Integrated intelligent LEARNing environment for Reading and Writing

D3.1 – State of the Art and User Requirements Analysis Report

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1. Executive Summary

This document aims to provide a set of draft user requirements for the ILearnRW application. The requirements are primarily informed by domain expertise in dyslexia and technology-enhanced learning. Describing how this knowledge underpins the features of our system forms a substantial part of the current document. The recommendations drawn are by no means definitive at this stage, but simply intended to promote informed discussion about our design direction. An iteration of this deliverable due in September will have tested these ideas, and refined them, through the involvement of end users.

2. A Definition of Dyslexia
We motivate and present a definition of dyslexia that will guide the ILearnRW project. Six key features characterize this definition:

- Dyslexia primarily affects the skills involved in accurate and fluent word reading and spelling.
- Characteristic features of dyslexia are difficulties in phonological awareness, verbal memory and verbal processing speed.
- Dyslexia occurs across the range of intellectual abilities.
- It is best thought of as a continuum, not a distinct category, and there are no clear cut-off points.
- Co-occurring difficulties may be seen in aspects of language, motor coordination, mental calculation, concentration and personal organisation, but these are not, by themselves, markers of dyslexia.
- A good indication of the severity and persistence of dyslexic difficulties can be gained by examining how the individual responds or has responded to evidence-based intervention.

3. The Impact of Different Writing Systems on the Dyslexic Reader
Alongside defining dyslexia, we discuss the impact of different orthographic systems. We establish the importance of undertaking studies that compare different orthographies, which examine how particular characteristics of each writing system affect the way that reading develops.

4. Dyslexia in the Learning Context
Each dyslexia-related literacy difficulty manifests differently and is subsequently supported within the school environment. Within UK primary schools by the time children reach the age of 6, more emphasis is given on reading. By age 8, phonics work has been completed, with children lagging behind requiring more focused support. When children reach age 11 and are ready to transition to secondary school any vulnerable pupils, such as those with dyslexia, are flagged up and the schools manage their transition process more closely. The key point of this section is to show that while 1:2:1 support may be effective in primary school, when children reach secondary school the learning gap has often become too wide and such provisions alone may not be adequate.

5. Interventions
A number of evidence-based interventions for dyslexia are discussed. The research findings highlight the positive impact of making multisensory connections between print, sound, movement and meaning to support the learning of reading and spelling skills. The evidence from the studies reviewed within this section indicates that learning programmes need to include a range of activities, working at different levels of text, and that the benefits are greatest when the linkage is made explicit. The findings also suggest that there are important roles for computer activities and for home support activities alongside individual and class-based methods.

6. Technological Interventions for Dyslexia

In having defined dyslexia and shown how children are supported, we turn our attention to technological interventions. We distinguish between assistive and instructional technology. Assistive technology is designed to be used to bypass or work around reading difficulties and support individuals who are unable to read at a level adequate for written communication. Specific examples given include *text-to-speech*, *phonetic spell checkers*, *text predication* and *speech recognition* as well as *structured documents* and *mindmaps*. Instructional technology is designed, on the other hand, to develop or improve specific skills in areas such as letter-recognition, reading, spelling, writing, or maths. Illustrative examples are discussed including *tutorial support* and *complete structured software interventions*.

Section 6 proceeds to identify a number of challenges as well as potential areas of opportunity for the project. These opportunities include: a current lack of awareness of assistive technologies in schools and the fact that instructional packages rarely contain these assistive features, older children perceiving many current solutions to be 'child-like', the need for high levels of teacher intervention in current software, a lack of a connection between existing technologies and the real world school environment as well as opportunities for peer learning.

7. ILearnRW Goals

This section describes the goals of the project. It firstly identifies a number of essential requirements. These requirements must form part of any technology aimed at dyslexic learners. They are:

(1) *Creating Meaningful Learning Contexts:* creating a rationale to any instructional activities given.
(2) *Responsive to a Range of Cognitive Difficulties:* taking into account other difficulties that co-occur with dyslexia to ensure that a learning intervention is presented appropriately.
(3) *Development of Independence and Meta-Cognition:* assisting children with internalising what they have learned and teach them coping strategies.

It secondly defines the outcomes we strive for when teaching reading and writing skills, which include:

(1) *Increasing Motivation and Self-esteem*: strengthening children's self-esteem, which is often a barrier to learning.
(2) *Supporting Cognitive and Perceptual abilities*: ILearnRW will increase children's fluency in reading and in writing.
(3) *Supporting Linguistic abilities*: children will be taught to match sounds and combination of sounds to graphical representations. As a result of using our system, their phonological awareness will improve.

8. Design Principles

In having determined the skills we want to teach, this section will cover discussions from Technology-Enhanced Learning and Human-Computer Interaction to propose a number of high-level design principles that will guide the work within this project in order to achieve its goals. These principles are:

- *Use a combination of theory-led and user-centred design approaches*: we will base any instructional materials on domain expertise while user-centred design will guide other considerations e.g. point to novel use cases.
- *Support reflection and agency*: we will build on known strengths of technologies to engage learners in reflecting back on their progress and taking charge of their learning.

- *Should be designed with engagement in mind:* a guiding principle in our project will be to create engaging and motivating learning experiences.
- *Inclusive both in terms of access and social inclusion*: we will ensure that the technology we design will be both accessible and will not single out children to socially exclude them.
- *Fit with existing practice*: we will take care to scaffold existing learning practices with a view to better support them whenever gaps/needs exist.

9. Stakeholders

This section describes the target user group for the ILearnRW project. We are primarily focusing on children aged 9-11 as this is the age at which dyslexia begins to have a significant impact upon a child's ability to learn in the classroom, particularly as reading and writing skills become more important. There are two different user groups that we are aiming to support:

- Learners who have been identified but haven't been able to be helped - this group typically suffers from severe difficulties.
- Learners who have not been identified - this group have generally learnt some basic steps to managing their dyslexia but have not learnt the more advanced steps.

Based on this, we construct a number of personas that intend to provide a more detailed description of the potential types of users of our technology.

10. The ILearnRW Application

Section 10 begins by discussing the potential hardware options for this project. Dedicated e-Readers are firstly considered, but are deemed unsuitable for this project to the limitations of the hardware, their low processing speed and the small amount of RAM. The focus of this section instead shifts to tablets and a number of different tablet platforms are discussed as well as different input hardware such as the C-Pen and LiveScribe Pen. We go on to discuss the specific design features that will be focused on within this project and specify two sets of features. Firstly those outlined in the proposal (essential) and secondly those based on expert opinions and the review of current literature (additional). This section also presents a number of general requirements related to the *co-occurring difficulties* associated with dyslexia to prevent them from becoming barriers and also to support the development of *metacognitive skills*. Lastly two use cases are outlined as scenarios of use. The first use case focuses on the use of the technology for supporting *schoolwork/homework* and the second use case focuses on *reading for pleasure*.

11. Summary and Next Steps

This report ends by outlining a number of open questions that are seen as research and development challenges within this project, and will be addressed in the subsequent deliverables. The questions we have highlighted are:

- The interactions within our system must be clearly defined and structured. How do we provide a developmental structure for a reader?
- We envision three modes of operation (reading, learning and playing). How should the breakdown of the three modes be presented and does it support genuine use cases?
- Our learner model is envisioned to assess a child's difficulties and respond accordingly. Which signals can and should our learner model collect and how?
- Given the wide scope of activities offered in ILearnRW, adaptation will be achieved through the (1) choice of content (2) text presentation (3) learning activities and (4) teaching strategies. How do we design the analogue – which is often made meaningful through social interaction – into the digital where children may be working alone?

- How can the technology-based learning experience be made appealing to students in the target age group?
- How can we balance the use of content provided by the tool, content required by the curriculum and content selected by the user?

2. A Definition of Dyslexia

Historically, there have been many definitions of dyslexia (Rice and Brooks. 2004). In 2009, an influential report agreed a consensus definition based on research evidence. Having considered research evidence, the Expert Advisory Group for the Rose report adopted the following definition of dyslexia and this is the one that has been taken up by Dyslexia Action, the British Dyslexia Association and the Dyslexia SpLD Trust in the UK.

- Dyslexia primarily affects the skills involved in accurate and fluent word reading and spelling.
- Characteristic features of dyslexia are difficulties in phonological awareness, verbal memory and verbal processing speed.
- Dyslexia occurs across the range of intellectual abilities. It is best thought of as a continuum, not a distinct category, and there are no clear cut-off points.
- Co-occurring difficulties may be seen in aspects of language, motor coordination, mental calculation, concentration and personal organisation, but these are not, by themselves, markers of dyslexia.
- A good indication of the severity and persistence of dyslexic difficulties can be gained by examining how the individual responds or has responded to evidence-based intervention.

Like many previous definitions, this emphasises lack of accuracy and/or fluency in word-level reading and spelling as the primary areas of difficulty. Also in agreement with other current definitions, it proposes that word reading and spelling difficulties are related to underlying deficits in phonological processing skills, thus placing dyslexia firmly in the category of a developmental disorder of language and learning and not primarily, a visual problem.

There is evidence that indicates that, whilst reading accuracy may improve as children get older and are exposed to appropriate intervention and experience, the difficulties with the rate of word reading often persist into adulthood and spelling often remains inaccurate. In languages with a more transparent orthography, problems with accuracy are often less significant than problems with speed and spelling.

Dyslexia primarily affects the skills involved in accurate and fluent word reading and spelling. Table 1, taken from the Rose report, gives a recent synthesis of current dyslexia research showing the common features of dyslexia-related literacy difficulties observed during childhood.

Developmental phase	**Signs of dyslexia**
Preschool	Delayed or problematic speech Poor expressive language Poor rhyming skills Little interest/difficulty learning letters
Early school years	Poor letter-sound knowledge Poor phoneme awareness Poor word attack skills Idiosyncratic spelling Problems copying
Middle school years	Slow reading Poor decoding skills when faced with new words

	Phonetic or non-phonetic spelling
Adolescence and adulthood	Poor reading fluency Slow speed of writing Poor organisation and expression in work

Table 2.1: Developmental phases of dyslexia in children and young people learning to read in English Adapted from Snowling (2008)

The table shows some of the early signs that can be observed during preschool before formal literacy instruction begins. It also highlights how literacy difficulties for children with dyslexia can change during development. For example, some children cope well during primary school but struggle during secondary school years as the demands on reading and writing fluency change. We now revisit the Rose definition to elaborate on each of its features.

'Characteristic features of dyslexia are difficulties in phonological awareness, verbal memory and verbal processing speed'.

Phonological awareness is defined as the ability to identify and manipulate the sounds in words, and is recognised as a key foundation skill for early word-level reading and spelling development. Verbal (phonological short-term) memory is the ability to retain an ordered sequence of verbal material for a short period of time; it is used, for example, to recall a list of words or numbers or to remember a list of instructions. Verbal processing speed is the time taken to process familiar verbal information, such as letters and digits. Phonological awareness, verbal memory and verbal processing speed are all aspects of phonological processing and a convincing body of evidence shows they are reliable markers of dyslexia.

'Dyslexia occurs across the range of intellectual abilities'

The definition recognises that dyslexia can affect children across the range of intellectual abilities. This represents an important shift in thinking, away from the practice of using a discrepancy between measured IQ and measured attainment in reading and spelling to identify dyslexia. Current evidence shows that, regardless of general level of ability, those with marked reading and spelling difficulties perform badly on tasks such as decoding, word recognition and phonological skills. In other words, the types of difficulties with word reading and phonological processing that dyslexic poor readers have are the same types of difficulties that poor readers that are not identified as dyslexic usually have. Of course there may be other differences in the two groups, but when it comes to teaching word level reading skills, their needs are very similar.

'Dyslexia is best thought of as a continuum, not a distinct category, and there are no clear cut-off points'

The definition proposes that dyslexic difficulties are best thought of as existing on a continuum from mild to severe, rather than as forming a discrete category. Recent evidence supports this view and requires a move towards recognition that learning difficulties, including dyslexia, are associated with multiple risk factors that are continuous (varying from mild to severe in the general population).

Until recently, a child was deemed to either have or not have dyslexia but the Rose definition has made it clear that there is no sharp dividing line between having or not having the labelled difficulty. Deciding where the dividing line falls is a matter of professional judgement, but we should note that those on either side of the cut-off will vary only in the severity and not the nature of their difficulties.

Those performing just above the cut-off point are also in need of intervention and support, although perhaps less of it.

Even though dyslexia may be regarded as a continuous scale, difficulties can be sufficiently severe to constitute an 'impairment which has a substantial and long-term adverse effect on [a person's] ability to carry out normal day-to-day activities' - that is, a disability, as defined in section 1 of the Disability Discrimination Act 1995. Moreover, given the continuous nature of dyslexia, estimates of the prevalence of dyslexia will obviously vary according to choice of where to draw the line on that continuum. Snowling (2008) estimates that dyslexia may significantly affect the literacy attainments of between 4% and 8% of children.

