

Felder, R. M. (1989). *Meet Your Students: 1. Stan and Nathan* (p. 68).

Felder, R. M. (1990). *Meet Your Students: 2. Susan and Glenda* (p. 7).

Felder, R. M. (1993). Reaching the Second Tier Learning and Teaching Styles in College Science Education. *Journal of College Science Teaching*, *23*(5), 286–290.

Felder, R. M. (1996). Matters of Style. *ASEEE Prism.* (Vol. 6, pp. 18–23).

Felder, R. M., & Silverman, L. K. (2002). Learning and Teaching Styles In Engineering Education. *Engr. Education. The paper is preceded by a 2002 preface that states and explains changes in the model that have been made since 1988*, *78*(7), 674–681.

Felder, R. M., & Soloman, B. A. (2008). Index of Learning Styles. *North Carolina State University*. Retrieved from http://www.engr.ncsu.edu/learningstyles/ilsweb.html

Felton, R. H., Naylor, C. E., & Wood, F. B. (1990). Neuropsychological profile of adult dyslexics. *Brain and Language*, *39*(4), 485–497.

Felton, R.H., Wood, F.B., Brown, L.S., Campbell, S.K., Harter, M. R. (1987). Separate verbal working memory and naming deficits in attention deficit disorder and reading disability. *Brain Lang*, *31*, 171–184.

Ferguson, R. (2012). *The State Of Learning Analytics in 2012: A Review and Future Challenges* (p. 18).

Fink, R. P. (1998). Literacy development in successful men and women with dyslexia. *Annals of Dyslexia*, *48*(1), 311–346. doi:10.1007/s11881-998-0014-5

Firth, N., Frydenberg, E., & Greaves, D. (2008). Perceived control and adaptive coping : programs for adolescent students who have learning disabilities. *Learning Disability Quarterly*, *31*(3), 151. doi:10.2307/25474645

Fleming, N., & Mills, C. (1992). Not another inventory, rather a catalyst for reflection. *To improve the academy*, *11*, 137–149.

Fletcher, J. M. (1985). Memory for verbal and nonverbal stimuli in learning disability subgroups: Analyis by selective reminding. *Journal of Experimental Child Psychology*, *40*, 244–259.

Florian, B. (2013). *Technology-enhanced support for lifelong competence development in higher education (Ph.D. Thesis)*. University of Girona, Girona, Spain.

Florian, B., Baldiris, S., & Fabregat, R. (2010). A new competency-based e-assessment data model: Implementing the AEEA proposal. *IEEE Education Engineering (EDUCON)* (pp. 473 – 480).

Florian, B., Glahn, C., Drachsler, H., Specht, M., & Fabregat, R. (2011). Activity-Based Learner-Models for Learner Monitoring and Recommendations in Moodle. In C. Kloos Delgado, D. Gillet, R. M. García Crespo, F. Wild, & M. Wolpers (Eds.), *Towards Ubiquitous Learning, Lecture Notes in Computer Science Volume 6964* (pp. 111–124). Springer Berlin Heidelberg. doi:10.1007/978-3-642-23985-4_10

Fontenla, J., Caeiro, M., & Llamas, M. (2009). Una Arquitectura SOA para sistemas de e-Learning a través de la integración de Web Services. *V Congreso Iberoamericano de Telemática. CITA 2009*.

Forness, S. R., Sinclair, E., & Guthrie, D. (1983). Learning disability discrepancy formulas: Their use in actual practice. *Learning Disability Quarterly*, *6*, 107–114.

Forster, K. I. (1976). Accessing the mental lexicon. In R. J. Wales & E. Walker (Eds.), *In New approaches to language mechanisms* (Vol. 1, pp. 257– 287). Amsterdam.

Frederiksen, J. R., & Kroll, J. F. (1976). Spelling and sound: approaches to the internal lexicon. *Journal of Experimental Psychology: Human Perception and Performance*, *23*, 361–379.

Fullick, P., Bajraktarevic, N., & Hall, W. (1993). ILASH : Incorporating learning strategies in hypermedia. *Fourteenth Conference on Hypertext and Hypermedia*.

García, E. (2004). Evaluación de procesos cognitivos en la dislexia mediante ayuda asistida a través de ordenador.

García, F. (2003). *Proyecto Aprender – maqueta inicial* (pp. 1–38). Madrid.

García, F., Amandi, A., Schiaffinoa, S., & Campoa, M. (2006). Evaluating Bayesian networks' precision for detecting students' learning styles. *Computers & Education*.

García, J. N. (1995). *Manual de Dificultades de Aprendizaje – Lenguaje, Lecto-Escritura y Matemáticas*. Madrid: Narcea S.A.

Gaudioso, E. (2002). *Contribuciones al Modelado del Usuario en Entornos Adaptativos de Aprendizaje y Colaboración a través de Internet mediante técnicas de Aprendizaje Automático (Ph.D. Thesis)*. Universidad Complutense de Madrid, Madrid, Spain.

Gelvez, L., Baldiris, S., & Fabregat, R. (2011). Modelado de Usuario para apoyar el Proceso de Enseñanza y Aprendizaje de Personas con Déficit Auditivo. *Congreso Internacional de Ambientes Virtuales de Aprendizaje Adaptativos y Accesibles: Hacia un sistema educativo*.

Gilger, J. W. (1992). Using self-report and parental- report survey data to assess past and present academic achievement of adults and children. *Journal of Applied Developmental Psychology*, *13*(2), 235–256. doi:10.1016/0193-3973(92)90031-C

Gilger, J. W., Geary, D. C., & Eisele, L. M. (1991). Reliability and validity of retrospective self-reports of the age of pubertal onset using twin, sibling, and college student data. *Adolescence*, *26*(101), 41–53.

Gills, P. A. (2007). College Students with Disabilities: an Information Handbook. *Norwich University Printing Services*.

Giménez de la Peña, A., Buiza, J. J., Luque, J. L., & López, J. (2010). Cuestionario de Autoinforme de Trastornos Lectores para Adultos (ATLAS). *XXVII Congreso de la Asociación Española de Logopedia, Foniatría y Audiología (AELFA 2010)*. Valladolid.

Glahn, C., Specht, M., & Koper, R. (2009). Visualisation of Interaction Footprints for Engagement in Online Communities. *Educational Technology & Society*, *12*(3), 44–57.

Glahn, Christian. (2009). *Contextual Support of Social Engagement and Reflection on the Web (Ph.D. Thesis)*. Open University of The Netherlands, Heerlen, The Netherlands. Retrieved from http://dspace.learningnetworks.org/handle/1820/2062

Goldberg, R. J., Higgins, E. L., Raskind, M. H., & Herman, K. L. (2003). Predictors of success in individuals with learning disabilities: a qualitative analysis of a 20-year longitudinal study. *Learning Disabilities Research and Practice*, *18*(4), 222–236.

Goldman, S., & Hasselbring, T. (1997). Achieving meaningful mathematics literacy for students with learning disabilities. *Journal of Learning Disabilities*, 198–208.

Gómez, S. (2013). *Learning Design Implementation in Context-Aware and Adaptive Mobile Learning (Ph.D. Thesis)*. University of Girona, Girona, Spain.

González, C. S. (2001). *Sistema tutorial inteligente para la enseñanza en niños con dificultades intelectuales y cognitivas*. Universidad de la Laguna.

González, C. S., Estevez, J., Muñoz, V., Moreno, L., & Alayon, S. (2004a). SICOLE: Computerized Assessment and Treatment of Dyslexia in Spanish. *Pixel-Bit. Revista de Medios y Educación*, (24), 101–111.

González, C. S., Estevez, J., Muñoz, V., Moreno, L., & Alayon, S. (2004b). SICOLE: Computerized Assessment and Treatment of Dyslexia in Spanish. *Pixel-Bit. Revista de Medios y Educación*, (24), 101–111.

González, D., Jiménez, J. E., García, E., Díaz, A., Rodríguez, C., Crespo, P., & Artiles, C. (2010). Prevalencia de las dificultades específicas de aprendizaje en la Educación Secundaria Obligatoria. *European Journal of Education and Psychology*, *3*(2), 317–327.

González-Pienda, J. A., Núñez, J. C., González-Pumariega, S., Álvarez, L., Roces, C., García, M., González, P., et al. (2000). Autoconcepto, proceso de atribución causal y metas académicas en niños con y sin dificultades de aprendizaje. *Psicothema*, *12*, 548–556.

Goodglass, H., & Kaplan, E. (1976). *Assessment of Aphasia and Related Disorders*. Philadelphia: Lea & Febiger.

Goswami, U. (2010). Phonology, reading and reading difficulty. In K. Hall, U. Goswami, C. Harrison, S. Ellis, & J. Soler (Eds.), *Interdisciplinary Perspectives on Learning to Read: Culture, Cognition and Pedagogy*. London: Routledge.