'Co-occurring difficulties may be seen in aspects of language, motor co-ordination, mental calculation, concentration and personal organisation, but these are not, by themselves, markers of dyslexia'

Co-occurring difficulties also vary from mild to severe within the general population, with mild 'tendencies' unlikely to reach the threshold for identification of an additional learning difficulty. In the absence of large-scale epidemiological studies, we do not have reliable estimates of rates of co-occurrence. Hulme and Snowling (2009) discuss this issue at length to highlight the main difficulties:

- Specific language impairment (SLI): There is strong evidence of overlap (rather than mere co-occurrence) between SLI and dyslexia: between 35-40% of children with reading problems have been reported to have a language impairment and vice versa.
- Motor coordination: Some children have difficulties with fine motor coordination (drawing, handwriting, manual dexterity) and/or gross motor control (running, skipping, cycling) and, for some of these children, their difficulties are severe enough to be identified as having Developmental Coordination Disorder (DCD, previously known as dyspraxia) . DCD does co-occur with dyslexia but there are also dyslexic children who are good at activities involving art and physical education.
- Mental calculation: Difficulties with arithmetic (sometimes called dyscalculia) can arise for many reasons, including poor teaching and 'maths anxiety'. However we know that the kinds of difficulties that underpin dyslexia can also affect arithmetic. For example both dyslexia and dyscalculia involve verbal memory and retrieval of verbal facts.
- Concentration: If children struggling with basic literacy they may become disengaged and inattentive. Some children have Attention Deficit Hyperactivity Disorder (ADHD where there are severe difficulties in relation to being inattentive, impulsive and overactive. There is debate as to whether Attention Deficit Disorder (ADD), i.e. inattention alone, is separate from ADHD. There is good evidence that dyslexia and ADHD have some common genetic risk factors as well as some likely causal connections at the behavioural level (Pennington and Bishop, 2009)
- Personal organisation: Parents and many practitioners mention forgetfulness and disorganisation as particular problems in dyslexia, perhaps more so in older learners. Some of this may relate to cognitive difficulties in memory and speed of processing that underpin literacy difficulties, but it seems likely that other factors are more related to personality but at the present time there is a lack of strong research evidence in this area.

3. The Impact of Different Writing Systems on the Dyslexic Reader

The majority of studies in the area of literacy acquisition and of reading disabilities have been performed with English-speaking persons. However, multilingual studies have suggested differences between writing systems, leading us to think that results from English language studies are not totally applicable to those with different orthographies. According to this line of study, development of reading skills is produced differently in different orthographic systems, being influenced by the orthographic system and the linguistic environment in which the reader is developing.

Orthographic systems are distributed in an opaqueness-transparency continuum according to the degree to which they respect the alphabetic principle. Thus, transparent orthographies are those where the grapheme -phoneme correspondence is one to one. Opaque orthographies are those where one phoneme corresponds to several graphemes, and one grapheme can correspond to several phonemes. Different writing systems are distributed along this continuum, closer or further from either end as a function of their characteristics. There is a good deal of consensus as to where each one should be placed along this opaqueness-transparency range. Regarding European orthographies, those closer to the transparent end would be Finnish, Greek, Italian and Spanish; those closer to the opaque end would be English, French, Danish and Portuguese.

The importance of carrying out studies which compare different orthographies is justified by the fact that the particular characteristics of each writing system may affect the way that reading develops in each of them, as mentioned above. Transparency-opaqueness could influence the early correlates of reading. While decoding and phonological factors would be important reading indicators in English orthography, in more transparent orthographies where decoding is easier than in opaque ones, this skill could have a lesser influence. Likewise, the transparent- opaque nature of languages can influence development of reading from its earliest stages until fluent reading. In a transparent orthography it is easier to reach an expert level of reading than in an opaque one.

Dyslexia might also be influenced by differences among orthographic systems. It has been supposed that the prevalence of learning disabilities in different countries reflects differences in their orthographic complexity. Dyslexia is more common in countries where the orthography is complex, that is, where the writing system is more opaque, than in those where it is more transparent.

In any case, and despite these differences, it is still maintained that reading disabilities are based principally on a phonological processing deficit, independently of the orthographic system. A recent study by Paulescu et al. (2001) showed that, although manifestations of dyslexia might change as a function of the orthographic system under consideration, the main cognitive deficit and the brain-level bases for this problem were universal.

4. Dyslexia in the Learning Context

Table 2.1 (Section 2) demonstrated the dyslexia-related literacy difficulties associated with different stages in development. Here, we take the UK as a case study to explain how these difficulties manifest in the school environment and how they are dealt with in practical terms by schools.

4.1. Nursery (0-4 years old)

In nursery, children will begin to learn some of their phonic sounds and match them to the written symbol in preparation to move on to reception.

4.2. Reception (4-5 years old)

When children turn five years old, they will start reception. At that time, they will participate in more formal phonics lessons. Typical activities will involve forming letters and distinguishing between their shapes, as well as sounding them out. Alongside this phonic work, children will also learn to read whole words. It is at this stage that children will start working within the school's reading scheme, which largely depends on the school's preference of currently available commercial schemes. From this early age, children will be grouped by ability for both whole word reading and phonics tasks.

They will be asked to share books with the whole class, for instance by reading the book aloud. This models good practice for reading by getting children accustomed to aspects of a book, e.g. its title, author, familiarity with reading texts. Children will also start taking books home to be read with their parents. Once a week, a TA, teacher or voluntary helper, will listen to them read. Listeners will usually keep a 'read log' on how the reading went owned by the child, including notes about areas requiring more attention. Books encountered by this age group will have visual cues to help the reader. In general, a book should present 90% of known words with 10% unfamiliar words. This level of difficulty will challenge children but not to demotivate them.

4.3. Primary School (6-7 years old): Year 1 and 2, Key Stage 1

In year 1 and 2, more focus is placed on reading and this is expected to be done at home as part of homework. Typically when a pupil is confident and has demonstrated competence in reading several of the books at that level without help, the child is allowed to move up a level. Children will now do guided reading in levelled groups. This will involve a comprehension aspect to the reading, usually done through speaking and listening tasks, although some schools will still do written comprehension tasks. At this stage, phonics work is ongoing but often reduced for many pupils as they have acquired the necessary knowledge. Even though some schools will still opt to do phonics sessions, its frequency will be reduced and it will be part of a whole class activity. Some children will need extra work, as they will not have mastered the basic reading lists employed by the school. This will be done in small groups, organised by ability, led by a tutor (TA, teacher or voluntary helper) who will listen to them read and record their progress in a read log. Higher ability groups may work alone. Special focus will be given to comprehension tasks to prepare children for their second year SATs.

4.4. Primary School (8-11 years old): Year 3 to 6/Key stage 2

From Year 3 to 6, most children will have moved on from phonics work. In progressing through the reading scheme, they will be given free access to the library. Typically, the library is visited once a week so that the children can borrow new books. All children are expected to take a book home, unless they have failed to return it, which may lead to them being banned from further borrowing. Only children who are demonstrating difficulty with reading or identification of letters will have extra phonics classes. Children with difficulties will generally be taken out of the classroom to participate in classes led by a TA. Such classes are usually small in nature: they could be 1:2:1, but no more than 4.

For those who are not responsive to these text interventions, more sessions of 1:2:1 reading will be held. Within this cohort, an average student will be no more than 2 years behind their chronological age. During these sessions, the tutor's aim is to transition them into independent reading with sessions held once a term, up to once a week. These guided reading sessions will still be organised in levelled groups. As the children progress with their work, more emphasis is put on comprehension in preparation for the SATs.

When children reach the age of 11, they are at a transition point to secondary school. Anyone who is deemed to be vulnerable at that time will be flagged up by the primary school. The outcome of this is a document recording a student's learning difficulty and any health issues, which is forwarded to the secondary school. This can result in increased meetings between the two schools and pupil visits to the secondary school.

4.5. Secondary school (11-16 years old): Key stage 3 and 4

In entering secondary school, children go through an assessment. It is assumed that pupils will be able to read by this time and most secondary schools will not offer a reading scheme. During their induction, many schools will give children a book to take home. The hope is that when the book is returned, the child will take another one out. Since this is not compulsory, many children choose not to. Anecdotally, a couple of librarians have told us that, on average, children take out about 120 books per month and that the majority of these books are KS3. Even though children are encouraged to read outside of school, often they will not. During school time, there is generally only a maximum of 1 hour reading time, with 20 minutes a week where they are allowed free choice of reading material. This is often held separately from the formal lesson, taking place as part of the registration time in their tutor groups. Children who are highlighted as having difficulty will have reading catch-up groups and in some cases will have 1:2:1 lessons. Generally, no alternative provision is provided with many schools have, over the last year, reducing the number of staff they have for SEN provision.

5. Interventions

5.1. Evidence Based

One of the most influential evaluation studies was done by Hatcher, Hulme and Ellis (1994). They studied 7-year-old children in Cumbria, UK who were experiencing difficulties learning to read. The children were randomly assigned either "no training", "reading alone", "phonological skills training alone" and "reading with phonology" groups. The reading programme was based on the Reading Recovery programme of Clay (1985) which includes extensive practice in reading from books, with progression to the next level of difficulty only when a consistent level of accuracy (94%) has been achieved. The "phonology-alone" group followed a programme of activities including rhyme detection, identification of sounds within words, segmenting, substituting and deleting sounds from words. The Reading plus Phonology (R+P) group had roughly half the amount of time on each of the R and P programmes plus specific linkage activities that included letter-sound associations, sound categorisation supported by plastic letters and phonologically based writing tasks. The mean Reading Ages on the British Abilities Scales test of Word Reading are shown in Table 5.1, along with the ratio gain in months of Reading age per month of elapsed time. A similar pattern was obtained for measures of prose reading accuracy and comprehension and measures of spelling.

BAS Reading Age	**Pre-test**	**Post-test**	**Ratio gain (months/month)**
Reading + Phonology	5.85	6.73	1.42
Reading Alone	5.90	6.60	1.07
Phonology Alone	5.90	6.55	1.05
Control	5.96	6.60	1.03

Table 5.1 - Mean Reading Ages (in years and months) before and after the intervention for the 4 treatment groups in Hatcher Hulme and Ellis (1994)

It can be seen that the greatest gains in reading were made by the R+P group who received the programme in which phonological activities and reading experience were linked explicitly. The Effect Size for gains in reading for the R+P group compared to the Control group was 0.53 (See Rack, 2004). What this means is that, for every unit of improvement made by the control group (in this case months of reading age), the R+P were making 'half as much progress again'. Based on their initial findings, Hatcher and colleagues went on to develop the Reading Intervention programme using 'sound linkage' methods and this programme has been used extensively in Cumbrian schools.

Wise, Ring, & Olson, (2000) tested two models of intervention which involved groups of 4 students working on their own computer with input from one teacher. Two hundred children from Colorado took part; they were aged between 7 and 12 who were in the lowest 10% on a measure of word reading. There were two intervention groups, both of which were given computer reading experience in which they read graded stories on the screen with the opportunity to request speech-feedback on unknown words. One intervention group was termed the "phonological analysis" (PA) group and they were given additional activities and computer exercises learning about phonemes through their association with articulatory motor movements (Lindamood and Lindamood, 1975). The second intervention group, termed "accurate reading in context" (ARC) had a greater emphasis on accurate reading of stories, on and off the computer, and were given explicit training in comprehension strategies. The students received training in half-hour sessions over a period of 4 months amounting to a total of around 29 hours; they were post-tested at the end of the intervention and a year later.

	Pre-test Standard Score	**Gain in Standard Score Units**	**Effect Size**
Word Reading (WRAT)			
ARC Program	74.6	7.0	.31
PA Program	74.0	9.0	.26
Spelling (WRAT)			
ARC Program	75.9	3.1	.04
PA Program	76.4	3.6	-.15

Table 5.2 - Intervention Effect Sizes

The table above shows that both the ARC and PA programs were making progress at a rate that allowed them to begin to catch up to their peers. The gains of 7-9 points in reading were achieved with around 29 hours teaching and this therefore shows rates of growth per hour compare favourably to other studies, as discussed later. There was no untreated control group in this study so the effect sizes reflect the gains expressed in standard deviation units. There were few differences between the two intervention conditions. The PA group showed an advantage on the post-training tests on measures of phoneme awareness and phonological decoding (nonword reading) which is perhaps not surprising as their programme had included more work on these skills. The ARC group, on the whole, showed advantages on timed reading tests. Thus the more phonologically explicit training programme was effective in producing benefits in terms of phonological skills, but not in terms of more general reading skills (and at some expense in terms of speed).

Torgesen et al (2001) conducted a study using sixty pupils from Florida, aged between age 8 and age 12, selected to be in the lower 2% of the population on national norms. The pupils received very intensive intervention amounting to an average of almost 68 hours of instruction over a 2-month period. Two intervention groups were compared; both were taught letter-sound decoding rules, but the emphasis of each programme was different. The Auditory Discrimination in Depth (ADD Group) was also based on the Lindamood programme and was similar to the PA group from the Colorado study. The Embedded Phonics group had a greater emphasis on letter-sound decoding rules, but in the context of text reading. This programme was similar in many ways to the Accurate Reading in Context of Wise et al and to the Reading Intervention group of Hatcher et al in which rules are applied and reinforced in context.

Table 4 below shows the standard scores on a measure of word identification for the two groups who received the different intervention packages, immediately before and after the programmes and at 2 follow-up points. The percentage of children scoring below the low end of the average range, defined here as a standard score of 90, is shown in brackets for the three of the times of measurement. It can be seen the participants in the Torgesen et al study made substantial progress over the 2 months of the intervention and, more importantly, these gains were maintained at the 1 year and 2 year follow-ups.

	Pre-test	Post-test	1 year Follow up	2 year Follow up
Word Attack				
ADD Package	68.5 (100)	96.4 (16)	90.7	91.8 (31)
EP Package	70.1 (100)	90.3 (54)	87.0	89.9 (46)
Word Identification				
ADD Package	68.9 (100)	82.4 (72)	82.7	87.0 (61)
EP Package	66.4 (100)	80.5 (83)	78.2	83.9 (67)
Passage Comprehension				
ADD Package	83.0 (65)	91.0 (40)	92.8	94.7 (15)
EP Package	82.2 (75)	92.0 (46)	91.5	96.9 (21)

Table 5.3 - Mean Standard Scores for the two teaching groups before, during and after the intervention period

As can be seen in the above table, post-test and follow-up scores on measures of single word identification and passage comprehension were remarkably similar for the two groups. The ADD group were found to make greater gains on measures of phonological decoding, during the intervention however, this advantage for the ADD group was not maintained at the follow-up tests. Moreover, this short-term advantage in terms of phonological decoding did not translate to more general benefits in terms of other reading skills.

Torgesen et al (2001) suggest that a useful measurement of progress is the standard score gain divided by the number of hours intervention. For Word Identification the gain per hour was .20 for the ADD group and .21 for the EP group. Putting this another way, 10 hours of intervention would produce a gain of 2 points; 50 hours would produce a gain of 10 points and so on. The figure of about .2 compares very closely with the results of other studies. For example, the gain ratios for word recognition were .22 to .33 from the Wise et al (2000) study, discussed above, and a similar figure of .22 was found in an earlier study by Wise, Ring and Olson (1999). The gain ratios for phonological decoding in the Torgesen et al study were .41 for the ADD programme and .30 for EP, again comparing well with .31 from Wise et al (1999). Gains for passage comprehension were the least impressive in the Torgesen study at .12 of the ADD group and .15 for the EP group and the same was true for the Wise et al study where a gain of .14 was obtained. Whilst this might be thought of as rather disappointing, the participants in these studies were typically starting out with better comprehension levels. At the end of the intervention, as the above table shows, comprehension remained the least of the children's difficulties.

The evidence from Hatcher et al.'s work is that improving poor reader's phonological skills does not, on its own, bring about substantial improvement in reading skills. Rather, development of phonological skills linked to reading experience and practice is required. The inclusion of phonological skills training is important, since reading experience and practice, on its own, does not produce significant gains. Hatcher et al's work, building on Bradley and Bryant's (1985) seminal study, suggests that children with poor phonology need the linkage between spoken sounds and written letters to be made explicit. Moreover, it suggests that the teaching of word-level and sub-word-level decoding strategies must be explicitly linked to reading of connected text. In the Reading plus Phonology group, the teachers would highlight and consolidate taught rules during structured reading practice. This is an important practical point: it is not simply a matter of teaching phonic rules and then practicing them in isolation, rather the practice provides opportunities to reinforce the rules and to demonstrate their use explicitly in context.

The work of Wise and Olson and of Torgesen and colleagues is consistent in showing that the same kinds of results can be obtained using two rather different methods. Both research groups used a programme that emphasised decoding rules with a highly structured progression and an emphasis on awareness of sound patterns via articulatory gestures. These were 'Phonological Analysis' in the Colorado studies and Auditory Discrimination in Depth in the Florida study. Both groups also used an approach that emphasised the application of word decoding skills in context – Accurate Reading in Context in Colorado and Embedded Phonics in Florida. It should be stressed that the programmes were delivered by experienced specialist teachers and that the differences were more in the 'mix' of the activities rather than one programme having all one type of activity and the contrasting programme having completely different activities.

The most striking aspect of the Florida study is the rapid gains in standard scores that can be made with very intensive intervention. As has been pointed out these gains 'per hour' are not necessarily better than has been achieved by some other studies over a longer period, but the effect for the individual is dramatic. Importantly, these rapid gains seem also to be sustainable. The argument is similar to that for early intervention – progress can be made at a later time, but it is clearly much better to effect the 'catch-up' at an early time and so avoid a constant feeling of being behind despite making progress.

In conclusion, the research findings and the practical experiences of skilled, specialist teachers converge to suggest a number of key principles of effective literacy support. At the core of these methods is the idea of making multisensory connections between print, sound, movement and meaning to support the learning of reading and spelling skills. The weight of evidence from the studies reviewed here, and from others, is that learning programmes need to include a range of activities, working at different levels of text, and that the benefits are greatest when the linkage is made explicit. The evidence of studies that have used different models of providing support is encouraging as it suggests that there are important roles for computer activities and for home support activities alongside individual and class-based methods.

5.2. Specialist Dyslexia Teaching

The core features of dyslexia identified in the Rose definition make sense of the fact that children with dyslexia almost always experience problems in learning to break sounds down into individual elements and mapping letters on to sounds and, consequently using those mappings to build up and break down words for reading and spelling (Snowling, 2000; Vellutino & Fletcher, 2005; Vellutino et al, 2004). Unsurprisingly teaching approaches for dyslexia are designed to support dyslexic children in learning to use these phonic mappings (see Torgesen, 2005), but the techniques used have to be more varied in order to achieve this for children who have substantial difficulties.

Recent reports such as Rose 2009 and OFSTED 2010 have highlighted those features of practice that promote successful learning outcomes in classrooms. OFSTED's report was concerned with good learning outcomes in general, but many of the highlighted points are relevant to literacy and dyslexia. In this report entitled 'A Statement is Not Enough' it was argued that children and young people learned best when:

- Teachers presented information in different ways to ensure all children and young people understood
- Teachers adjusted the pace of the lesson to reflect how children and young people were learning
- The effectiveness of specific types of support was understood and the right support was put in place at the right time
- Assessment was secure, continuous and acted upon

- Teachers' subject knowledge was good, as was their understanding of pupils' needs and how to help them
- The staff understood clearly the difference between ensuring children and young people were learning and keeping them occupied
- Respect for individuals was reflected in high expectations for their achievement
- Lesson structures were clear and familiar but allowed for adaptation and flexibility
- All aspects of a lesson were well thought out and any adaptations needed were made without fuss to ensure that everyone in class had access

Children and Young People's learning was least successful when:

- Expectations of disabled children and young people and those who had special educational needs were low
- Activities and additional interventions were inappropriate and were not evaluated in terms of their effect on children and young people's learning
- Resources were poor, with too little thought having been given to their selection and use
- Teachers did not spend enough time finding out what children and young people already knew or had understood
- Teachers were not clear about what they expected children and young people to learn as opposed to what they expected them to do
- Communication was poor: teachers spent too much time talking, explanations were confusing, feedback was inconsistent language was too complex for all children and young people to understand the tone, and even body language, used by adults was confusing for some of the children and young people who found social subtleties and nuances difficult to understand
- The roles of additional staff were not planned well or additional staff were not trained well and the support provided was not monitored sufficiently
- Children and young people had little engagement in what they were learning, usually as a result of the above features

Rose's 2009 Review highlighted the importance of teachers having an understanding of the normal processes of development in reading and spelling and, in particular, the Simple Model of Reading. A Survey of practitioners who were consulted for this review identified the following features of good practice as most important.

- Using multisensory methods for teaching & encouraging multisensory learning
- Planning and delivering lessons so that pupils/ students experience success
- Planning and adapting the teaching programme to meet individual needs
- Teaching a structured programme of phonics
- Building in regular opportunities for consolidation and reinforcement of teaching points already covered
- Maintaining rapport with pupils/students
- Planning a purposeful and engaging balance of activities in lessons
- Teaching pupils/ students to be aware of their own learning strategies
- Teaching pupils/ students to develop effective learning strategies
- Showing sensitivity to the emotional needs of pupils/students
- Teaching pupils/students to improve their working memory
- Selecting appropriate resources to support particular learning needs

The features of good practice identified by OFSTED and by Rose show close agreement. It is interesting to see that good practice for those with dyslexia is not just about individualised learning

programmes and the specific content of these programs. The ethos and organisation of learning within the classroom and across the whole school also make a big difference. In summary, effective learning for children with dyslexia depends on four factors.

First, the whole school ethos must respect individuals' differences, maintain high expectations for all and promote good communication between teachers, parents and pupils. Second, knowledgeable and sensitive teachers are required who understand the processes of learning and the impact that specific difficulties can have on these. Third, creative adaptations to classroom practice must be made, enabling children with special needs learn inclusively, but meaningfully, alongside their peers. Finally, access to additional learning programs and resources should be given to support development of key skills and strategies for independent learning. Amongst the list of good practice features mentioned above, it is the last one – access to additional learning programs and resources – that is perhaps most relevant to our project. The third point, which covers inclusive practice is also relevant in terms of adaptation to assist in learning rather than directly teach skills. What then do we know about effective learning programs?

Current thinking remains very similar to the ideas developed in the 50s and 60s by Orton, Gillingham and Stillman who claimed that "The technique…is based upon the constant use of association of all of the following – how a letter or word looks, how it sounds and how the speech organs or the hand in writing feels when producing it." (Gillingham & Stillman, 1969, p. 17)

In the UK, these ideas have developed and evolved, with key work being done by organizations such as the Hornsby International Dyslexia Centre and The Dyslexia Institute. For example, Alpha to Omega (Hornsby and Shear, 1974) and Hickey language training course (Hickey, 1977; Augur & Briggs, 1992) were based on Gillingham-Stillman. The Dyslexia Institute Literacy Programme (DILP), Walker and Brooks (1996) was based on the Hickey Program and, along with Units of Sound Literacy program, is the core program used by Dyslexia Action, the organization formed from the merger of The Hornsby Cent.re and The Dyslexia Insitute. Jean Walker (2000) has specified five key principles of specialist teaching for children with dyslexia and has outlined the reasons behind these. Table 5.4 summarises these approaches.

Principle	**Description**	**Written English**	**Relevant skills to Dyslexic Student**
MULTISENSORY	Links four sensory modalities: visual, auditory, oral and manual.	Words need to be seen and read: heard and spelled.	The student must use all four sensory channels in synchrony to reinforce strong modalities, improve the weak ones and ensure automaticity.
PHONIC	Links graphemes to phonemes.	English is basically an alphabetic-phonetic system.	Student with poor phonological awareness must improve phonic skills.
STRUCTURED	An imposed order of presentation of graphemes, orthographic patterns and concepts.	The language can largely be ordered and classified into a coherent system of patterns and regularities.	The dyslexic student may show good understanding of rules and classification,. By applying this skill to language he can use analogy and reduce the

			burden of learning.
CUMULATIVE	Built up in small steps, to ensure mastery of each, before progressing to the next step.	Simple letters build into morphemes and thence into longer words.	The dyslexic student is slow to establish automatic responses. They ensure that he can consolidate single responses before more complex skills.
SEQUENTIAL	Simple responses and concepts are taught before more complex ones. Easy before hard. High frequency before more esoteric.		

Table 5.4 - Why use multisensory teaching? (from Walker, 2000, p. 102)

Jan Townend (2000) extended the principles above highlighting the key features of specialist teaching as follows:

- Structure – i.e. logical progression of elements with small steps teaching and explicit links being made between steps.
- Multisensory – i.e. active and interactive integration of visual, auditory, kinaesthetic and tactile elements.
- Reinforcement – i.e. reinforcement of all skills through regular practice to provide automatic access to all components of learning.
- Skill teaching – i.e. teaching should concentrate on the development of useful and transferable skills rather than on learning facts and information, which would create unnecessary burdens on memory.
- Metacognition – i.e. encouraging the student to think about what strategies and approaches would be best for them to use in different circumstances.

In relation to our project it is the need for reinforcement and the need to develop meta-cognitive strategies that are particularly important.

6. Technological Interventions for Dyslexia

Having defined dyslexia, detailed how it is dealt with at schools and described best practices on interventions, we turn our attention to current technological interventions. In presenting the current state-of-the-art, our aim is to conclude with gaps and thus areas of opportunity that will be taken up in our project.

6.1. Typology of Technological Interventions

Appendix 2 comprises of a comprehensive list of existing technological interventions for dyslexia. In Table 6.1 we present a typology to capture the main characteristics of these interventions, spanning from the purpose they aim to fulfill, to the way in which they achieve their aims.

Dimension	Description
Purpose	▪ Assistive: Used to mitigate for cognitive deficiency every time reader uses computer, often as a lifelong practice ▪ Instructional: Used to develop skills for limited time during instruction (although could be for a longer time in some cases)
Type of interaction	▪ Student centred ▪ Teacher centred ▪ Mixed
Modality (mostly for assistive software)	▪ Audio ▪ Visual ▪ Mixed
By focus	▪ Development of spefic skills ▪ Development of curriculum skills ▪ Development of general skills
By location of install	▪ Personal PC ▪ LAN (Units of Sound) ▪ Tablets ▪ Online (EducationCity.com, MyMaths)
Scope	▪ Literacy only ▪ Literacy and numeracy ▪ Across curriculum
Type of purchase	▪ One off purchase ▪ Subscription
User group	▪ Specific SEN needs ▪ General student population
Type of activity	▪ Activities ▪ Fun games ▪ Games where achievements are collected ▪ Non-educational games
Age (typically for teaching software)	▪ Younger ▪ Older ▪ Age neutral
Software / Hardware	▪ Software only ▪ Hardware only ▪ Software and hardware both necessary

Table 6.1 - Typology of dyslexia software.

We recognise that not all software may be classified by all of the dimensions proposed. In the remainder of Section 6 we present existing software solutions clustered by type, before turning our attention back to this typology to identify areas of opportunity and challenge.

6.2. Assistive and Instructional Technology

A major distinction is made between two kinds of software or technology: assistive and instructional. Assistive technology is designed to be used to bypass or work around reading difficulties and support individuals who are unable to read at a level adequate for written communication. Instructional technology, on the other hand, is designed to develop or improve specific skills in areas as letter-recognition, reading, spelling writing, or maths. As a result, assistive technologies tend to be used in more variable contexts and are often used by the user always or for extended periods of time. The use of instructional technologies is bounded by the span of the intervention. This can be as short as several months, or as long as the course of attendance of an educational institution. The outcomes of the use of instructional technologies can be more easily measured since their focus is explicitly on teaching key skills.

6.3. Text-to-Speech Software

Both dyslexic and visually impaired people have found text-to-speech to be a great leap forward in making text accessible. Research has shown that having audio available as a supplemental or even main modality improves both results and emotional attitudes of struggling readers towards text. In particular, the benefits highlighted have been:

- Higher results in exams (when compared to scribed, Nisbet et al 2005)
- Higher identification of spelling errors (when compared to human readers, Raskind and Higgins, 1995)
- Increased comprehension (Elkind and Elkind, 2007)
- Increased speed and processing (Elkind and Elkind, 2007)
- Reduced stress and unease from reading (Milani et al. 2009)
- Increased accuracy in reading (Milani et al. 2009)

Furthermore, recent advances in text synthesis have made text-to-speech sound much more natural and thus suitable for most people, and for most kinds of text.