Goswami, U. (2011). A temporal sampling framework for developmental dyslexia. *Trends in cognitive sciences*, *15*(1), 3–10. doi:10.1016/j.tics.2010.10.001

Govaerts, S., Verbert, K., Klerkx, J., & Duval, E. (2010). Visualizing Activities for Self-reflection and Awareness. *9th international conference on Web-based Learning* (pp. 91–100). Springer.

Govaerts, Sten, Verbert, K., & Duval, E. (2011). Evaluating the Student Activity Meter : two Case Studies. *9th International Conference on Advances in Web-based Learning (ICWL 2011)* (Vol. 7048, pp. 188–197).

Graf, S. (2007). *Adaptivity in Learning Management Systems Focussing on Learning Styles (Ph.D. Thesis)*. Vienna University of Technology, Vienna, Austria.

Grainger, J., & Ferrand, L. (1996). Masked orthographic and phonological priming in visual word recognition and naming: Cross-task comparisons. *Journal of Memory Language*, *35*, 623–647.

Grande, G. (2009). *La cuestión de la dislexia y la disgrafía en la adquisición de segundas lenguas*. Universidad Nebrija.

Grasha, A. F., & Riechmann, S. W. (1974). A Rational Approach to Developing and Assessing the Construct Validity of a Student Learning Style Scales Instrument. *The Journal of Psychology*, *87*, 213–223.

Gregg, N. (1998). Diagnostic issues & adults with LD: Postsecondary programs in the United States: UGA model of assessment. *International Invitational Conference on Adults with Learning Disabilities*. Beit Berl, Israel.

Gregg, N. (2007). Underserved and Unprepared: Postsecondary Learning Disabilities. *Learning Disabilities Research and Practice*, *22*, 219–228. doi:10.1111/j.1540-5826.2007.00250.x

Gregg, N., Coleman, C., Stennett, R., Davis, M., Nielsen, K., Knight, D., & Hoy, C. (2002). Sublexical and lexical processing of young adults with learning disabilities and attention deficit/hyperactivity disorder. In: E. Witruk, A. D. Friederici & T. Lachmann (eds.). Basic Functions o. *Basic Functions of Language, Reading and Reading Disability*, *20, 2002*, 329–358.

Gregorc, A. F. (1985). *Style Delineator: a self-assessment instrument for adults*. Gregorc Associates Inc.

Grigoriadou, M., Papanikolaou, K., Kornilakis, H., & Magoulas, G. (2001). INSPIRE: An Intelligent System for Personalized Instruction in a Remote Environment. *Eight International Conference on UserModeling (UM2001)*. Sonthofen, Germany.

Gutierrez, E., Boticario, J. G., Santos, O. C., Barrera, C., Rodríguez, A., Couchet, J., & Granado, J. (2009). Avances españoles y europeos en e-learning personalizable y adaptable. *I Congreso Internacional Sociedad Digital*, *14*, 182–195.

Guzmán, R., & Jiménez, J. E. (2001). Estudio normativo sobre parámetros psicolingüísticos en niños de 6 a 8 años: la familiaridad subjetiva. *Cognitiva*, *13*(2), 153–191.

Guzmán, R., Jiménez, J. E., Ortiz, R., Hernández-valle, I., Estévez, A., Rodrigo, M., García, E., et al. (2004). Evaluación de la velocidad de nombrar en las dificultades de aprendizaje de la lectura. *Psicothema*, *16*, 442–447.

Hallahan, D. P., & Mercer, C. D. (2000). Learning Disabilities: Historical Perspectives. In R. Bradley, L. Danielson, & D. P. Hallahan (Eds.), *Identification of Learning Disabilities: Research to Practice* (p. 2002). Mahwah, New Jersey: Lawrence Erlbaum Associates, Inc. Retrieved from http://www.nrcld.org/resources/ldsummit/index.html

Hallgren, B. (1950). Specific dyslexia ("Congenital word blindness"): A clinical and genetic study. *Acta Psychiatrica and Neurologica Scandinavica* (Vol. 65 (supp.)).

Hampton, G., & Gosden, R. (2004). Fair play for students with disability. *Journal of Higher Education Policy and Management*, *26*(2), 225–238. doi:10.1080/1360080042000218276

Hanley, J. R. (1997). Reading and Spelling Impairments in Undergraduate Students with Developmental Dyslexia. *Journal of Research in Reading*, *20*(1), 22–30. doi:10.1111/1467-9817.00017

Harris, T. L., & Hodges, R. E. (1981). *A dictionary of reading and related terms*. (T. L. Harris & R. E. Hodges, Eds.). Newark, NJ.

Hasselbring, T., Going, L., & Bransford, J. (1988). Developing math automaticy in learning handicapped children: the role of computerized drill and practice. *Focus and Exceptional Children*, 1–7.

Hatcher, J., Snowling, M. J., & Griffiths, Y. M. (2002). Cognitive assessment of dyslexic students in higher education. *British Journal of Educational Psychology*, *72*(Pt 1), 119–133. doi:10.1348/000709902158801

Heiman, T., & Precel, K. (2003). Students with Learning Disabilities in Higher Education: Academic Strategies Profile. *Journal of Learning Disabilities*, *36*(3), 248–258. doi:10.1177/002221940303600304

Hellendoorn, J., & Ruijssenaars, W. (2000). Personal experiences and adjustment of Dutch adults with dyslexia. *Remedial and Special Education*, *21*(4), 227–239.

Herrmann, N. (1989). *The creative brain*. North Carolina: Brain Books.

Hetzroni, O. E., & Shrieber, B. (2004). Word Processing as an Assistive Technology Tool for Enhancing Academic Outcomes of Students General Classroom. *Journal of Learning Disabilities*, *37*(2), 143–154.

Heyman, B., Swain, J., & Gillman, M. (2004). Organisational simplification and secondary complexity in health services for adults with learning disabilities. *Social Science & Medicine*, *58*(2), 357–367. doi:10.1016/S0277-9536(03)00210-7

Hinshelwood, J. (1900). *Congenital word-blindness : .* (pp. 1506–1508).

Høien, T., & Lundberg, I. (2000). *Dyslexia: From Theory to Intervention* (p. 230). Springer.

Holland, A. L., Frattali, C., & Fromm, D. (1999). *Communication Abilities of Daily Living, Second Edition (CADL-2)*. PRO-ED.

Holzinger, A., Kickmeierrust, M., Wassertheurer, S., & Hessinger, M. (2009). Learning performance with interactive simulations in medical education: Lessons learned from results of learning complex physiological models with the HAEMOdynamics SIMulator. *Computers & Education*, *52*(2), 292–301. doi:10.1016/j.compedu.2008.08.008

Honey, P., & Mumford, A. (1986). *The Manual of Learning Styles*. Maidenhead, Berkshire: Ardingly House.

Honey, P., & Mumford, A. (2006). *Learning Styles Questionnaire (80-item)* (p. 67). Peter Honey Publications Ltda. Retrieved from http://www.councillor.peterhoney.com/documents/Learning-Styles-Questionnaire-80-item_QuickPeek.pdf

Hossiep, R., & Parchen, M. (2006). *BIP. Inventario Bochum De Personalidad Y Competencias*. Madrid: TEA Ediciones, S. A.

Hsiao, I.-H. (2012). *Navigation support and social visualization for personalized e-learning (Ph.D. Thesis)*. University of Pittsburgh, Pittsburgh, USA.

Hsiao, I.-H., Sosnovsky, S., & Brusilovsky, P. (2010). Guiding Students to the Right Questions: Adaptive Navigation Support in an E-learning System for Java Programming. *Journal of Computer Assisted Learning*, *26*(4), 270–283.

Huerva, D. (2008). *Integració del sistema MAS-SHAAD amb la plataforma dotLRN (Master Thesis)*. University of Girona, Girona, Spain.

Huerva, D., Vélez, J., Baldiris, S., Fabregat, R., & Mérida, D. (2008). Adaption of courses and learning environment to the user context in dotLRN. *International Conference on Computational Intelligence for Modelling, Control and Automation - ISE08* (pp. 2–5).

IMS. (2003). IMS Learner Information Package Accessibility for LIP. *IMS Global Learning Consortium*. Retrieved July 12, 2010, from http://www.imsglobal.org/accessibility/index.html

Ingesson, S. G. (2007). Growing Up with Dyslexia: Interviews with Teenagers and Young Adults. *School Psychology International*, *28*(5), 574–591. doi:10.1177/0143034307085659

Jackson, C. (2002). Manual of the Learning Styles Profiler. Retrieved from www.psi-press.co.uk

James, W. B., & Gardner, D. L. (1995). Learning Styles: Implications for Distance Learning. *New Directions for Adult and Continuing Education*, *67*, 19–32.