Text-to-speech software aimed at dyslexic readers will generally do the simple task to read out selected or copied text. Very often this is accompanied by highlighting the text at the same time which research has identified as immensely valuable to many dyslexic readers. Many of these packages are available for free. More advanced commercial packages will often combine text-to-speech with other aspects of the reading workflow, including OCR, to convert printed text into speech in one go. Specialist programs include other features to help with reading, spelling and word finding problems.

Commercial solutions include:

- **Texthelp Read & Write**, which combines text-to-speech and OCR packages to scan in documents, read them aloud and make notes, amongst many other tools.
- **Dolphin SaySo**. SaySo reads aloud as you type, and provides advanced spell checking and AutoCorrect options that work across programs and applications.

Free solutions include:

- **Wordtalk:** This is a free MS Word plug in that will read documents out loud while highlighting them.
- **Balabolka/Orato/DSpeech:** This is an example of free software that can read and text out loud or save text as an MP3.

- **ChromeSpeak:** This is a free plug-in for the Chrome browser that will read text out loud.

Companies selling text-to-speech include Ivona, Cereproc, SVox and Acappela. It is worth pointing out that this approach is not ideal for teaching pronunciation in all contexts. For instance, words like read (reed) and read (red) will often cause problems. However, many text-to-speech engines have become much better at inferring pronunciation from context and can also draw on data from a pronunciation dictionary.

6.4. Phonetic Spell Checkers: Software and Hardware

Spelling is a particularly troublesome activity for dyslexic students. Any solution focusing on providing assistance to struggling readers must address this issue. There are both hardware and software solutions currently on the market. Many of them are integrated with other functionality.

Examples of hardware solutions are:

- **DMQ-118N** is a pocket sized spell checker with a dictionary and thesaurus
- **Franklin Literacy Word Bank** is integrated with the Oxford Primary Dictionary and Thesaurus. It is designed for children in Key Stage 1 and 2. For those who need speech feedback there is the Franklin Collegiate Speaking Dictionary that also comes with a calculator and address book.

Software applications with a phonetic spell checker come in two types. They can be built into word processors. An example of this is Write:Outloud that uses the same spell checking routine as the Franklin handheld. Or they can be software independent utilities. Read & Write, for instance, offers speech feedback and word prediction within word processing applications; Spell Catcher offers interactive spell checking in a number of languages along with an English dictionary and thesaurus.

6.5. Writing Assistance: Text Prediction and Speech Recognition

There is a whole class of applications that are primarily aimed at assisting struggling readers with writing. Many of them are of direct interest to the project because they also support acquisition of reading skills or sometimes even assist with the organization of reading.

6.5.1. Text Prediction

The writing process for dyslexic readers can be greatly assisted by offering suggestions as to what to type next. This helps with a wide variety of language difficulties and addresses questions of spelling as well as composition. Several commercial and free packages are available to assist readers.

6.5.2. Speech Recognition

Speech Recognition has progressed enormously but it still has many limitations. Computers cannot automatically understand a voice, nor can they discriminate between different voices. So to use the software you must go through a training process that involves reading a script. In the past, this has meant reading for up to an hour but the new generation of software has reduced this to about 10 minutes for a normally fluent reader. Users with speech impediments have had varying success and may still prefer the older style packages where you have to speak each word separately, or discretely, i.e. with a noticeable gap between words.

Despite its limitations, speech recognition can provide significant improvements in the writing experiences of struggling readers. Advances in commodity hardware have made speech recognition accessible to almost anyone. Many mobile devices now also offer capable speech recognition although that often requires a live internet connection. Both major desktop operating systems (Windows and

MacOS) include capable speech recognition engines. The last remaining desktop speech recognition package available for purchase by end users is Dragon NaturallySpeaking now sold by Nuance. This includes text-to-speech and has a wide variety of training scripts including those written specifically for children.

6.6. Literacy Teaching Programmes

As pointed out by Wise et al (2000), a computer offers tremendous advantages when it comes to practicing reading skills and in working through a structured teaching programme. The computer doesn't mind how many times the child asks for something to be repeated, it doesn't express frustration when the same mistake is made over and over again and, unlike words on the printed page, the appearance of the text can be changed or highlighted to draw attention to key information. Computer Assisted Instruction/Learning (CAI or CAL) programs also have the advantage of supporting controlled presentation of text and the measurement and monitoring of progress. There are a number of well established instructional software packages that provide either 1) tutorial support or 2) complete structured literacy intervention programme.

Perhaps the best-known example of tutorial support is WordShark, which will be familiar to most teachers, even if only by name. A similar example aimed at younger readers is Nessy. Both of these consist of mini learning games and practice activities. Although they require tutor guidance, they can also operate with minimal supervision. Examples of complete structured software interventions include Units of Sound developed by Dyslexia Action, A.R.R.O.W and AcceleRead AcceleWrite. These programmes require varying degrees of tutor involvement from low in Units of Sound to ubiquitous with AcceleRead AcceleWrite. Perhaps the most prominent feature of the latter category is that it did not originate as a primarily digital solution. The software is a computerised version of existing literacy programmes some of which precede the digital versions by decades. They are the result of many iterations and years of refinement. With the exception of Units of Sound, they are not examples of off-the-shelf software that can be installed by the end-user and used without teacher intervention.

6.7. Text Organization: Structured Documents and Mindmaps

Being presented with large chunks of text is not only cognitively challenging for dyslexic readers but can also be very stressful. Due to increased cognitive load and working memory requirements, long unstructured segments of text, often prevent a struggling reader from gaining understanding of what the text is about. This difficulty is present also during writing, where the task is seen as a challenge.

6.7.1. Structured Documents

The most basic technology to assist with accessing text in smaller chunks is built into all major word processors such as Microsoft Word (even in the starter edition), Google Docs and Open/LibreOffice. The structure is achieved by application of heading styles to section headings instead of just formatting them visually. Word and Open/Libre Office contain a feature Document Map or Navigation, which makes it possible to jump from section to section. The added benefit of this feature is that it allows instantaneous creation of tables of contents, which can then be converted into PDF bookmarks. This is also how GoogleDocs makes navigation possible. Inserting a table of contents into a structured Google Doc makes it possible to use the links to jump to different sections.

Structured documents are an absolute requirement for visually impaired readers who are accessing text by audio or Braille. Neither of these modalities allows for scanning or skimming and blind readers use document structure to get the gist of the document. Dyslexic readers share the same difficulties, albeit for different reasons, although it is worth pointing out that dyslexia used to be called "word blindness". However, due to the predominant focus on phonological awareness, designers often fail to recognise

that larger text organization must form part of the solution. More recently, there has been a greater emphasis on text organisation with structured Word documents chosen as the default format for storing scanned textbooks for blind and dyslexic learners made available through the Load2Learn project. Inferring structure from unstructured documents was seen as an important challenge, with a separate developmental effort conducted in the context of the Navitext project.

6.7.2. Mind Mapping

A popular solution for dyslexic students is mind maps which add a visual element to document structure and lists. These are used both to organise existing knowledge and ideas, and to plan new writing and projects. Several packages allow users to draw maps quickly and easily and the computer has the huge advantage over paper that it is very easy to change or develop a map without having to start again. Other advantages of concept mapping software include the ability to change the layout of the diagram as you go along; use images within the diagram; use brainstorming mode to quickly build up a diagram; spell check diagram. Many mind mapping tools allow for an export of a mind map into a structured Word document which can then be used for composing a larger text. However, there is no reader tool on the market, that would make it easy to create a mind map based on a text.

6.8. Opportunities and Challenges

So far we have provided a high level overview of existing technological interventions for dyslexia. We now return to some of our typology dimensions from Section 6.1 to identify specific areas of challenge and opportunity. These gaps are picked up in Sections 7 (ILearnRW Goals) and 8 (Design Principles). The insights and recommendations we present are the outcome of our typology analysis backed up by interviews we have held with school representatives of various levels, as part of a previous project (Load2Learn).

6.8.1. User Group and Scope

We have learned that schools are struggling with resources both in terms of tight budgets and limited time to implement priorities. They are also limited by the skill capacity and awareness of their staff. As a consequence, schools tend to prefer solutions that can address the largest number of their priorities in one package. These include more comprehensive solutions that cover multiple subjects and are more curriculum focused. Solutions that cover students with wider range of abilities are also of importance. Therefore, software that has not been designed for SEN ends up being used in schools as part of their SEN provision. These systems generally include a variety of activities and have an advertised literacy component. These complex solutions are increasingly popular with many schools considering themselves to be fulfilling their duty of care for the majority of print-impaired and other SEN students. Examples of particularly popular solutions are

- @School http://www.atschool.co.uk/
- Education City http://www.educationcity.com
- MyMaths http://www.mymaths.co.uk/

We note that if our project were of commercial nature, these attitudes would require careful consideration. Since we are designing with a vision to the future, which in practical terms means that children will be given tablet computers to use for the duration of the evaluation, this challenge is partly circumvented.

6.8.2. Purpose

Despite the existence of many assistive software solutions, these are not actively promoted at primary or secondary school. This might partly be due to the fact that these solutions are divorced from the curriculum. In looking at current teaching software, a core shortcoming is that it is based on

generalized language and not actual language the student is encountering as a reader. Instructional packages will in general not contain assistive features, and as such will not encourage development of assistive strategies.

6.8.3. Age

Despite the fact that some commercial software is marketed as age neutral, our school representatives have mentioned that the software is actually perceived by older children as child-like.

6.8.4. Type of Interaction

There are certain characteristics that current solutions share regarding interaction with the student, among the student and neglecting the student's current environment.

- Most teaching software requires some form of teacher intervention. Software that does not require constant supervision, does not promote learner independence by design.
- Teaching software often promotes directed discovery only peripherally but not as a central activity.
- It does not seek student input other than the completion of pre-set exercises.
- Tracking of reading progress in real world outside the software is ignored.
- Peer interaction and support are not encouraged.

7. ILearnRW Goals

The ILearnRW goals can be separated into two strands. The first strand is concerned with essential requirements that must be first achieved in order for a technology-enhanced learning (TEL) programme aimed at dyslexic learners to be effective. The second strand focuses on learning outcomes aiming at teaching reading and writing skills, which are the primary focus of this project. These goals are derived from existing best practice, based on existing interventions, which are intended to assist dyslexic children in overcoming their main difficulties.

7.1. Essential Goals

7.1.1. Creating Meaningful Learning Contexts

Any instructional activity that goes beyond what is required in mainstream education presents an additional hurdle for children. It is thus vital to provide a purpose and a rationale for the additional work required to use the ILearnRW application.

7.1.2. Cognitive Difficulties

As discussed earlier, there are numerous co-occurring difficulties with dyslexia, such as poor short-term memory, organisation and motor coordination (Pauc, 2005). Even though our system does not aim to directly impact on these difficulties, the entire design of our system components - spanning from learning activities, to setting up modes of use - must be responsive to them.

7.1.3. Development of Independence and Meta-cognition

Our system will assist children to develop meta-cognitive skills. Metacognition is identified as an essential component of modern dyslexia intervention. Among other things, it allows struggling readers to develop compensatory strategies and bolster development of cognitive and linguistic capacities (See for instance Reid, 2001; Reid, 2009; Camahalan 2006). The development of these skills should be integrated into all activities rather than represent separate activities. The skills include:

- Learn to modify text to suit a learner's preferences
- Develop skills to find modes of reading suitable to a learner's preferences.
- Develop skills to identify elements of text that are causing decoding difficulties
- Develop skills for transferring rules for decoding into spelling
- Develop skills to discover underlying rules to help with decoding
- Develop skills of self-observation

7.2. Learning Goals

7.2.1. Motivation and Self-esteem

Dyslexic children suffer from low self-esteem. Although learning activities should be designed to be motivating, given the debilitating impact of low self-esteem on learners' willingness to engage in reading, our application will also attempt to teach children to recognize reading as a pleasurable and purposeful activity. It will additionally cultivate more complex motivations for reading beyond the requirement to read for school and will teach them strategies to cope with the stresses involved in reading (Fawcet and Riddick 2009).

7.2.2. Cognitive and Perceptual

ILearnRW will increase children's fluency in reading and in writing. It will also increase their ability to focus and manage memory load. Additionally, it will help increase reading vocabulary in terms of both words that can be decoded and words that are understood.

7.2.3. Linguistic

Children will learn to match sounds and combination of sounds to graphical representations. As a result of using our system, their phonological awareness will improve e.g. rhymes, non-words, prosody. They will also develop awareness and understanding of word structure including terminology and application of rules. For example, they will be able to segment words into syllables, identify types of syllables (open, closed, stressed, unstressed, initial, mid, final) or identify elements of a syllable (onset, rime, coda).

8. Design Principles

If our learning aims express the outcomes we strive to achieve in our project, design principles are intended in part to express how we will achieve them. While the evidence-based perspective that details how to support dyslexic children's learning will guide our design efforts, it is also important to situate our learning aims within more general discussions held in the TEL domain toward exploring how technology in particular is best suited to fulfil our needs.

8.1. Theory-Led and User-Centred Design

It is important to emphasise that our project will heavily draw on expert knowledge to achieve its learning aims (Scaife et al., 1997). The best practice described in **Section 5** and detailed in the **teaching strategies deliverable** will serve as our main starting point. For instance, guiding principles will include structuring lessons and using a multisensory teaching approach personalised to the child's needs as well as the promotion of children's self esteem through positive reinforcement and rewarding experiences. Exercises typically employed by dyslexia specialists will form the basis of our tool. This initial foundation will evolve into a first set of concepts that will be additionally informed by our understanding of the proven strengths and opportunities of TEL, as well as a consideration of users' practices, attitudes and values. To ensure our efforts will be impactful for the user groups we aim to reach, children and their extended network of care (e.g. teachers, parents) will participate in our project as informants and design partners (Good and Robertson, 2006).

8.2. Reflection and Agency

While technologists have been often inspired by the calm computing vision, which aims at making our lives stress-free and effortless, deriving users' needs from context has been met with technical challenges. These barriers have proven to be an inspiration for technologists, amongst which educational technologists, who have reconsidered its role (Rogers, 2006). These discussions have led to the recognition that technology can play a powerful role in shaping learners' skills (as opposed to passively catering to them), for instance by giving them tools that develop their creativity. In a related commentary, it has been argued that technologies that assess a learner's progress and point him/her in the right direction undermine his/her sense of responsibility and agency. The consequence of this is that learners do not actively engage in their learning, for example to recognise which learning strategy may best suit them (Friedman and Kahn, 1992). Importantly, for our current purposes, agency is a necessary condition in developing meta-cognitive skills. These considerations are thus central to our efforts. We envision ILearnRW to provide users with insight into areas of weakness, which we hope will help them develop better learning strategies. Alongside the importance of supporting reflection, we recognise that developing coping strategies by encouraging the learner to take responsibility is an essential skill that dyslexic learners must work on. Our system will thus aim to balance the requirement for a personalised learning programme, with the need for active participation and decision-making in which children will be able to tailor aspects of their learning experience.

8.3. Engagement

A widely accepted premise is that learning technologies must be designed with engagement in mind. The most telling case of a technology that failed due to its inability to engage users was the earlier generation of learning games, which were designed to support linear interactivity and limited agency (Egenfeldt-Nielsen, 2007). Learning technologies must consider engagement as an intrinsic property of the learning activity, as opposed to a reward system that is later tacked onto the system (Van Eck, 2006). To achieve this, in our project, it is important to look at domain experts' practices. Domain experts who work with dyslexic children are acutely aware of the need to construct engaging learning experiences. This is achieved for instance by ensuring that texts given to children are playful (e.g.

rhymes, poems) and appeal to their interests while an appropriate level of challenge is provided (Wolf, 2007). In our project, we will turn to these practices and express them, as deemed appropriate, within the different components of our application. Additionally for certain components of the application it may be useful to ask children from our target age group both with and without dyslexia for their ideas and opinions in relation to what makes technology engaging for them. This input can therefore be combined with the experts' practices to ensure that engagement has been considered across the entire ILearnRW learning experience.

8.4. Inclusion

Inclusive technologies are often associated with breaking down access barriers, albeit evidence showing that despite the adoption of inclusive practice, children with learning challenges suffer from social exclusion (Pavri and Luftig, 2000). ILearnRW will be designed with inclusion in mind, both from an access perspective and a social inclusion perspective. From an access perspective, we will achieve this by personalising texts that will enable children to participate more meaningfully in activities they might be typically excluded from due to their learning difficulties. From a social inclusion point of view, the ILearnRW application will be designed for all learners, including those without learning difficulties. Involving children, who have no learning difficulties as informants and design partners, will ensure that younger learning activities pitched to dyslexic children are shared, understood and accepted by their classmates. It will also encourage the use of our application by all students, albeit in a lean format (e.g. a basic e-reading view), aimed at removing the unwanted attention that the tablet would otherwise cast on the dyslexic learner.

8.5. Fitting Learning with Practice

Technologies are more likely to be adopted if they fit with existing practice. This has been shown to be particularly true for contexts such as the home and school where rigid practices and routines operate (Bonner, 2008; Egenfeldt-Nielsen, 2007). Understanding how dyslexic children do their school work within these contexts in collaboration with adults or peers can reveal valuable design opportunities. Responsiveness to contextual nuances is important for a second reason. Dyslexic children will often have networks of support, such as parents who are vested in their children's education and progress. It is important not to undermine the affective and social function of these interactions, but instead to find ways to scaffold this activity. For instance, for parents who care about their children's education but do not have the expertise, our application may propose and set up a personalized learning programme to undertake with their child. Equally, it can externalise the learner model so that parents can assess how the application, or their involvement through it, impacts on their child's progress. At a strategic level, in our view, this design principle can also distinguish our system from others: we teach on top of real text the learner uses for a real purpose (cf. literacy across curriculum) and capitalise on drawing out the links between activities in different contexts.

9. Stakeholders

9.1. User group

We first describe some of the broad characteristics of our target user group (i.e. dyslexic children) before presenting three distinct personas, which help inform our consideration of potential users. In general, older dyslexic children have bigger challenges to overcome because divergence in skill level becomes more pronounced. We are primarily focussing on children aged 9-11 as this is the age at which dyslexia begins to have a significant impact upon a child's ability to learn in the classroom, particularly as reading and writing skills become more important.

There are two different user groups that we are aiming to support:

- People who have been identified but haven't been able to be helped - this group typically suffers from severe difficulties
- People who have not been identified - this group have generally learnt some basic steps to managing their dyslexia but have not learnt the more advanced steps

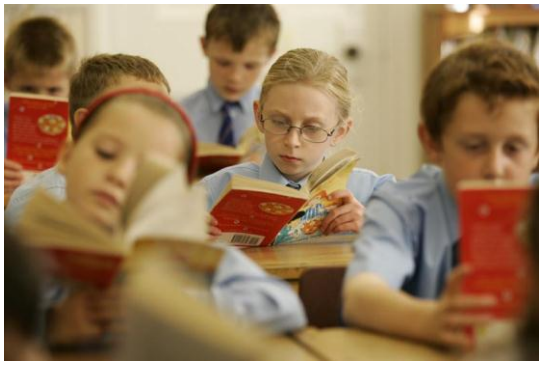
In aiming to support older children, however, we are also facing a higher degree of difficulty, as we effectively need to target the system as spanning the entire spectrum of dyslexia difficulties. If we support learning the advanced steps, then we are supporting the lower steps too by necessity.

9.2. Personas

Personas are a way of communicating key characteristics of user archetypes. It's a good way for personifying our end users for people who will not meet them. By defining certain stereotypical characteristics of users, design decisions begin to be explored. "A persona is usually generated to help designers understand, describe, focus and clarify user's goals and behaviour patterns" (Chang 2008).

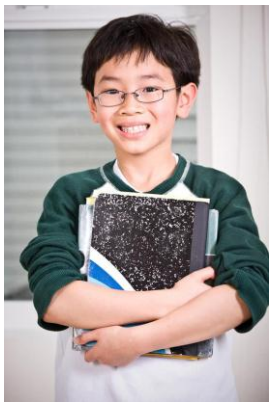
Although personas are typically based on user research, the expert-driven approach of the early stage of this project has resulted in the generation of a set of proto-personas. These differ from standard personas in that they "originate from brainstorming workshops where [experts] try to encapsulate the organization's beliefs (based on their domain expertise and gut feeling) about who is using their product or service and what is motivating them to do so" (Gothelf, 2012). These proto-personas are useful as a starting point to explore possible design hypotheses. Having served their purpose by generating design ideas, proto-personas are subsequently refined by user research, generally resulting in a series of more traditional personas. We now move on to discuss three specific personas, embodying the range of difficulties our users may face.

9.2.1. Persona 1: Emily



Emily is 10 years old and has severe learning difficulties connected to her reading and writing abilities. Given these difficulties, she would have made more educational progress had she been supported earlier. Emily uses a learning program suggested by her school's SEN teacher, Nicky. At 51, Nicky has a lot of experience in working individually with children who have learning difficulties and personally selected a learning program for Emily to follow at both school and home. Steven, 38, is Emily's dad. He supports his dyslexic daughter by encouraging her to follow the instructional software recommended and used by the school.

9.2.2. Persona 2: Victor



Victor is 9 years old who generally performs okay at school but is somewhat slower than his peers; brilliant at some tasks, Victor lags behind other children when undertaking certain activities. Maria, 45, is Victor's mum and has been trying to encourage Victor's school to recognise his difficulties and provide additional appropriate support. However, because Victor performs well in most activities, Sally, Victor's mainstream teacher, does not recognise that the problem is serious enough to merit any additional support despite repeated calls for help from Victor's mum. Therefore, Maria has resorted to devising her own support strategy based on online resources and commercially available software. However, as the school does not recognise Victor's problem, this strategy is limited to home use only.

9.2.3. Persona 3: Stavros

Stavros, aged 11, is looking forward to transferring from primary to secondary school but is worried that he will struggle to keep up in classes that involve a lot of reading and writing. Thus far he has demonstrated an average performance at school. Being very bright, he has discovered his own ways of dealing with the amount of reading and writing he has faced so far, meaning that his teachers did not suspect a diagnosis of dyslexia. Cynthia, Stavros' mother, trained as a teacher before giving up her career to focus on her desire to become a children's author. Thus when she became concerned about his poor organisational skills, persistent forgetfulness and Stavros' ease in communicating verbally compared to on paper, she became concerned that he might be dyslexic. After being assessed independently from his primary school, Stavros was confirmed as being dyslexic. Both his parents and secondary school have taken the diagnosis seriously, believing that Stavros' results to date do not reflect what he is capable of, given appropriate support. As such the school have provided additional support for Stavros through the provision of colour overlays, electronic spell dictionaries and teaching him specific strategies for checking his written work as well as providing educational technology intended to help further develop Stavros' reading skills. He plans to use this extensively at home as he has previously avoided reading for pleasure but is keen to read some of the books his friends talk about in class.

10. The ILearnRW Application

10.1. School Facilities

There are many assistive hardware technologies and general-purpose hardware technologies in use in education. By considering the range of features and facilities that these different technologies provide we can select a hardware platform for the ILearnRW application, which both fits within existing practices within schools and will provide an appropriate platform for using the software features we intend to develop.

10.2. Reading Hardware

Dedicated e-Readers vs. Tablets

Dedicated hardware reading devices (Kindle, Kobo, etc.) or "reading-friendly" multipurpose devices (tablets or phones) are becoming increasingly popular in the general population as well as in schools. Although e-readers have a number of advantages for reading within schools (including low cost, a short charging time coupled with an extremely long battery life and a screen that does not emit a glare), the devices are hardware limited. Predominantly using e-ink screens e-readers are also associated with low processing speed and a small amount of RAM. This makes them unsuitable for the dynamic aspects of the ILearnRW project, especially the gaming facility.

- Tablets offer interaction by touch which is a much more immediate interface for interacting with text than the mouse. Touch allows easier highlighting, zoom and page turning. This also allows an application to track the user's interaction with text.
- Tablets can be held in the hand very much like a book and are much more portable than computers (and almost as portable as e-Ink e-readers)
- Tablets have much simpler task-focused interface compared to the generalized interface of computers and limited interface of e-Ink e-readers. Students generally require little to no instruction in the use of tablets or specific apps.
- The battery on most tablets will last a whole working day and students do not need to carry chargers.
- Unlike a computer, a tablet will turn on instantly making it much more suitable for work in the classroom and consulting reference resources.

However, there are some limitations of tablets that need to be taken into account:

- Tablets (with some exceptions) make it impossible to have two applications open side by side on the screen at once.
- Barring the use of an external keyboard, tablets make for a relatively limited keyboarding experience.

Many schools are buying tablets for students giving a variety of reasons including:

- Saving money on distributing printed materials.
- Having a more flexible equivalent to a computer for classroom access in research.
- Making learning more interactive through various teaching apps.
- Having a single platform for learning across lessons and outside of the school.

These reasons highlight some of the weaknesses of paper-based materials (namely cost and lack of interactivity) as well as the limitations of using a PC-based approach (namely flexibility and portability). Tablets have a number of advantages over reading on other platforms. The digital nature of the reading technology means that custom features (such as text highlighting) can be included to assist in an individual's comprehension of a particular book, without the investment of large amount of effort necessary to customise a paper-based book. A tablet can also commonly be used to play games on, something that integrates well with the engagement and gaming elements of the ILearnRW project.

Tablet platforms

While the iPad has become synonymous with tablets as a founding device in the modern incarnation of the category, android-based devices are making inroads into the tablet market, especially within schools. This is due to several factors including the lower price of android tablets, a greater variety of form factors (including devices with pen input or 7 inch screen size) and flexibility in the deployment of applications (including the initial investment necessary for development). Given the advantages we have discussed here, we have decided to use an android-based tablet as the primary hardware platform for the ILearnRW project.

It is necessary to note that although there are a number of advantages to using the android platform, manufacturers are free to innovate and produce their own features whilst remaining under the term of "android tablet". As a simple example, android screen sizes vary, typically between 10 inches (Google Nexus 10 for example) and 7 inches (Amazon's Kindle Fire for example). Our application will need to take into account that different android tablets will have different form-factors and differing software features.

Given that many people (9% according to a recent study by Book Industry Study Group, 2012) also report using phones as their primary reading device, there is not necessarily a technological barrier to the ILearnRW software being available on phones. This is significant given our stated aim of integrating our intervention in existing practices. As the trend of increasing the default screen sizes of smart phones continues, such compatibility could have a longer-term advantage. However, we do not intend to demonstrate that our software does work on android phones; we merely highlight it as a possible benefit to our selection of hardware platform.

It is of note that much of the current interest in tablets and e-readers is aimed at using this technology within mainstream schools. The same benefits apply for SEN alongside other additional benefits. The fact that the introduction of tablets into education would benefit both SEN and mainstream children means that tablets could serve as a significant driver of inclusion rather than isolation.

Input hardware

Hardware to increase the accessibility of input has been available in the SEN for a long time. Scanners, dedicated input alternatives, digitisers, etc. have been marketed to schools for a long time. These go beyond the pen-input of current android tablets such as the Samsung Galaxy Note 8. There have been some recent developments that are worth highlighting in the context of the current project.

- **C-Pen:** Is a highly effective scanner that scans printed text into a computer while providing audible feedback. Because the product relies on the computer to do most of the processing, it can achieve remarkable accuracy and almost instantaneous speed.
- **LiveScribe Pen:** Despite sharing part of its name with the C-Pen, this device operates on a different principle. It is an actual pen that also records sound when writing on special paper. However, the note taker can review what was being said when a particular note was being made simply by tapping a particular note.