Jameson, M. (2009). *Good practice guide for justice professionals: guidelines for supporting clients and users of the justice system with dyslexia and related SpLDs*. Retrieved from http://www.bdadyslexia.org.uk/

Jiménez, J. E. (1997). A reading-level match study of phonemic processes underlying reading disabilities in a transparent orthography. *Reading and Writing: An Interdisciplinary Journal*, 23–40.

Jiménez, J. E. (1999). *Psicología de las Dificultades de Aprendizaje. Una disciplina emergente*. Madrid: Síntesis.

Jiménez, J. E., & Artiles, C. (2007). *Definiciones y criterios de identificación de las Dificultades Específicas de Aprendizaje (DEA)* (pp. 1–7). La Laguna.

Jiménez, J. E., Díaz, A., Rodrigo, M., García, E., Guzmán, R., Hernández-valle, I., Estevez, A., et al. (2002). SICOLE: A tutorial intelligent system in assessing and remedial education of reading disabilities in the Spanish language. *Multilingual and Cross-Cultural Perspectives on Dyslexia*. Washington, D.C.: The International Dyslexia Association.

Jiménez, J. E., & García, C. (2007). Learning Disabilities in Guatemala and Spain: A Cross-National Study of the Prevalence and Cognitive Processes Associated with Reading and Spelling Disabilities. *Learning Disabilities Research & Practice*, *22*(3), 161–169. doi:10.1111/j.1540-5826.2007.00247.x

Jiménez, J. E., Gregg, N., & Díaz, A. (2004). Evaluación de habilidades fonológicas y ortográficas en adolescentes con dislexia y adolescentes buenos lectores Assessment of sublexical and lexical processing of Spanish young adults with reading disabilities and young adults normal readers. *Infancia y Aprendizaje*, *27*(1), 63–84. doi:10.1174/021037004772902105

Jiménez, J. E., & Hernández-valle, I. (2000). Word identification and reading disorders in the Spanish language. *Journal of Learning Disabilities*, 267–275.

Jiménez, J. E., & Ortiz, R. (1993). Phonological Awareness in Learning Literacy, *5*(2), 153–170.

Jiménez, J. E., & Rodrigo, M. (1994). Is It True That the Differences in Reading Performance. Journal of Learning Disabilities.

Johan, R., & Bull, S. (2010). Promoting Collaboration and Discussion of Misconceptions Using Open Learner Models. *Workshop on Opportunities for Intelligent and Adaptive Behavior in Collaborative Learning Systems, Intelligent Tutoring Systems* (pp. 9–12).

Johnson, D. J., & Blalock, J. W. (1987). *Young adults with learning disabilities*. Orlando, FL: Grune & Stratton.

Jones, I. (1994). The effect of a word processor on the written composition of second grade pupils. *Computers in the Schools*, *11*, 43–54.

Judge, S., & Floyd, K. (2011). Making Web Enhanced Learning Accessible for All Students. In T. Bastiaens & M. Ebner (Eds.), *World Conference on Educational Multimedia, Hypermedia and Telecommunications* (pp. 3477–3483). Chesapeake, VA: AACE.

Kalmár, M. (2011). *The Chairman's (Annual) report of 12th General Assembly of the European Dyslexia Association* (p. 12). Luxembourg.

Kaufman, A. S., & Kaufman, N. L. (1993). *Manual for the Kaufman Adolescent and Adult Intelligence Test (KAIT)*. American Guidance Service, Circle Pines, MN.

Kaufman, L. (2000). Prueba para diagnosticar la dislexia. *The International Dyslexia Association*. Retrieved from http://www.interdys.org

Kavcic, A. (2001). *Adaptation in Web-Based Educational Hypermedia With Regard to the Uncertainty of User Knowledge*. University of Ljubljana.

Kolb, D. (1984). *Experiential learning: experience as the sourceof learning and development* (p. 256). New Jersey: Prentice Hall.

Kramer, M., Sartorius, N., Jablensky, A., & Gulbinat, W. (1979). The ICD-9 classification of mental disorders: a review of its developments and contents. *Acta psychiatrica scandinavica*, *59*(3), 241–262.

Kump, B., Seifert, C., Beham, G., Lindstaedt, S. N., & Ley, T. (2012). Seeing What the System Thinks You Know - Visualizing Evidence in an Open Learner Model. *LAK 2012, ACM* (p. 2012).

Kussmaul, A. (1877). Word deafness and word blindness. In H. Von Ziemssen & J. A. T. McCreery (Eds.), *Cyclopedia of the practice of medicine* (pp. 770–778). New York: William Wood.

Lachmann, T., & Van Leeuwen, C. (2008). Different letter-processing strategies in diagnostic subgroups of developmental dyslexia. *Cognitive Neuropsychology*, *25*, 730–744.

Lancaster, P. E., Schumaker, J. B., & Deshler, D. D. (2002). The development and validation of an interactive hypermedia program for the teaching a self-advocacy strategy to student with disabilities. *Learning Disability Quarterly*, 277–302.

Laroussi, M. (2001). *Conception et réalisation de système didactique hypermédia adaptatif: CAMELEON*. Manouba University.

Lázaro, A. (1996). *Prueba de comprensión lectora*. Madrid: TEA Ediciones, S. A.

Lefly, D. L., & Pennington, B. F. (1991). Spelling errors and reading fluency in compensated adult dyslexics. *Annals of Dyslexia*, *41*, 143–162. doi:10.1007/BF02648083

Lefly, D. L., & Pennington, B. F. (2000). Reliability and validity of the adult reading history questionnaire. *Journal of Learning Disabilities*, *33*(3), 286–296. doi:10.1177/002221940003300306

Lin, T., & Kinshuk. (2005). Cognitive Profiling in Life-Long Learning. In C. Howard, J. V. Boettcher, L. Justice, K. Schenk, P. L. Rogers, & G. A. Berg (Eds.), *Encyclopedia of International Computer-Based Learning* (pp. 245–255). Hershey, PA, USA: Idea Group Inc.

Lindgren, H. (2011). Towards Personalized Decision Support in the Dementia Domain Based on Clinical Practice Guidelines. *User Modeling and User-Adapted Interaction*, *21*(4–5), 377–406.

Lindgrén, S.-A. (2012). *Mild Developmental Dyslexia in University Students Diagnosis and Performance Features in L1 , L2 , and L3 Signe-Anita Lindgrén*. English Department Publications 6.

Löwe, C., & Schulte-Körne, G. (2004). Dyslexia in Germany. In I. Smythe, J. Everatt, & R. Salter (Eds.), *International book of dyslexia: A guide to practice and resources* (pp. 100–102). Chichester: Wiley.

Luna, C. (2009). "But How Can Those Students Make It Here?": Examining the Institutional Discourse about What It Means to Be "LD" at an Ivy League University. *International Journal of Inclusive Education*, *13*(2), 157–178.

Luque, J. L., Bordoy, S., Giménez de la Peña, A., López-Zamora, M., & Rosales, V. (2011). Severidad en las dificultades de aprendizaje de la lectura: diferencias en la percepción del habla y la conciencia fonológica. *Escritos de Psicología*, *4*(2), 45–55.

Lyon, G. R., Shaywitz, S. E., & Shaywitz, B. A. (2003). A definition of dyslexia. *Annals of Dyslexia*, *53*(1), 1–14. doi:10.1007/s11881-003-0001-9

Lyytinen, H., Erskine, J. M., Tolvanen, A., Torppa, M., Poikkeus, A.-M., & Lyytinen, P. (2006). Trajectories of Reading Development: A Follow-up From Birth to School Age of Children With and Without Risk for Dyslexia. *Merrill-Palmer Quarterly*, *52*(3), 514–546. doi:10.1353/mpq.2006.0031

Mabbott, A., & Bull, S. (2006). Student Preferences for Editing , Persuading , and Negotiating the Open Learner Model. In M. Ikeda, K. Ashley, & T.-W. Chan (Eds.), *Intelligent Tutoring Systems* (Vol. LNCS 4053, pp. 481–490). Springer-Verlag Berlin Heidelberg.

MacArthur, C. (1999). Overcoming barriers to writing: computer support for basic writing skills. *Reading and Writing Quartely*, *15*, 169–192.

Macaruso, P., & Walker, A. (2008). The Efficacy of Computer-Assisted Instruction for Advancing Literacy Skills in Kindergarten Children. *Reading Psychology*, *29*(3), 266–287. doi:10.1080/02702710801982019

Madaus, J. W., Foley, T. E., Mcguire, J. M., & Ruban, L. M. (2001). A Follow-Up Investigation of University Graduates with Learning Disabilities. *Career Development for Exceptional Individuals*, *24*(2), 133–146. doi:10.1177/088572880102400204

Malet, J. C., & Mainer, B. (2010). Proyecto HADA: Ibermática colabora en el desarrollo de un sistema de formación "online" que permite la prevención y el tratamiento del fracaso escolar. *Ibermatica newsletter*.