These technologies are worth noting as they highlight that our project does not sit in isolation but as part of an ecology of interventions. Although beyond the scope of the project, we can see that additional technologies could integrate with ILearnRW. For example, it is not inconceivable that a dyslexic student could sit down with a printed book and highlight passages that would then be read into the reading tool being developed by ILearnRW. As such, wherever possible the ILearnRW software will be developed in a modularised fashion, allowing for the integration of such additional tools at some later date.

Having described the hardware the ILearnRW software will be based upon, we move on to consider how the application will be used.

10.3. User Experience Scenario

ILearnRW will promote learning and the development of literacy skills. Given the extensive nature of existing teaching interventions, it is unlikely we will be able to provide a complete structured intervention. The novelty of our application will be in the combination of instructional with assistive, and its heavy use of real texts for real reading. Thus, ILearnRW will be used both at school, at home and in the context of any reading task, i.e., it will be designed to be responsive to any situation. The application will be accessed through a portable tablet computer. Depending on the context of use, the user (children, parents or teachers), will have the option to choose between three modes. The reading mode will adapt the text presentation according to a child's difficulties while text to speech will be an additional option if reading is cumbersome. When in class, the text used for the day's lesson will be presented, giving the child the opportunity to follow the lesson. If the child wants to read a book for leisure, books will be suggested that are aligned to their interests and at the same time are not too difficult. When time permits, e.g. either at home, or during SEN sessions, users will be able to instantiate the learning mode. The text will be presented in a way that practices important decoding skills according to the child's needs, through targeted learning activities. If the user wants to learn through play, the playing mode will be used to instantiate the game. During game play, text and learning activities encountered in other modes will appear, with learning aims integrated in game objectives.

10.4. Design Features

As with any software project, there is literally no limit to the features, which could be developed. Within this section we distinguish between two sets of features. The first set consists of those features, which are discussed within the project proposal and as such will be developed as part of the ILearnRW software. The second set, based on a combination of expert opinion and a review of the existing literature, lists features which need to be considered when formalising the final set of user requirements. These are not an essential part of the project as a whole. Not all of the possibilities outlined here can be implemented as part of this project. To assist the reader in understanding the rationale of each feature, we link it back to the design principles described in Section 8.

10.4.1. Essential

The following list of features is outlined within the project proposal. These must be included within the ILearnRW software.

Learner Model

The software will contain a user model of the specific child. Since we are modelling learner progress, in moving forward, we will use the term learner model. The learner model needs to be discussed first as it interacts with a number of other elements of the software. The model will hold details of the specific reading and writing difficulties a child may experience including, but not limited to,

difficulties in recognising or elaborating on specific letters, difficulties in reading words in sequence and difficulties in writing letters. Additionally, the model will hold other, non-dyslexia focussed information such as age, IQ, reading age and interests. The model is likely to be seeded from a series of introductory activities, which may also include input from parents, class teachers and SEN teachers. The model will be updated either by automated evaluation (recording a user's activities with the text or game and feeding the data back to the profile) or based on specific tests.

Design principle: personalising a child's intervention is a theory-informed and user-centred principle, which will inform and adapt all three modes of our application (8.1).

Serious Games

The ILearnRW software suite will contain a game. The reason for including a game is that, if designed appropriately, it can be motivating, flexible and fun - thus encouraging students to engage in learning activities they might not otherwise undertake. In addition to the main game, it is likely that there will be a series of mini-games/activities, possibly integrated into both the game and/or the reader, which are intended to assist a child in learning strategies to overcome their specific difficulties. Introducing game like elements across the ILearnRW application can ensure that engagement is embedded within the entire thread of activities presented.

Design principle: designing for engagement forms part of the theory-informed and user-centred design principle (8.1): while domain experts have the know-how to create activities that appeal to dyslexic children, the children themselves are also able to provide information about what makes an activity engaging for them. Engagement has also been highlighted as a priority in the context of learning technologies more generally (8.3).

Reader Facility

In addition to the game, the other main feature of the ILearnRW software suite is the "reader". This is an e-reading technology designed specifically to assist dyslexic children with reading particular texts as well as improving their reading skills more generally. The means through which this assistance is provided is the personalised presentation and/or adaptation of text based on the user profile. This will include: (1) introducing support at the paragraph, sentence, word, syllable and single letter levels based on the learner model (2) highlighting text at reading speed (3) including APIs such that the reader (and possibly the learner model) can be used within a number of different applications and (4) including a text to speech facility which speaks at same speed as the text highlighter.

Design principle: the reader simultaneously fulfils a number of our principles. It provides a purpose to the activity and therefore fits with current practice (8.5). It enables access and in doing so, it supports inclusion (8.4). In giving children control to customise some of its features, it allows for agency and reflection (8.2), which both develop meta-cognitive skills. Personalised text adaptation will follow a theory-informed design ensuring it does not challenge children's other difficulties, e.g. short-term memory (8.1).

Content Classification

The ILearnRW suite will also contain a content classification system. This system will assess the level of difficulty associated with a given text based on a child's specific difficulties (including their size of vocabulary, age, syntactic complexity of the text etc.). This difficulty level supports the selection of appropriate texts for an individual child. The content classification may also take into account children's preferences for certain book genres.

Design principle: in predicting text appropriateness, content classification is a theory-informed design principle that will be guided by experts' opinion (8.1). Matching a text to a child's interests draws on the principle of engagement (8.3).

10.4.2. Additional

In addition to our set of essential features, there are a number of other possibilities that the ILearnRW system could include. As with Section 10.3.1, we link them back to the design principles in order to justify their importance.

Collaborative play

To create a more engaging experience, the user may be able to play the game locally, or as part of a group effort. For instance, drawing on current player literacy, player statistics could encourage them by comparing their efforts to those of other users, gaining achievements over time, collaborating with others on tasks, proposing or receiving challenges from others.

Design principle: Will support engagement (8.3).

Externalising the Learner Model to the Learner

Our system will collect data about the child's progress and the strategies used. This information is meant to inform the system adaptation. However, some of this data could be presented to the learner toward supporting meta-cognition. Externalising the learner model has been argued to elicit learner reflections (Bull and Kay, 2006).

Design principle: Will support reflection and agency (8.2).

Customisation and flexibility

Our application could provide more flexibility in terms of situating children's learning within purposeful activities. As part of this, it could allow users to upload their own text into a personal library. For example, this could be homework, or a website they have visited.

Design principle: Will support fitting learning with practice (8.5).

Externalising the Learner Model to the Tutor

ILearnRW could also provide additional ways to empower and involve the support network. Using information stored in the learner model, we could summarise how much reading the child has done, in what way, and demonstrate the particular weaknesses and strengths identified. These indicators could be accessed through a website by the tutor in wanting to establish the child's progress and get insight on how to best help them.

Design principle: Will support fitting learning with practice (8.5).

Collaboration and peer support

A powerful way for children to learn without feeling judged is through peer learning (EEF, 2013). Our application could promote social reading between peers through challenges proposed within the game, joint reading tasks set up through the reader, or even by setting up a reading task with a younger non-player game character.

Design principle: Will support engagement and theory-led design (8.1).

Assessing relevance

Turning our attention to the content classification, sophisticated metrics could be used. Readability algorithms could classify texts by grade level. Matching such algorithms with similarity of words between documents previously encountered we could identify whether a child has encountered a similar text before. Moreover, words that are difficult for children might be identified based on which relevant learning activities could be constructed.

Design principle: Will support theory-led design (8.1).

10.5. General Requirements

As described in Section 7, our system must be responsive to difficulties that are typical of dyslexia and co-occur with dyslexia, which if not considered could become barriers to the child's use of the system. The following requirements are proposed to this end:

- Should be suitable for sustained reading and approach text in small chunks. The reader should present document structure if present, and allow the learner to create their own
- Should offer both immediate, medium and long-term rewards
- Should support individual preferences about times for working (10 minutes every day or 2 hours at the weekend for example)
- Navigation and design must be sensitive to memory load. For example, instructions should be chunked and difficult steps not presented in a rapid sequence or on a single page
- Should accommodates memory difficulties generally (see structure navigation above)
- Should accommodate speed of processing difficulties (see instructions above)
- Should accommodate frequent difficulties dyslexic readers have with organization and coordination. For instance, make it easy to plan reading, provide reminders of achievements and next steps. Make it easy to move data from one device to another (in case of a loss of device)

Our application must also support the development of meta-cognitive skills, including:

- Learning to modify text to suit a learner's preferences
- Developing skills to find modes of reading suitable to a learner's preferences.
- Developing skills to identify elements of text that are causing decoding difficulties
- Developing skills for transferring rules for decoding into spelling
- Developing skills to discover underlying rules to help with decoding
- Developing skills of self-observation

Table 10.1 presents examples of interactions that support meta-cognitive skills, although which ones to pursue will be determined both by their fit with the use cases and technical constraints.

Interactions supporting cognitive and linguistic development	**Interactions supporting meta-cognitive and meta-linguistic development**
• Choose support mode level (e.g. how many difficult words should be highlighted) • Choose how much text to have displayed at once (page, paragraph, sentence, word,	• Tap a word and drag it to the side of the text to categorize it as difficult or easy or as belonging to a certain category • Switch text to display with difficult words

syllable) • Have text auto scroll (automatically present text in different chunks) at different speeds. Control the speed of text change by tapping • Choose to have text read out by text to speech at different speeds • Tap a word and have it split up into component parts (letters, syllables, etc.) • Tap screen several times and only display words of that number of syllables.	highlighted and easy words displayed in softer colour • Look up statistics about the text: number of words, length, estimated reading time based on time to read previous texts, etc. • Look up statistics about the reader's use of the text: how long they've been using it, how much they've read, what fonts they were using and what was the speed of reading • Tap a word to find other words in the text that follow the same pattern of letters or the same spelling rule • Look up a rule and identify words that follow the rule in the text • Choose text properties: font type, colour/background, line spacing, letter kerning • See all words in text arranged by frequency in word cloud or KWIC (keyword in context) format.

Table 10.1: Examples of interactive features for meta-cognition.

10.6. Use Cases

Use cases are a useful technique for gathering requirements; by creating scenarios of use, requirements engineers have to consider the possible interactions and facilities that their software will provide (Shneiderman and Plaisant, 2010; Anton et al., 2001).

Within this deliverable we are providing two use cases: one use case which uses the reader in the classroom and for homework and one use case which uses the reader at home for reading for pleasure. By providing these use cases we highlight how the design features we have previously discussed may operate in practice. Additionally, the use cases provide a specification of features, which is useful for the development aspects of the project.

10.6.1. Use Case 1: Schoolwork/Homework

Year 6 have been reading a book within class, using the ILearnRW reader. At the end of the lesson, the class is set the homework of reading a chapter of the class text in preparation for their next literacy lesson the next week. For the children within the class who have reading difficulties this homework is set using the ILearn tool.

1 Teacher (or child) uploads the chapter to be read for homework to the ILearn tool and inputs a description of the homework task and the due date.
2 At home the child begins their homework by opening the text within the tool
3 The system tailors the presentation of the text based on the child's learner model
4 The child begins reading the text and gets stuck on a particular word/phrase
5 The child selects the word/phrase they are having difficulties with
6 The system provides additional help for that word/phrase
7 The system records the word/phrases the child had difficulty with in the learner model
8 The child stops reading the text

9 The child (or their parent?) indicates if they have completed reading the entire text or will come back to it later
10 If the child has only part completed the text:
    a The system saves the position in the text the child has reached
    b The child reopens the text at a later time
    c The system displays the text from the saved position
    d Go to step 3
11 If the child has completed reading the entire text:
    a The system provides positive feedback to the child
    b Go to step 12
12 The parent/teacher views a report of the child's progress with the text
13 The system generates the report based on the difficulties the child indicated they had with specific words/phrases during their reading of the text and the time spent reading in combination with the difficulties additionally identified by the system itself.

10.6.2. Use Case 2: Reading for Pleasure

A child is at home and wants to read a text that is fun and different to the texts he/she has been studying in school.

- The child opens the iLearn tool and navigates to the home screen screen
- The system displays two options 'continue reading previous text or 'choose new text.
- If the child chooses chooses 'continue reading previous text:
    - The system displays a list of images representing texts the child has previously begun reading
    - The child scrolls through the text images until they see the text they wish to continue reading and clicks on the chosen text image
    - Go to step 6
- The system displays the images representing texts targeted at the child's age group, reading level and interests based on information from the learner model
- The child scrolls through the text images until they see one that looks interesting and the clicks on the chosen text image
- The system tailors the presentation of the chosen text based on the child's learner model
- The child begins reading the text and gets stuck on a particular word/phrase
- The child selects the word/phrase they are having difficulties with
- The system provides additional help for that word/phrase
- The system records the word/phrases the child had difficulty with in the learner model
- The child stops reading the text and closes it
- If the child has both looked at every page of the text and is currently on the last page of the text:
    - The system asks the child if they have completed reading the text
    - If the child indicates that they have finished:
        - The system records the text as completed
        - The system provides positive feedback to the child
        - Go to Step 14
    - If the child indicates that they have not finished:

- The system saves the position in the text that the child has reached (i.e. the last page)
- Go to Step 14

- The system saves the position in the text that the child has reached
- The system presents the child with a choice of activities/mini-games tailored to the child's preferences within the learner model and incorporating text from the pages the child has just been reading.
- The child selects the activity/mini-game they wish to play
- The child plays the activity/mini-game
- The system records the errors/successes of the child within the learner model
- The child finishes playing the activity/mini-game
- The system provides positive feedback to the child
- The parent/teacher views a report of the child's progress with their reading
- The system generates the report based on the difficulties the child indicated they had with specific words/phrases during their reading of the text, the time spent reading and the difficulties/successes the child experienced during the activities/mini-games.

We note that both use cases are equally applicable to speakers of Greek and English. Both use cases are inclusive to the three personas we presented earlier.