Mancera, L. (2008). *Machine learning for user modelling upon dotLRN (Master Thesis)*. University of Girona, Girona, Spain.

Mancera, L., Baldiris, S., Fabregat, R., Viñas, F., & Caparros, B. (2011). Adapting Suitable Spaces in Learning Management Systems to Support Distance Learning in Adults with ADHD. *11th IEEE International Conference on Advanced Learning Technologies* (pp. 105–109). Athens.

Marcos, J. A., Martinez, A., Dimitriadis, Y. A., & Anguita, R. (2006). Adapting Interaction Analysis to Support Evaluation and Regulation: A Case Study. *Sixth International Conference on Advanced Learning Technologies* (pp. 125–129).

Marcos, J. A., Martínez-Monés, A., Dimitriadis, Y. A., & Anguita, R. (2006). Interaction Analysis for the Detection and Support of Participatory Roles in CSCL. *12th international conference on Groupware: design, implementation, and use (CRIWG'06)* (pp. 155–162). Medina del Campo, Spain.

Marken, F. (2009). Learning Styles Self Assessment Questionnaire. *Disability Service of the University of Bradford*. Retrieved January 24, 2011, from http://www.brad.ac.uk/admin/disab/screening/

Marslen-Wilson, W. D. (1987). Functional paralellism in spoken word recognition. *Cognition*, *25*, 71–102.

Mayer, R. E., Fennell, S., Farmer, L., & Campbell, J. P. (2004). A personalization effect in multimedia learning: Students learn better when words are in conversational style rather than formal style. *Journal of Educational Psychology*, *96*, 389–395.

McLaughlin, M. J., Dyson, A., Nagle, K., Thurlow, M., Rouse, M., Hardman, M., Norwich, B., et al. (2006). Cross-cultural perspectives on the classification of children with disabilities. *The Journal of Special Education*, *40*, 46–58.

Mcloughlin, D., Leather, C., & Stringer, P. (2002). *The adult dyslexic: interventions and outcomes*. (J. Wiley & Sons, Eds.) (p. 304). Lavoisier S.A.S.

Mejia, C. (2009). *Adaptation Process to Deliver Content based on User Learning Styles (Master Thesis)*. Universitat de Girona, Girona, Spain.

Mejia, C., Baldiris, S., Gómez, S., & Fabregat, R. (2009). Personalization of E-Learning Platforms Based On an Adaptation Process Supported on IMS-LIP and IMS-LD. In I. Gibson, R. Weber, K. McFerrin, R. Carlsen, & D. A. Willis (Eds.), *Society for Information Technology & Teacher Education International Conference 2009* (pp. 2882–2887). Charleston, SC, USA: AACE. Retrieved from http://www.editlib.org/p/31077

Mejia, C., Bull, S., Vatrapu, R., Florian, B., & Fabregat, R. (2012). PADA : a Dashboard of Learning Analytics for University Students with Dyslexia. *Last ScandLE Seminar in Copenhagen* (pp. 9–11).

Mejia, C., Clara, J., & Fabregat, R. (2011). DetectLD: Detecting university students with learning disabilities in reading and writing in the Spanish language. In T. Bastiaens & M. Ebner (Eds.), *World Conference on Educational Multimedia, Hypermedia & Telecommunications - ED-MEDIA 2011* (pp. 1122–1131). Chesapeake: VA: AACE.

Mejia, C., Díaz, A., Florian, B., & Fabregat, R. (2012). El uso de las TICs en la construcción de analíticas de aprendizaje para fomentar la autorregulación en estudiantes universitarios con dislexia. *Congreso Internacional EDUTEC 2012*.

Mejia, C., Díaz, A., Jiménez, J. E., & Fabregat, R. (2011). Considering Cognitive Traits of University Students with Dyslexia in the Context of a Learning Management System. In D. D. Schmorrow & C. M. Fidopiastis (Eds.), *Foundations of Augmented Cognition. Directing the Future of Adaptive Systems. presented at 14th International Conference on Human-Computer Interaction (HCII 2011)* (pp. 432–441). Springer Berlin Heidelberg. doi:10.1007/978-3-642-21852-1_50

Mejia, C., Díaz, A., Jiménez, J. E., & Fabregat, R. (2012). BEDA: A Computerized Assessment Battery for Dyslexia in Adults. *Procedia - Social and Behavioral Sciences*, *46*, 1795–1800. doi:10.1016/j.sbspro.2012.05.381.

Mejia, C., & Fabregat, R. (2010). Towards a Learning Management System that Supports Learning Difficulties of the Students. In P. Rodriguez (Ed.), *XI Simposio Nacional de Tecnologías de la Información y las Comunicaciones en la Educación (ADIE), SINTICE 2010* (pp. 37–44). Valencia, Spain: Ibergarceta.

Mejia, C., & Fabregat, R. (2012). Framework for Intervention and Assistance in University Students with Dyslexia. *IEEE International Conference on Advanced Learning Technologies (ICALT 2012)* (pp. 342–343).

Mejia, C., Fabregat, R., & Marzo, J. L. (2010). Including Student's Learning Difficulties in the User Model of a Learning Management System. *XXXVI Conferencia Latinoamericana de Informática (CLEI 2010)* (pp. 845–858).

Mejia, C., Florian, B., Vatrapu, R., Bull, S., & Fabregat, R. (2013). A novel web-based approach for visualization and inspection of reading difficulties on university students. *Computers & Education*.

Mejia, C., Giménez de la Peña, A., & Fabregat, R. (2012). ATLAS versión 2: una experiencia en la Universitat de Girona. *XXVIII Congreso Internacional AELFA: Asociación Española de Logopedia, Foniatría y Audiología*.

Mejia, C., Giménez de la Peña, A., & Fabregat, R. (2013). Evidence for Reading-Writing Disabilities in Spanish University Students – Applying ADDA. *The Scientific World Journal*, 30.

Mejia, C., Mancera, L., Gómez, S., Baldiris, S., & Fabregat, R. (2008). Supporting Competence upon DotLRN through Personalization. *7th OpenACS / .LRN conference* (pp. 104–110). Valencia.

Mellard, D., Fall, E., & Woods, K. (2010). A path model of reading comprehension for adults with low literacy. *Journal of Learning Disabilities*, *43*(2), 154–165. doi:10.1177/0022219409359345

Merida, D., Fabregat, R., Arteaga, C., & Cannataro, M. (2004). MAS-SHAAD: a multiagent system proposal for an adaptive hypermedia system. *International Journal of Continuing Engineering Education and Life Long Learning*, *14*(4-5), 331–352.

Metsala, J. L. (1999). The development of phonemic awareness in reading-disabled children. *Applied PsychoLinguistics*, *20*(1), 149–158. doi:10.1017/S0142716499001058

Miller, J. F., Heilmann, J., Nockerts, A., Iglesias, A., Fabiano, L., & Francis, D. J. (2006). Oral Language and Reading in Bilingual Children. *Learning Disabilities Research and Practice*, *21*(1), 30–43. doi:10.1111/j.1540-5826.2006.00205.x

Miller-Shaul, S. (2005). The characteristics of young and adult dyslexics readers on reading and reading related cognitive tasks as compared to normal readers. *Dyslexia Chichester England*, *11*(2), 132–151. doi:10.1002/dys.290

Millon, T. (2003). *Millon Index of Personality Styles, Manual Revised*. San Antonio, Tx: The Psychological Corporation.

Mirel, B. (2003). General Hospital: Modeling Complex Problem Solving in Complex Work System. *21st annual international confer-ence on Documentation - SIGDOC '03* (pp. 60–67).

Mishoe, W. (1994). *An Investigation of the Most Commonly Preferred Learning Styles of Learning Disabled Adult Students in Postsecondary Institutions Using the Myers-Briggs Type Indicator* (p. 286).

Mitrovic, A., & Martin, B. (2007). Evaluating the Effect of Open Student Models on Self-Assessment. *International Journal of Artificial Intelligence in Education*, *17*(2), 121–144. Retrieved from http://dl.acm.org/citation.cfm?id=1435369.1435372

Mohanarajah, S., Kemp, R. H., & Kemp, E. (2005). Opening a Fuzzy Learner Model. *Workshop on Learner Modelling for Reflection, International Conference on Artificial Intelligence in Education* (pp. 62–71).

Molina, S., Sinués, A., Deaño, M., Puyuelo, M., & Bruna, O. (1998). *El Fracaso en el Aprendizaje Escolar (II)* (p. 364). Aljibe.

Montgomery, S. (1995). Addresing Diverse Learning Style Through the use of Multimedia. *ASEE National Conference*. Anaheim.

Moore, D. (2008). Brain Research, Reading and Dyslexia. *GreatSchools*, 1–2. Retrieved from http://www.greatschools.org/special-education/LD-ADHD/brain-research.gs?content=668

Morales, R., Pain, H., & Conlon, T. (2000). Understandable Learner Models for a Sensorimotor Control Task. In G. Gauthier, C. Frasson, & K. VanLehn (Eds.), *Intelligent Tutoring Systems* (pp. 222–231). Springer-Verlag Berlin Heidelberg.

Moreno, G. (2008). *E-Learning For All: adaptación considerando el contexto de acceso (Master Thesis)*. University of Girona, Girona, Spain.

Morgan, W. P. (1896). A case of congenital world-blindness.

Mortimore, T. (2008). *Dyslexia and learning style -A Practitioner's Handbook* (p. 310). John Wiley & Sons, Ltd.

Myers, I. B., & McCaulley, M. H. (1985). *Manual: a guide to the development and use of the Myers-Briggs Type Indicator*. Palo Alto, CA.

Näslund, J. C., & Schneider, W. (1991). Longitudinal effects of verbal ability, memory capacity, and phonological awareness on reading performance. *European Journal of Psychology of Education*, *4*, 375–392.

Natale, K., Aunola, K., Nurmi, J.-E., Poikkeus, A.-M., Lyytinen, P., & Lyytinen, H. (2008). Mothers' causal attributions concerning the reading achievement of their children with and without familial risk for dyslexia. *Journal of Learning Disabilities*, *41*(3), 274–285. doi:10.1177/0022219408316094

National Academy of Engineering. (2012). Advance personalized learning, most important research challenges of 21st Century. *National Academy of Sciences*. Retrieved from http://www.engineeringchallenges.org/cms/8996/9127.aspx

National Joint Committee on Learning Disabilities. (1991). Learning Disabilities: Issues on Definition. *Asha*, *33*(5), 18–20. Retrieved from http://www.ldonline.org/about/partners/njcld/archives

Newman, S., Fields, H., & Wright, S. (1993). A developmental study of specific spelling disability. *British Journal of Educational Psychology*, *63 (Pt 2)*, 287–296. doi:10.1111/j.2044-8279.1993.tb01058.x

Nicolson, R. I., & Fawcett, A. J. (1990). Automaticity: a new framework for dyslexia research? *Cognition*, *35*(2), 159–182. doi:10.1016/0010-0277(90)90013-A

Nielsen, J. (2000). Why You Only Need to Test With 5 Users. *Jakob Nielsen's Alertbox*.

Niemi, P. (1998). Svårigheter och lösningar [Difficulties and solutions]. In K. Strandén (Ed.), *Ingen dumbom bara annorlunda: En handbok om dyslexi [Not a fool, just different: A handbook of dyslexia]* (pp. 28–31). Helsinki:Stakes.

Núñez, C. J., Gonzalez-Pienda, J. A., Gonzalez-Pumariega, S., Roces, C., Alvarez, L., & Gonzalez, P. (2005a). Subgroups of attributional profiles in students with learning difficulties and their relation to self-concept and academic goals. *Learning Disabilities Research and Practice*, *20*(2), 86–9.

Núñez, C. J., Gonzalez-Pienda, J. A., Gonzalez-Pumariega, S., Roces, C., Alvarez, L., & Gonzalez, P. (2005b). Subgroups of attributional profiles in students with learning difficulties and their relation to self-concept and academic goals. *Learning Disabilities Research and Practice*, *20*(2), 86–97.

Olguin, C. J., Delgado, A. L., & Ricarte, I. L. (2000). An Agent Infrastructure to Set Collaborative Environments. *IFETS/IEEE Educational Technology & Society*, *3*, 65–73.

Olson, R., & Byrne, B. (2005). Genetic and environmental influences on reading and language ability and disability. In H. W. Catts & A. G. Kamhi (Eds.), *The connections between language and reading disabilities* (pp. 173–200). Mahwah: Lawrence Erlbaum Associates Publishers.

Olson, R. K., Forsberg, H., & Wise, B. (1994). Genes, environment and the development of orthographic skills. In V. Berninger (Ed.), *Varieties of orthographic knowledge, 1: Theoretical and developmental issues* (pp. 27–71). Kluwer Academy.

Oppermann, R., Rashev, R., & Kinshuk. (1997). Adaptability and Adaptivity in Learning Systems. In A. Behrooz (Ed.), *Knowledge Transfer (Volume II)* (Vol. 2, pp. 173–179). London, UK: pAce.

Ortega, F. D., Gea, M., & Gutiérrez, F. L. (2002). *Estudio de un sistema hipermedia adaptativo para el proceso de enseñanza-aprendizaje de la lectoescritura*. Granada: Publications of the University of Granada.

Ortigosa, A., Paredes, P., & Rodriguez, P. (2010). AH-questionnaire!: An adaptive hierarchical questionnaire for learning styles. *Computers & Education*, *54*(4), 999–1005.

Orton, S. T. (1928). *Specific reading disability strephosimbolia* (Vol. 90, pp. 1095–1099).

Paciello, M. (2000). *Web Accessibility for People with Disabilities* (p. 381). Lawrence, USA: CMP Media, inc.

Padget, S. (1998). Lessons from research in dyslexia: implications for a classification system for learning disabilities. *Learning Disability Quarterly*, *21*(2), 167–178.

Papanikolaou, K. A., Grigoriadou, M., Kornilakis, H., & Magoulas, G. D. (2003). Personalizing the Interaction in a Web-Based Educational Hypermedia System: The Case of INSPIRE. *User-Modeling and User-Adapted Interaction*, *13*(3), 213–267.

Paredes, P., & Rodriguez, P. (2004). A Mixed Approach to Modelling Learning Styles in Adaptive Educational Hypermedia. *Advanced Technology for Learning*, *1*(4), 372–377. doi:10.2316/Journal.208.2004.4.208-0823

Paredes, P., & Rodriguez, P. (2006). The Application of Learning Styles in Both Individual and Collaborative Learning. *Sixth IEEE International Conference on Advanced Learning Technologies (ICALT'06)* (pp. 1141–1142). Ieee. doi:10.1109/ICALT.2006.1652663

Parrila, R. K., Georgiou, G., & Corkett, J. (2007). University Students with a Significant History of Reading Difficulties : What Is and Is Not Compensated? *Exceptionality Education Canada*, *17*(2), 195–220.

Passano, S. (2000). Cuestiones epistemológicas en Psicopedagogía clínica. *xpsicopedagogia: El portal de Psicopedagogía en internet, todo sobre psicopedagogia*. Retrieved from http://www.xpsicopedagogia.com.ar/

Pedersen, A. L. (2008). *Educational Reading and Writing assistance for Dyslexic students at the University of Aarhus , Denmark* (pp. 1–11). Aarhus.

Pennala, R., Eklund, K., Hämäläinen, J., Richardson, U., Martin, M., Leiwo, M., Leppänen, P. H. T., et al. (2010). Perception of phonemic length and its relation to reading and spelling skills in children with family risk for dyslexia in the first three grades of school. *Journal of Speech, Language and Hearing Research*, *53*(3), 710–724. doi:10.1044/1092-4388(2009/08-0133)

Peña, C. I. (2004). *Intelligent agents to improve adaptivity in a web-based learning environment control adaptivity in a web-based learning (Ph.D. Thesis)*. University of Girona, Girona, Spain.

Peña, C. I., Gómez, S., Mejia, C., & Fabregat, R. (2008). Competence Formation through Learning Objects in a Multiagent Virtual Educational Environment. *Web Intelligence and Intelligent Agent Technology, 2008. WI-IAT '08. IEEE/WIC/ACM International Conference on* (Vol. 3, pp. 343–347). Ieee. doi:10.1109/WIIAT.2008.400

Peña, C. I., Mejia, C., Gómez, S., & Fabregat, R. (2008). Learning Objects Production for Competence Formation by Adaptive Virtual Educational Environments. In B. Chang & H.-J. So (Eds.), *Workshop Proceedings: Supplementary Proceedings of the 16th International Conference on Computers in Education* (pp. 40–47). Taipei, Taiwan.

Peña-Casanova, J. (1991). *Programa Integrado de Exploración Neuropsicológica (PIENB). Test de Barcelona*. Madrid: TEA Ediciones, S. A.

Pereira-Laird, J., Deane, F. P., & Bunnell, J. (1999). Defining Reading Disability Using a Multifaceted Approach. *Learning Disability Quarterly*, *22*(1), 59–71.

Perez-Marin, D., Alfonseca, E., Rodriguez, P., & Pascual-Neito, I. (2007). Automatic Generation of Students' Conceptual Models from Answers in Plain Text. In C. Conatiet, K. McCoy, & G. Paliouras (Eds.), *User Modeling* (pp. 329–333). Springer Berlin Heidelberg.

Perfetti, C. A., Zhang, S., Berent, I. (1992). Reading in English and Chinese: evidence for a universal phonological principle. En ,. In R. Frost & L. Katz (Eds.), *Orthography, phonology, morphology, and meaning* (pp. 227–248). Amsterdam, North-Holland.