11. Summary and Next Steps

This deliverable has presented an evidence-based account of dyslexia. We have explained how different orthographic systems may introduce difficulties and have explored how dyslexia is managed in the school system, using the UK as a case study. In shifting our attention to what technology can offer, we have undertaken an analysis of existing systems followed by the development of a set of learning aims which our application wants to support. We have drawn from expert knowledge, technology studies and TEL expertise to identify a number of design principles that will guide our work. To motivate our efforts, these principles have been mapped onto core features of our system, as documented in the DoW. In addition to this, we have identified additional features, which if our time and resources permit we would like to address. Finally, after defining our user group, we have gone on to develop two use cases that will guide our initial technical efforts over the next few months.

Despite the wealth of information around appropriate interventions in our consortium, in laying this first foundation for our system, we must recognize that a number of open questions remain. These questions are seen as research and development challenges, which we will address through design-oriented research with stakeholders over the coming months. These findings will be reported in subsequent deliverables (i.e. user modelling, revised user requirements, game design). We detail each question in turn and explain our approach to addressing it.

The interactions within our system must be clearly defined and structured. How do we provide a developmental structure for a reader?
Low fidelity prototypes will be designed and shared with SEN teachers and dyslexic children. They will be revised based on their feedback.

We envision three modes of operation (reading, learning and playing). How should the breakdown of the three modes be presented and does it support genuine use cases?
A combination of participatory design sessions and more focused workshops with low fidelity prototypes will be conducted with SEN teachers, mainstream teachers, parents and dyslexic children. Use cases will be proposed and revised based on their feedback.

Our learner model is envisioned to assess a child's difficulties and respond accordingly. Which signals can and should our learner model collect and how?
Although our experts will provide an initial list of dyslexia indicators, it is unlikely that we will be able to computationally measure all of them (e.g. fluency). Alongside the need to design to fit learning with practice, this technical constraint will need to be met pragmatically by defining a role for the tutor in an assessment activity. We will also need to explore whether behavioural (or interactional) proxies can be interpreted as signals of reading ease or difficulty. We further need to distinguish the features of the reading experience that are available to the reader's introspection, those that can be gleaned by a qualified teacher or lay support person (e.g. a parent) and those that can only be measured based on data collected by a tool. To determine how we can involve tutors in the construction of the learner model in a way that is meaningful, we will interview teachers and parents followed up with participatory design sessions. During these sessions, we will also investigate ways through which we can externalise the learner model, while looking at whether this feature may provide tutors with the incentive to provide constant input to the learner model.

Given the wide scope of activities offered in ILearnRW, adaptation will be achieved through the (1) choice of content (2) text presentation (3) learning activities and (4) teaching strategies. How do we design the analogue – which is often made meaningful through social interaction – into the digital where children may be acting alone?

Teachers' perception of the child and their response to his/her needs to be considered concurrently. We will interview and observe teachers to identify how they engage children into reading, when they pick their moments to intervene and how they do this in a way that doesn't lower children's self-esteem. Special attention will be given to how teaching strategies vary between mainstream schools and specialist intervention programs (e.g. Dyslexia Action) and where the key successes/gaps in these strategies might be. This research may point to additional use cases by revealing new needs. It will inform the learner model, for instance by expanding it to include other important characteristics, such as a child's interests. It will also guide the adaptation, e.g. by informing the frequency of system feedback and the etiquette through which the teaching strategies are expressed. Given the project's focus on developing confidence and self-esteem, the expression of teaching strategies will be further explored in participatory design sessions held with dyslexic children where they will design the format and frequency of their progress tracking, feedback and rewards.

How can the technology-based learning experience be made appealing to students in the target age group?
Although our design will be guided by teacher heuristics on how to engage children with this difficult topic, technologies open up the design space to additional forms of engagement. To reveal these opportunities, we will involve children as design partners at various stages of the design process.

How can we balance the use of content provided by the tool, content required by the curriculum and content selected by the user?
ILearnRW in general aims to "support the classification of learning material based on a user profile". To do this, however, it will have to balance content from different sources over which the project may have limited control. Although the teaching component of the tool may provide predefined texts, the reader may have the ability to work with any text obtained in various formats from different sources. These may be provided by the teacher, downloaded from a third party service, or identified by the student independently, for instance when online (either as web pages or free e-books). The use cases we develop based on user input, will in part determine which of these possibilities to further pursue. We note that depending on the direction we take, we may take advantage of recent developments in SEN. In particular, there are four projects of extreme relevance to ILearnRW. These are:

- **Load2Learn:** A repository of secondary and primary textbooks in digital formats used in the UK schools. These books are available in a variety of formats with the default being a structured Word document. Developed by RNIB and Dyslexia Action, the service is now available for free to all schools in the UK
- **Metall:** A project to make discovery of digital content more accessible
- **Azzapt:** An online service that allows online conversion of digital documents between various accessible formats including text to speech
- **NaviText:** A reader aimed at summarizing text. This product was just announced and we have not had opportunity to test it.

Establishing relationships or building in compatibility with the efforts listed above could augment the power of the final product and make it more useful in the school context.

To make the text easier to read, the tool may rely on three sources of information: 1) Information provided automatically by ILearnRW tool (e.g. words other readers found difficult, words this reader previously found difficult, words that are generally known to be difficult), 2) information provided by teacher or other persons providing support (e.g. ways of approaching reading a difficult section, or how to apply relevant rules to help with decoding a particular word) 3) information provided by peers (e.g. underlining useful packages, or useful sharing strategies for decoding difficult words). The

relative balance of utility will be further explored by observation of teacher practices and investigation of ways in which learners discover new strategies for dealing with text.

As a closing remark to this deliverable, we note that reflexivity and responsiveness are guiding research principles in undertaking these activities. At the same time, we remain acutely aware that the components we are now designing need to be evaluated incrementally to determine how they improve a child's learning experience.

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13. Appendices

Appendix 1: Student Case Histories

These brief case histories developed based on the work of Dyslexia Action teachers provide more background and further illustration of the range of difficulties faced by dyslexic readers.

Jenny

Jenny's difficulties became apparent in year two, aged seven. She had difficulty with her phonics and mapping them to letters and had a limited sight vocabulary. Her parents did not read with her at home and did not display any interest in Jenny's education. Jenny would undergo intervention three times a week consisting of practising her phonics, extra reading and educational games. As Jenny progressed through primary school the intervention stayed in place and the deficit of her knowledge became more apparent in comparison to her peers. By year four, aged nine Jenny began to become very disruptive during lessons and moved away from her previous friendship group. Jenny would act out whenever she found frustration with the task given and would frequently leave the classroom to be destructive elsewhere in the school. Her parents were consulted who believed this was solely the problem of the school and that they were unable to help their child.

By year five aged 10 the school has decided due to Jenny's behaviour getting worse to have her assessed by an educational psychologist. She was diagnosed with ADHD and dyslexia. Jenny refused to attend intervention as she believed this made her look stupid and the other children would know that she had difficulties. As the work got harder throughout the year, her behaviour got worse and her acting out resulted in physical violence resulting in her being excluded. This was the beginning of a series of exclusions which led in her being expelled part way through year six.

It was agreed by another school in the area that they would accept Jenny as a pupil and she finished her year at a different primary school. Jenny still experienced difficulties in this new school and although intervention was put in place Jenny refused to attend. When asked, she would become disruptive and sometimes destructive to property.

She was highlighted as a vulnerable child who experiences difficulties of dyslexia and ADHD on entry to secondary school, however she was very disengaged and would skip lessons on a regular basis. Her behaviour continued to be disruptive and she would only attend intervention if she was taken out of another class. If however she was left to take herself to intervention she would truant. It became clear that Jenny was experiencing great anxiety within the secondary school and this was the cause of her destructiveness; therefore after three exclusions it was decided that Jenny would attend school on a reduced timetable. This meant that she would only attend school on three mornings a week and that she would also attend a social intervention group which met outside of school on two afternoons a week. This situation continued until the last term where Jenny got very frustrated with an English teacher for asking her to read out loud to the class and actually attacked the teacher. This resulted in Jenny being expelled from the school.

It was decided after the difficulties that Jenny experienced within the formal educational setting that it was in her best interest to go into alternative provision. Initially Jenny was expected to complete 25 hours at the alternative provision unit which is in line with the statutory duty but in reality she only averaged about 12 hours a week. One of the downfalls of this system is it relies on the people themselves to get to the unit independently and therefore it is very easy for the students to decide whether or not they want to turn up. Jenny will do on average about 2 to 3 hours per day focusing on basic skills of English and maths. She also attends a beauty therapy course at college one day per

week. She is now at risk as she is unable to reach the level one requirement for English to continue this course. Jenny is currently working hard with her reading and writing so that she can continue doing her beauty therapy course. She is frustrated but motivated at going back to basics and learning her phonics and letter combinations again.

Lewis

Lewis went to primary school performing below average level. The level he was working at occasionally dipped to 2 years below his chronological age. When this happened, Lewis would experience intervention. The intervention focused on two things: some of his phonics/letter mapping was missing and work was done on this, as well as focusing on sight words. His performance in reading was inconsistent, despite the fact that his general performance within the classroom was acceptable.

On entering secondary school, the assessment tests showed that Lewis was working at a below average range. Despite this, he did not warrant intervention as his difficulties weren't bad enough to fit within that bracket. During his first year, one of his teachers requested that he be screened for dyslexia. The results of that screening showed that he was borderline and therefore the school chose not to give intervention.

In the second term of that year he undertook a full dyslexia assessment the results of which showed that Lewis was severely dyslexic. He then underwent specialist teaching which helped fill the gaps in his phonics knowledge and also looked at strategies to assist him read and write. These were extremely successful and several of his teachers commented on how he was more able within class. For instance, he actively chose to read for himself and he was working more independently. His classmates also noticed the difference and as a result of that went to request that they too undertook these lessons.

Unfortunately the intervention only lasted two terms and whilst Lewis thrived whilst he was undertaking these lessons, there was a subsequent decline after they finished. No intervention followed this and Lewis was marginalised for the rest of the time he was at secondary school. Lewis is currently in his GCSE year and is not expected to gain qualifications upon leaving school.

Norman

Norman's difficulties were evident by year four, age 9. He had difficulties reading, mapping phonics to letters and also had difficulty writing. Intervention was put in place but only because his mother insisted that the school do something. After a year of intervention Norman appeared not to have progressed in his reading, writing and spelling. His mother decided to get an assessment of his difficulties. The educational psychologist diagnosed dyslexia and dysgraphia. Norman had specific problems with processing speed and working memory. His mother then wanted to get a specialist dyslexia teacher to help Norman so that he wouldn't be left behind with his reading and spelling. Since the nearest dyslexic Association office was over an hour's drive away it was decided that they would try and find a specialist teacher who was more local to them. Norman underwent a year of specialist teaching. However, he found that this was not suitable to his needs and felt he learnt more from his mother teaching him toe by toe than he did from the teacher. His mother then decided to teach him herself using the program toe by toe which progressed his phonics knowledge so that by the end of year 6 aged 11 he was reading just below average. At the same time, he was also getting intervention at primary school which consisted of sight words, Word shark, maths intervention and extra reading.

On entry to secondary school his mother arranged for a dyslexic specialist to teach him once a week during school hours. Progress was made by utilising audiobooks to assist with his reading. This then progressed to Norman reading a page and the teacher or his mother reading a page. After two terms

Norman decided that he was now able to read successfully on his own and chose to read as well as still utilising audiobooks. The librarians within his secondary school assisted him to make choices of books that he would like to read. Norman became an avid reader. He would read for at least an hour each day, sometimes more. Norman's comprehension of these books would be tested by a program utilised in the school called Accelerated reader. Clearly not only did Norman now enjoy reading but he was able to comprehend the text that he was reading. During the course of five terms with his specialist dyslexia teacher, Norman progressed his reading age from 10 years and seven months to 16 years and five months. He became one of the top five readers in the school and was part of the Millionaires club, so named because you have two read more than 1 million words to be in that club. Norman became more and more successful in school until he moved to the top sets in every subject.

Norman was still experiencing difficulty with writing especially when put under time pressure. His writing in this situation would be so erratic even Norman had difficulty reading his own work and many of the teachers were unable to mark the work because they could not understand it. After consultation with the specialist dyslexic teacher it was agreed that Norman would be able to trial Dragon within the school. However, he was unable to get this to work successfully with his MacBook and after trialling it for two terms then decided to type his work out instead. This has now become his preferred way of working and allows him to produce work at a similar standard to his peers.

Rebecca

Rebecca has a Dyslexic mother who monitored all her children and by the age of 7 it was apparent that Rebecca was demonstrating multiple traits of dyslexia. She was assessed and diagnosed with dyslexia at 7. Her specific difficulties were reduced to working memory and processing speed while she was of high intelligence.

At this point she was struggling with reading but was not 2 years below her chronological reading age and therefore the school was not prepared to give her intervention as resources and man power were given to the least able. It was also clear from a meeting with the SENCO of the school that there was little understanding of what this meant to a child's learning abilities, while it became apparent that they did not know how to deal with working memory issues or processing difficulties. Following the diagnosis, the school eventually bought in a working memory game which Rebecca was asked to play in place of her favourite lesson. The program did not have a variety of activities and Rebecca soon became bored. Disaffected by that intervention experience she requested for it to stop.

From that point on the school did not use any interventions. A specialist teacher started to work with her to increase her joy of reading and helped her with anything that she had difficulty with. At the age of 9 Rebecca moved school to a small rural primary school. There, they were able to put time into helping her improve her spelling and phonics once a week for 3 of the 6 terms that she was at the school. She was not allowed to be in the top reading/comprehension group for the first year as although her reading was one of the best in the school, her writing was too slow and this meant that when they wrote the answers to the questions others had to wait for her. Rebecca found this frustrating as she knew that she could read better with greater understanding than some of the students in the top group. She continued to work at home with specialist intervention and as a result of this was one of two children who were asked to take the level 6 SATs paper. Although her diagnosis said that she would benefit from extra time, this was not applied for exam arrangements for her SATs, which meant that Rebecca did not have enough time to work to her potential and as a result her SATs marks did not reflect her true ability.