Petrie, H., King, N., & Hamilton, F. (2004). *Accessibility of museum, library and archive websites: the MLA audit* (p. 34). London.

Phipps, L., Sutherland, A., Seale, J., Ball, S., Dilloway, M., Evans, S., Lakey, M., et al. (2002). Access All Areas : disability , technology and learning. *Access*.

Picard, R. W. (1997). *Affective Computing*. MIT Press, Cambridge, MA.

Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self - regulation* (pp. 451 – 502). San Diego, CA: Academic.

Pressley, M., & Forrest-Pressley, D. (1992). Learning disabilities in the 1990s: The state of the field and hoe it got there. (B. Y. Wong, Ed.)*Contemporary intervention research in learning disabilities. An international perspective*, 235–253.

Rack, J. P., Snowling, M. J., Olson, R. (1992). The nonword reading deficit in developmental dyslexia: A review. *Reading Research Quarterly*, *27*, 29–53.

Ramos, J. L., & Cuetos, F. (1997). *Prolec-SE. Evaluación de los procesos lectores en alumnos del tercer ciclo de Educación Primaria y secundaria*. Madrid: TEA Ediciones, S. A.

Ramus, F., Rosen, S., Dakin, S. C., Day, B. L., Castellote, J. M., White, S., & Frith, U. (2003). Theories of developmental dyslexia: insights from a multiple case study of dyslexic adults. *Brain: A journal of neurology*, *126*(Pt 4), 841–865. doi:10.1093/brain/awg076

Ransby, M. J., & Swanson, H. L. (2003). Reading comprehension skills of young adults with childhood diagnoses of dyslexia. *Journal of Learning Disabilities*, *36*(6), 538–55. doi:10.1177/00222194030360060501

Raskind, M. H., Goldberg, R. J., Higgins, E. L., & Herman, K. L. (1999). Patterns of Change and Predictors of Success in Individuals with Learning Disabilities: Results from a Twenty-Year Longitudinal Study. *Learning Disabilities Research and Practice*, *14*(1), 35–49. Retrieved from http://www.eric.ed.gov/ERICWebPortal/detail?accno=EJ581800#.UK5HmlwoOx4.mendeley

Raven, J. C. (1936). *Mental tests used in genetic studies: The performance of related individuals on tests mainly educative and mainly reproductive (Master Thesis)*. University of London, London.

Reid, G. (2001). Metacognition, learning style and dyslexia. *5th BDA International Conference*. York.

Reid, R., Bruce, D., Allstaff, K., & McLernon, D. (2006). Validating the Readiness for Interprofessional Learning Scale (RIPLS) in the postgraduate context: are health care professionals ready for IPL? *Medical education*, *40*(5), 415–22. doi:10.1111/j.1365-2929.2006.02442.x

Reiff, H. B., Gerber, P. J., & Ginsberg, R. (1994). Instructional Strategies for Long-Term Success. *Annals of Dyslexia*, *44* , 270–288. Retrieved from http://www.eric.ed.gov/ERICWebPortal/detail?accno=EJ496295#.UK5INa59wxg.mendeley

Reitan, R. M., & Wolfson, D. (2004). Comprehensive Handbook of Psychological Assessment. In G. Goldstein & S. Beers (Eds.), *Intellectual and Neuropsychological Assessment*. Hoboken, NJ: John Wiley & Sons, Ltd.

Remschmidt, H., Hennighausen, K., Schulte-Körne, G., Deimel, W., & Warnke, A. (1999). The influence of different diagnostic approaches on familial aggregation of spelling disability. *European child adolescent psychiatry*, *8 Suppl 3*(Suppl 3), 13–20. doi:10.1007/s007870050122

Reynolds, C. R., & Bigler, E. D. (1994). *Test of Memory and Learning*. Austin, Tx: PRO-ED.

Reynolds, C. R., & Kamphaus, R. W. (1992). *BASC: Behavior assessment system for children*. Circle Pines, MN: American Guidance Service.

Riart, J. (1994). *RA+PD. Test de Raonament Verbal i Programa de Desenvolupament*. Madrid: TEA Ediciones, S. A.

Richards, W. (1993). Research Methodology in Software Engineering. *Future directions in software engineering, summary of the Dagstuhl Workshop*, *18*(1), 36–37.

Rodrigo, M., Jiménez, J. E., Díaz, A., Ortiz, R., Hernández-valle, I., Estévez, A., & Hernández, S. (2004). Valoración del procesamiento ortográfico en niños españoles con dislexia : El papel de las unidades léxicas y subléxicas. *Electrónica de Investigación Psicoeducativa y Psicopedagógica*, *2*(2), 105–126.

Rodríguez, E. M. (2004). Trastornos del aprendizaje: Estilos de aprendizaje y el diagnóstico psicopedagógico. *Infomed, Portal de Salud de Cuba*. Retrieved January 8, 2012, from http://www.sld.cu

Rojas, E. (2008). *Diseño y validación de un videojuego para el tratamiento de la dislexia (Ph.D. Thesis)*. Universidad de La Laguna, La Laguna, Spain.

Rojewski, J. W. (1999). Occupational and Educational Aspirations and Attainment of Young Adults With and Without LD 2 Years After High School Completion. *Journal of Learning Disabilities*, *32*(6), 533–552. doi:10.1177/002221949903200606

Román, F. (2008). *Actualización en Dislexia del Desarrollo. Guía para orientadores y profesores de primaria* (pp. 1–96). Murcia.

Román, J. M., & Gallego, S. (1994). *ACRA. Escalas de Estrategias de Aprendizaje [ACRA. Learning Strategy Scales]*. Madrid: TEA Ediciones, S. A.

Roongpraiwan, R., Ruangdaraganon, N., Visudhiphan, P., & Santikul, K. (2002). Prevalence and clinical characteristics of dyslexia in primary school students. *Journal of the Medical Association of Thailand*, *85*(4), 1097–1103.

Rosati, P. (1988). A Study of the Relationship Between Students' Learning Styled and Instructor's Lecture Style. *IEEE transactions on education*, *31*(3).

Rosati, P. (1996). Comparisons of Learning Preference in an Engineering Program. *Frontiers in Education*.

Rosati, P. (1999). Specific Differences and Similarities in the Learning Preferences of Engineering Students. *29th ASEE/IEEE Frontiers in Education Conference,*. Puerto Rico.

Rueda, U., Arruarte, A., & Elorriaga, J. A. (2007). A Visual Concept Mapping Medium to Open Student and Group Models. *AIED, Assessment of Group and Individual Learning through Intelligent Visualization Workshop (AGILeViz)* (pp. 4–7). Marina del Rey, USA.

Santamaría, P., Arribas, D., Pereña, J., & Seisdedos, N. . (2005). *EFAI, Evaluación Factorial de las Aptitudes Intelectuales*. Madrid: TEA Ediciones, S. A.

Santiuste, V., & González-Pérez, J. (2005). *Dificultades de aprendizaje e intervención psicopedagógica* (p. 316). CCS editorial.

Santos, J. L., Verbert, K., Govaerts, S., & Duval, E. (2011). Visualizing PLE Usage. *EFEPLE11: 1st Workshop on Exploring the Fitness and Evolvability of Personal Learning Environments, CEUR workshop proceedings*.

Santos, O. C., Baldiris, S., Boticario, J. G., Gutierrez, E., & Fabregat, R. (2011). Open issues in personalized inclusive learning scenarios. In D. Pérez-Marín, M. Kravcik, & O. C. Santos (Eds.), *International Workshop on Personalization Approaches in Learning Environments* (pp. 1–5). Girona.

Santos, O. C., & Boticario, J. G. (2009). Guiding Learners in Learning Management Systems through Recommendations. *4th European Conference on Technology Enhanced Learning: Learning in the Synergy of Multiple Disciplines* (pp. 596–601).

Sartorius, N., Kaelber, C. T., Cooper, J. E., Roper, M. T., Rae, D. S., Gulbinat, W., Ustün, T. B., et al. (1993). Progress toward achieving a common language in psychiatry. Results from the field trial of the clinical guidelines accompanying the WHO classification of mental and behavioral disorders in ICD-10. *Archives of general psychiatry*, *50*(2), 115–124.

Sauro, J., & Kindlund, E. (2005). A method to standardize usability metrics into a single score. (G. C. Van Der Veer & C. Gale, Eds.)*Matrix*, 401–409. doi:10.1145/1054972.1055028

Scanlon, D., Mellard, D. F., Garrison, S., Lancaster, S., Mellard, J., & Rausch, T. (1998). *What We Know about Literacy Practices for Adults with Learning Disabilities: A Review of Published Research.* (p. 126). Kansas.

Schafer, J. Ben, Konstan, J., & Riedl, J. (1999). Recommender Systems in E-Commerce. *1st ACM conference on Electronic commerce (EC'99)* (pp. 23–26).

Schank, R. C. (1982). *Dynamic Memory: a Theory of Reminding and Learning in Computers and People*. Cambridge: Cambridge University Press.

Schehing, E., Carrasco, S., Guerra, J., & Parra, D. (2005). An adaptive Web Platform ase don a Multiagent System and Ontologies. *Nuevas Ideas en Informática Educativa*, *1*.

Scheuer, O., Loll, F., Pinkwart, N., & McLaren, B. (2010). Computer-supported argumentation: A review of the state of the art. *International Journal of Computer-Supported Collaborative Learning*, *5*(1), 43–102.

Schmitz, H., Scheffel, M., Friedrich, M., Jahn, M., Niemann, K., Wolpers, M., & Augustin, S. (2009). CAMera for PLE. *4th European Conference on Technology Enhanced Learning: Learning in the Synergy of Multiple Disciplines (EC-TEL 2009)* (Vol. 5794, pp. 507–520).

Schulte-Körne, G., Deimel, W., & Remschmidt, H. (1997). Can self-report data on deficits in reading and spelling predict spelling disability as defined by psychometric tests? *Reading and Writing: An Interdisciplinary Journal*, *9*(1), 55–63. doi:10.1023/A:1007941403441

Share, D. C., & Stanovich, K. E. (1995). Cognitive processes in early reading development: A model of acquisition and individual differences. *Issues in Education: Contributions from Educational Psychology*, 1–7.

Shaywitz, S. E, Shaywitz, B. A., Fletcher, J. M., & Escobar, M. D. (1990). Prevalence of reading disability in boys and girls. Results of the Connecticut Longitudinal Study. *Journal of the American Medical Association*, *264*, 998–1002.

Shaywitz, Sally E. (2005). *Overcoming Dyslexia: A New and Complete Science-Based Program for Reading Problems at Any Level* (p. 399). New York: Vintage books.

Shaywitz, Sally E., Morris, R., & Shaywitz, B. A. (2008). The education of dyslexic children from childhood to young adulthood. *Annual Review of Psychology*, *59*(1), 451–475.

Shaywitz, Sally E., Shaywitz, B. A., Fulbright, R. K., Skudlarski, P., Mencl, W. E., Constable, R. T., Pugh, K. R., et al. (2003). Neural systems for compensation and persistence: young adult outcome of childhood reading disability. *Biological Psychiatry*, *54*(1), 25–33. doi:10.1016/S0006-3223(03)01836-X

Sideridis, G. D., Mouzaki, A., Simos, P., & Protopapas, A. (2006). Classification of students with reading comprehension difficulties: the roles of motivation, affect, and psychopathology. *Learning Disability Quarterly*, *29*(3), 159–180.

Siegel, L. S. (1989). IQ is irrelevant to the definition of learning disabilities. *Journal of Learning Disabilties*, *22*, 469–478.

Siegel, L. S. (1999). Issues in the definition and diagnosis of learning disabilities: A Perspective on Guckenberger v. Boston University. *Journal of Learning Disabilites*, *32*, 304–319.

Siegel, L. S., & Heaven, R. (1986). Categorization of learning disabilities. In Ceci S.J. (Ed.), *Handbook of cognitive, social, and neuropsychological aspects of learning disabilities* (pp. 95–121). Hillsdale, NJ: Erlbaum.

Siegel, L. S., & Ryan, E. B. (1988). Development of grammatical-sensitivity, phonological and short term memory skills in normally achieving and subtypes of learning disabled children. *Developmental Psychology*, *24*, 28–37.

Siegel, L. S., & Ryan, E. B. (1989). The development of working memory in normally achieving and subtypes of learning disabled children. *Children Develpmental*, *60*, 973–980.

Siegel, L. S., & Smythe, I. S. (2006). Supporting dyslexic adults—a need for clarity (and more research): a critical review of the rice report "Developmental dyslexia in adults: a research review". *Dyslexia*, *12*(1), 68–79. doi:10.1002/dys.305

Siemens, G., Gašević, D., Haythornthwaite, C., Dawson, S., Buckingham Shum, S., Ferguson, R., Duval, E., et al. (2011). *Open Learning Analytics: an integrated & modularized platform* (p. 10).

Simmons, F. R., & Singleton, C. (2006). The mental and written arithmetic abilities of adults with dyslexia. *Dyslexia Chichester England*, *12*(2), 96–114. doi:10.1002/dys.312

Smith, S.D., Macaruso, P., W.J., Shankweiler, D., Crain, S. (1989). Syntactic comprehension in young poor readers. *Applied Psycholinguistics* (Vol. 10, pp. 429–454).

Snowling, M. J. (2000). *Dyslexia* (2nd editio., p. 253). Oxford: Blackwell Publishers Ltd.

Snowling, M. J., Adams, J. W., Bowyer-Crane, C., & Tobin, V. (2000). Levels of literacy among juvenile offenders: the incidence of specific reading difficulties. *Criminal Behaviour and Mental Health*, *10*(4), 229–241. doi:10.1002/cbm.362

Sparks, R. L., & Lovett, B. J. (2010). College Students With Learning Disability Diagnoses: Who Are They and How Do They Perform? *Journal of Learning Disabilities*. doi:10.1177/0022219409338746

Spool, J., & Schroeder, W. (2001). Testing Web Sites: Five Users Is Nowhere Near Enough. *The ACM CHI Conference on Human Factors in Computing*.

Stanovich, K. E. (1986). Matthew Effects in Reading: Some consequences of individual Differences in the acquisition of literacy. *Reading Research Quarterly*, *21*, 360– 407.

Stanovich, K. E., & West, R. F. (1989). Exposure to print and orthographic processing. *Reading Research Quarterly*, *24*, 402–433.

Stash, N., Cristea, A., & De Bra, P. (2004). Authoring of learning styles in adaptive hypermedia: problems and solutions. *Thirteenth World Wide Web Conference*. New York, USA.

Stephanidis, C., Paramythis, A., Sfyrakis, M., Stergiou, A., Maou, N., Leventis, A., Paparoulis, G., et al. (1998). Adaptable and Adaptive User Interfaces for Disabled Users in the AVANTI project. *5th International Conference on Intelligence and Services in Networks: Technology for Ubiquitous Telecom Services* (pp. 153–166). Antwerp: Springer-Verlag London.

Sternberg, R. (1985). *Beyond IQ: A triarchic theory of human intelligence*. New York: Cambridge University Press.

Stiles, M. J. (2000). Effective Learning and the Virtual Learning Environment. *European University Information System (EUNIS)*, 171–180.

Suárez, A., Seisdedos, N. y Meara, P. (1998). *Estimación del Vocabulario (EVOCA)*. Madrid: TEA Ediciones, S. A.

Sumner, P. (2006). The labyrinth of learning styles. *The journal of PATOSS*, *19*(1), 52–57.

Suthers, D., Vatrapu, R., Medina, R., Joseph, S., & Dwyer, N. (2008). Beyond Threaded Discussion: Representational Guidance in Asynchronous Collaborative Learning Environments. *Computers and Education*, *50*(4), 1103–1127. doi:10.1016/j.compedu.2006.10.007

Swanson, H. L., & Hsieh, C.-J. (2009). Reading Disabilities in Adults: A Selective Meta-Analysis of the Literature. *Review of Educational Research*, *79*(4), 1362–1390. doi:10.3102/00346 54309350931

Swinney, D. A. (1979). Lexical access during setence comprehension: Reconsideration of context effects. *Journal of Verbal Learning and Verbal Behavior*, *14*, 645–660.

Taylor, J., Roeck, A. de, Anderson, A., Sharples, M., Boyle, T., Hall, W., Rodden, T., et al. (2004). *A Grand Challenge for Computing: Learning for Life* (p. 9).

Tellado, F., Alfonso, S., & Deaño, M. (2007). El D.N:CAS. Un enfoque de evaluación, un instrumento de diagnóstico y un sistema para el diseño de la intervención psicopedagógica. *IX Congreso internacional galego-portugués de psicopedagoxía*.

Thomson, M. E. (1992). *La dislexia. Su naturaleza, evaluación y tratamiento*. Madrid: Alianza.

Thurstone, L. L., & Thurstone, T. G. (1994). *TEA - Test of Education Ability*. Madrid: TEA Ediciones, S. A.

Timoneda, C., Pérez, F., Hernández, J., Baus, J., & Mayoral, S. (2005). Una metodología innovadora para el diagnóstico y la reeducación de la dislexia: el programa informático PPIC. *XII Congreso Nacional de Modelos de Investigación Educativa: investigación e innovación educativa* (pp. 165–188). La Laguna.

Toro, J., Cervera, M., & Urío, C. (2002). *EMLE. TALE 2000. Escalas Magallanes de lectoescritura*. Madrid: Albero / Cohs.

Torppa, M., Lyytinen, P., Erskine, J. M., Eklund, K., & Lyytinen, H. (2010). Language development, literacy skills, and predictive connections to reading in Finnish children with and without familial risk for dyslexia. *Journal of Learning Disabilities*, *43*(4), 308–321. doi:10.1177/0022219410369096

Triantafillou, E., Pomportsis, A., & Georgiadou, E. (2002). AESCS: Adaptive Educational System based on Cognitive Styles. *AH2002 Workshop, Second International Conference on Adaptive Hypermedia and Adaptive Web-based Systems*. Malaga, Spain.

Van den Bos, K. (1998). IQ, phonological awareness and continuous-naming speed related to Dutch poor decoding children's perfomance on two word identification tests. *Dyslexia*, *4*, 73–89.

Van, V., & Van, L. (1992). Computer-based reading and spelling practice for children with learning disabilities. *Journal of Learning Disabilities*, 186–195.

Vatrapu, R., Reimann, P., & Hussain, A. (2012). Towards Teaching Analytics: Repertory Grids for Formative Assessment. *International Conference of the Learning Sciences (ICLS) 2012*. Sydney, Australia.

Vatrapu, R., Reimann, P., Johnson, M., & Bull, S. (2013). An Eye-Tracking Study of Notational, Informational, and Emotional Aspects of Learning Analytics Representations. Proceedings of the. *Third International Conference on Learning Analytics and Knowledge (LAK)*. ACM Press.

Vatrapu, R., Teplovs, C., Fujita, N., & Bull, S. (2011). Towards Visual Analytics for Teachers' Dynamic Diagnostic Pedagogical Decision-Making. *1st International Conference on Learning Analytics and Knowledge* (pp. 93–98). New York: ACM Press.

Vélez, J. (2009). *Entorno de aprendizaje virtual adaptativo soportado por un modelo de usuario integral (Ph.D. Thesis)*. University of Girona, Girona, Spain.

Vellutino, F. R., & Scanlon, D. M. (1987). Phonological coding, phonological awareness, and reading ability: Evidence from a longitudinal and experimental study. *Merrill-Palmer Quarterly*, *33*, 321–363.

Verbert, K., Drachsler, H., Manouselis, N., Wolpers, M., Vuorikari, R., & Duval, E. (2011). Dataset-driven research for improving recommender systems for learning. In P. Long & G. Siemens (Eds.), *1st International Conference Learning Analytics & Knowledge* (pp. 44–53).

Vickerman, P., & Blundell, M. (2010). Hearing the voices of disabled students in higher education. *Disability & Society*, *25*(1), 21–32. doi:10.1080/09687590903363290

Vilches, E. (2007). Analysis of steps of the platform of virtual learning Microcampus at The University Estatal to Distance of Costa Rica. *Revista Electrónica INIE*, 1–34.

Vinegrad, M. (1994). A revised Dyslexia Checklist. *Educare*, *48*, 21–23. Retrieved from http://www.fms-sas.co.uk/PDF/DyslexiaCheck.pdf

Virvou, M., & Tsiriga, V. (2001). Web Passive Voice Tutor: an Intelligent Computer Assisted Language Learning System Over The WWW. *IEEE International Conference on Advanced Learning Technologies* (pp. 131 – 134).

Virzi, R. A. (1992). Refining the test phase of usability evaluation: how many subjects is enough? *Journal of Human Factors - Special issue: measurement in human factors*, *34*(4), 457–468.

WAI. (2008). Web Content Accessibility Guidelines (WCAG) 2.0. *World Wide Web Consortium (W3C)*. Retrieved June 21, 2010, from http://www.w3.org/WAI/

Walker, W., Lamere, P., Kwok, P., Raj, B., Singh, R., Gouvea, E., Wolf, P., et al. (2004). *Sphinx-4: A flexible open source framework for speech recognition*.

Waters, G. A., Seindenberg, M. S., & Bruck, M. (1984). Children's and adults' use of spelling-sound information in three reading tasks. *Memory and Cognition*, *12*, 293–305.

Wechsler, D. (1997). *Wechsler Adult Intelligence Scale–Third Edition*. San Antonio, Tx: The Psychological Corporation.

Wechsler, David. (2001). *Wechsler Individual Achievement Test - Second Edition (WIAT-II)*. Pearson Education, Inc.

Werner, E. E. (1993). Risk and resilience in individuals with learning disabilities: Lessons learned from the Kauai longitudinal study. *Learning Disabilities Research & Practice*, *8*, 28–35.

Wesson, M. (2005). The Dyslexia Questionnaire. *Dyslexia Centers of Tennessee*. Retrieved January 20, 2011, from http://www.dyslexiacentershelp.com/id8.html

West, T. (1997). *In the Mind's Eye*. New York, USA: Prometheus Books.

Westwood, P. (2004). The affective components of difficulty in learning: Why prevention is better than attempted cure. In B. A. Knight & W. Scott (Eds.), *Learning difficulties: multiple perspectives* (pp. 187–202). Frenchs Forest, NSW: Pearson Education Australia.

White, B. Y., Shimoda, T. A., & Hall, T. (1999). Enabling Students to Construct Theories of Collaborative Inquiry and Reflective Learning : Computer Support for Metacognitive Development. *International Journal of Artificial Intelligence in Education*, *10*, 151–182.

Wilkinson, G. S. (1993). *The Wide Range Achievement Test: Manual. 3rd ed.* Wilmington, DE: Wide Range.

Wimmer, H., Mayringer, H., & Landerl, K. (2000). The double-deficit hypothesis and difficulties in learning to read a regular orthography. *Journal of Educational Psychology*, 668–680.

Wimmer, Heinz. (1993). Characteristics of developmental dyslexia in a regular writing system, Applied Psycholinguistics. *Applied Psycholinguistics*, *14*(1), 1–33.

Wise, B. W., & Olson, R. (1995). Computer-based phonological awareness and reading instruction. *Annals of Dyslexia*, *45*(1), 97–122. Retrieved from http://dx.doi.org/10.1007/BF02648214

Wise, B. W., Ring, J., & Olson, R. K. (2000). Individual differences in gains from computer-assisted remedial reading. *Journal of Experimental Child Psychology*, *77*(3), 197–235. doi:10.1006/jecp.1999.2559

Witkin, H., & Goodenough, D. (1981). *Cognitive styles -essence and origins: Field dependence and field independence*. New York: International Universities.

Wolf, C. (2002). iWeaver : Towards ' Learning Style ' -based e-Learning in Computer Science Education. In T. Greening & R. Lister (Eds.), *Research and Practice in Information Technology* (Vol. 20, pp. 1145–1146).

Wolff, U. (2006). *Att studera med dyslexi vid Göteborgs universitet [Studying with dyslexia at Gothenburg University]* (p. 24). Vasastan.

Wolff, U., & Lundberg, I. (2003). A technique for group screening of dyslexia among adults. *Annals of Dyslexia*, *53*(1), 324–339. doi:10.1007/s11881-003-0015-3

Wong, B. Y., Butler, D. L., Ficzere, S. A., & Kuperis, S. (1996). Teaching low achievers and students with learning disabilities to plan, write, and revise opinion essays. *ournal of Learning Disabilities*, *29*(2), 197–212.

Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). *Woodcock-Johnson III*. Itasca, IL: Riverside Publishing.

Woodcock, Richard W. (1990). Theoretical foundations of the WJ-R measures of cognitive ability. *Journal of Psychoeducational Assessment*, (8), 231–258.

World Health Organization. (1993). *The ICD-10 Classification of Mental and Behavioural Disorders* (pp. 1–267).

Yap, R. A., & Van der Leij, A. (1993). Word processing in dyslexics: An automatic decoding déficit? *Reading and Writing: An Interdisciplinary Journal*, *5*, 261–279.

Yudelson, M., & Brusilovsky, P. (2008). Adaptive Link Annotation in Distributed Hypermedia Systems : The Evaluation of a Service-Based Approach. *Adaptive Hypermedia and Adaptive Web-Based Systems, LNCS 5149* (Vol. 5149, pp. 245–254).

Yuste, C. (2001). *IGF - Inteligencia General y Factorial Manual (5ª Edición)*. Madrid: TEA Ediciones, S. A.

Zapata-Rivera, J. D., & Greer, J. E. (2004). Interacting with Inspectable Bayesian Models. *International Journal of Artificial Intelligence in Education* (Vol. 14, pp. 127–163).

Zhang, H., Almeroth, K., Knight, A., Bulger, M., & Mayer, R. (2007). Moodog: TrackingStudents' Online Learning Activities (pp. 1–6). AACE.

Zimmermann, A., Specht, M., & Lorenz, A. (2005). Personalization and Context Management. *User Modeling and User-Adapted Interaction*, *15*(3-4), 275–302. doi:10.1007/s11257-005-1092-2