On entering high school, Rebecca, new to the SENCO, did not inform the teachers about her dyslexia. Rebecca sat on all the assessments including CATs test without being granted any extra time to compensate for her slow processing speed. The results of these assessments placed her in second sets

for many of her subjects. This was a blow to her confidence while at the same time she was getting frustrated given that the lessons were too easy and disengaging. After consultation with the school about the problem they said they would re-evaluate in a new round of CATs tests. These matched the highest results that the school had ever seen and as a result Rebecca was moved into the top sets.

In the next term she had difficulty with an electronic maths assessment as she did not have enough time to complete it and she dropped to the second group. Once again, she found this group to be too easy and was starting to become disengaged with the lessons. On consultation with the Head of Maths he promised to ensure she received extra time during assessments. Instead, he spent the term asking her if she found the work easy and if she did why had she not completed more of the work. This really undermined Rebecca during class resulting in anger that he should question her all the time. During the next set of Maths assessments she was given extra time and proved that she belonged in the top set for maths.

Rebecca's parents know that it will be a continuous battle to keep making sure that Rebecca gets the extra time that she needs to demonstrate her potential especially in light of the fact that Rebecca has been recognised as gifted and talented for English, Maths, Science, Humanities, ICT and Art. This means that she is given extra homework which eats into her free time away from school. The school are now hoping that they can gain ongoing evidence that Rebecca needs extra time so that in year 9 she can have an exam arrangement award officially granting her with extra time. To do this they need to keep an on-going record of her failing for the next 3 years. The difficulty with this is that every time she fails to do her best, this results in a knock to her confidence about her ability and she is then dropped from the top sets to an easier set where she becomes disengaged.

Her parents are now funding an access arrangements test for her in year 7 so that the school has evidence over and above her diagnosis which says "she is likely to benefit from extra time". As this only says "likely", they feel this does not warrant them giving her extra time. The parents will have to fund this themselves and are willing to do so as they want to keep their child's confidence in her ability high.

Tom

During primary school Tom, though clever, had always difficulty with his phonics and mapping sounds to letters. Although this was noticed during reception and year one as the other children moved through the developmental stages it was clear that Tom found this area of learning difficult. Tom was highlighted as having difficulties and had extra lessons with a small group of other children concentrating on phonics and mapping letters to sounds.

As the other children progressed and moved out of this group, Tom was still experiencing great difficulty. By year 2 aged 7 Tom was also falling behind in Maths. He was able to count up to 10 but could not match any numbers to digits and could not order the digits up to 10. At this point, he was unable to count up to 20 which his peers were having no difficulty doing. Also, understanding Maths concepts such as addition and number bonds to 10 was unobtainable.

Throughout primary school he continued with these difficulties. By year 4 aged 9 the school had been monitoring him for two years and requested that he had a diagnosis from an educational psychologist. The educational psychologist diagnosed ADHD and severe dyslexia. ADHD explained his inability to sit still and listen over a period of time. He became easily distracted from the task, and the diagnosis of dyslexia explained his difficulties with mapping sounds to letters, his inability to recognise many sight words and his difficulty understanding mathematics concepts, orders and strategies. By this time, he was aware that he was not progressing through the reading levels. During a classroom setting he would have a TA to help him complete tasks including reading and writing. Tom was able to

contribute in lessons during primary school verbally and had little difficulty doing this. As he moved through primary school, the difficulties that he experienced created a greater divide between him and his peers in terms of academic ability. As he progressed through to year 6 aged 11 the levels of intervention and assistance within a classroom environment increased. Tom became increasingly disaffected as he was unable to express his learning or demonstrate his abilities through reading and writing. This lead to bad behaviour within the classroom environment. He was frequently reprimanded for his challenging behaviour within the classroom but this did not curtail it.

On transition to secondary school, Tom was given extra transition days so that he would feel comfortable within his new environment. This also allowed Tom to establish a bond with a member of staff in his new school. Tom saw this move as a new start and was highly motivated to try and perform well and get on with stuff. In his mind he believed secondary school would be easier academically than primary. The novelty of secondary school wore out quickly and he has since experienced greater challenges and requirements in terms of reading and writing. In order to save face and not look unintelligent, he defaulted to disruptive behaviour whenever he was asked to perform a task that involved reading or writing.

By the end of the first year of secondary school, Tom had completely withdrawn and was truanting many of his lessons. The lessons that he did attend he would refuse to participate in unless he could do that verbally and that he had help from a TA. Tom due to his difficulties was put in a class of other children with similar difficulties many of whom had also demonstrated challenging behaviour within the classroom. Because of this environment, it then became a regular issue that most of the classes Tom attended would be disrupted by one of the children as well as himself because of their inability to access the work the teachers were setting. These children often experienced work that was designed for a lower age group who would be less able and therefore they became disaffected with the subject matter knowing that it was designed for primary school children. Tom became so disaffected that the school decided to use their resources in terms of intervention to help other students who were better behaved. Tom was left in the position where he was unable to access the lessons and did not receive any intervention help other than a TA within a classroom situation that was shared during most lessons between five or six students.

Because of Tom's inability to access the curriculum, he began to miss more lessons. His behaviour became inappropriate both inside and outside the classroom. This led to a managed move to a different secondary school. Managed moves are designed to allow students a new start in a different environment. The hope is that this new start will allow the student to behave appropriately and to engage with education. This was not the case for Tom. To reduce his anxiety and the disruption he created, he was placed on a reduced timetable. During his time at school he received lessons from a dyslexia specialist who helped to put some strategies in place so that he would be able to function better when being asked to read or demonstrate his knowledge. During years nine aged 14 his timetable had changed so that he would attend English, maths, science and ICT and would also spend two days at a local college completing a bricklaying course.

At this point, Tom's specialist dyslexic lessons have been stopped. He has not been offered any other intervention and frequently missed his lessons at school. When he attended the lessons he would misbehave or just refuse completely to participate. Tom never missed any of his college days; his reports from college were always good and he was finding that now he could be successful in an educational environment doing a vocational course. His motivation for this was very high and he applied himself well. He went on to fail all of his GCSE. However, he did pass his college course.

Appendix 2: Software survey

These additional notes on common software were developed to give a more feature-rich overview of some typical software.

Clicker 6

Company name:

Crick software

Web page:

http://www.cricksoft.com/uk/home.aspx

Description

Clicker is a proven and essential classroom tool to support pupils with special needs. In addition to the extensive support for learners with reading and writing difficulties, Clicker offers unique benefits for pupils with a wide range of special needs. It is the leading product for supporting primary-age pupils with dyslexia, winner of many awards and used in tens of thousands of classrooms.

Writing support

Clicker's writing support works by providing a child-friendly talking word processor supported by the unique Clicker Grids, enabling pupils to produce a piece of writing to be proud of.

Reading support

The extensive range of Clicker talking books provides unique materials that pupils with dyslexia can use independently. Every title includes carefully designed, varied reading and writing activities that teach and reinforce new literacy skills.

Features

- Clicker 6 helps to promote independent reading and writing.
- Provides **automatic speech feedback** whilst pupils write; the words are clearly highlighted to reinforce word recognition.
- One male and one female **clear voice** available that sounds almost human rather than robotic.
- Intelligent **word prediction** encourages children to create flowing pieces of text, accurate spelling and grammatically correct sentences.
- **Point-and-click grids**; words and/or sentences with speech facilities in the cells to help pupils create a significant piece of writing.
- **Writing frames** to help children structure their writing.
- **Matching activities** to develop basic problem-solving and language acquisition skills.
- **Picture Library** so children can illustrate their own books and documents, and teachers can use the graphical support for learners who need additional help.
- Child-friendly **Sassoon font** helps children recognise words and letter patterns.
- Fully **customisable toolbar** with standard icons for pupils to become familiar with.
- **Quick Grid Wizards** and **Quick Page Wizards** for teachers to create personalised activities quickly and easily.
- **Quick Start** launches the word processor to allow children to start working immediately.
- **Primary word predictor** suggests words to fit the context of the pupils' writing to help with spelling, grammar and to provide a more adventurous vocabulary.
- **Click and Edit** activities allow pupils to independently create their own talking books and presentations.

- **Clicker Paint** is fully integrated with Clicker 6 giving pupils the opportunity to be more creative.
- **Webcam** support for taking photographs which will instantly appear in any Clicker document.
- Children can save Clicker activities to their '**favourites**' for future easy access.
- **Enhanced** library contains 2500 curriculum pictures for use in documents as well as in Clicker Sets, the predictor and spellchecker.
- **Mouse Dwell** improves access for those using joysticks, trackballs or eye-control devices.
- A **new way** of creating Clicker activities now available. Wizards can be used for sentence building, word banks, writing books, matching and speaking and listening activities.
- **New Editing tools** have made editing activities simple. Click on a cell and the toolbar instantly changes to display only the tools relevant to the item being edited.
- **Instant access** to Learning Grids within Clicker so no need to log-in to access the free resources.

Read & Write Gold

Company name:
Texthelp Ltd.
Web page:
http://www.dyslexic.com
Description
Read and Write Gold the text to speech software, provides literacy support for dyslexic people. It was **shortlisted** for the prestigious **Education Resource Award 2010** in the category of **Best Special Education Resource.** For those people who struggle with reading and writing due to disabilities such as dyslexia; text to speech software is the perfect solution.

Read and Write Gold is an easy to use toolbar which sits discreetly on top of any open Windows application. Users are given the opportunity to work in an inclusive manner with their peers by offering additional support when reading or composing text by providing text-to-speech facilities throughout the software program; making it an ideal solution for literacy difficulties, people who have dyslexia or for those learning English as a second language.

Benefits for Reading

***Screen Masking*:** Blocks any text that is not being read to provide valuable concentration aid. Other options include: whole screen tinting, underlining the line being typed to help with tracking and others.

*Read & Write****Text-to-Speech*:** Simple and accurate way to read text from word documents, email and from the web. Audio-visual reinforcement provided when the option for words to be highlighted is chosen. High quality natural sounding voices are available.

***PDF Aloud*:** Enables user to read PDF files.

***Scanning*:** OCR (Optical Character Recognition) facilities provided which allow the user to scan a text document such as letter or a page from a book to convert it into a readable format.

***Screenshot Reader*:** Makes inaccessible on-screen text accessible; with option to save to MS Word.

Benefits for Writing

***Translator*:** Easy access to the Spanish, French, German or Italian translations of English words. Works with any digital content, on-screen selections, accessible applications, website content or digital textbooks.

***Spell Checker*:** Corrects even more spelling mistakes than before. Corrections are based on the users own spelling patterns. Dictionary definitions of the suggested corrections can be read aloud.

***Sounds-like/Homophone Checker*:** Highlights homophones in the passage of text being written and offers solutions which can be read aloud. Words such as 'there', 'they're', and 'their' where the sound of the word is correct but the context maybe wrong.

***Predictions*:** TextHelp word prediction is a very useful tool which will learn the user's vocabulary and provide dyslexic people the opportunity to have the correct spelling at their fingertips, as unusual spelling can be added to the dictionary.

***Talking Dictionary*:** is a dictionary with definitions which can be accessed from any application and is an invaluable comprehensive writing aid.

Features

- Text-to-Speech functionality with natural sounding digital voices
- Homophone Checker - Sounds Like
- Word Prediction
- Daisy Reader (makes format for people who are blind or print disabled accessible)
- Screenshot Reader (speech-enables inaccessible text such as some PDF, Flash and text embedded in images)
- Study Skills Toolbar (highlighting and collecting of text)
- Speechmaker (text conversion into audio file)
- Picture Dictionary finds images for any selected word or clipboard text
- Verb Checker shows verb conjugation details
- Vocabulary Tool - build vocabulary lists!
- Phonetic Spell Checker which picks up more complicated errors than standard spell checkers
- Dictionary with definitions
- Web Highlighting
- Word Wizard (acts as thesaurus providing choice of alternative words)
- Scanning function allows for any paper-based document to be scanned into Word, PDF or HTML formats
- Screen Masking (provides ability to block out text, screen tinting and spotlights paragraphs and sentences)
- Calculator
- PDF Aloud (makes PDFs accessible for text-to-speech)
- Research Tools - Fact Finder, Fact Folder & Fact Mapper

Read & Write Standard

Company name:

Texthelp Ltd.

Web page:

http://www.dyslexic.com

Description

Read and Write Standard text to speech software provides extensive tools including speech feedback, phonetic spell checking and homophone checking to help dyslexic people. Providing the ultimate support tool for dyslexic students and adults, *Read and Write* offers users speech feedback and word prediction for practically any Windows program - for example, your word processor, spreadsheet, DTP, encyclopaedia, web page, Help file or an educational program.

Read and Write has been specifically designed for users with dyslexia and provides many tools to help access and compose written material. Features include high-quality speech feedback, phonetic spell checker, word prediction, dictionary and talking calculator.

The style of the toolbar can be customised to be appropriate to the age of the user. Users can chose whether they want basic or advanced word lists and definitions in the dictionary, word prediction list and homophone checker.

Features

- Extensive speech feedback functions using the highest quality voices available. Speech feedback options allow you to hear text as you type letter by letter, word by word or sentence by sentence or have text highlighted as it is read out
- Synchronised speech with text highlighted within an application, in a separate windows or with one word displayed at a time
- Screen-reading options enable speech from icons, menus, help files and menus
- Spell checking as you type or by marked block. The spell checker includes medical and scientific words as well as town and city names
- Homophone support including highlighting confusable words within Word documents
- Phonetic spell checking gives Spelt Alike and Sounds Alike suggestions
- Word suggestion and completion ("word prediction") for slow typists based on sentence context and specialist dictionaries
- Spoken selection lists for spelling, prediction and dictionary
- Simple calculator with in-built speech functions
- Speaking Help file
- Abbreviation expansion
- Automatic word endings
- Extensive, speech-enabled dictionary with a choice of basic or advanced definitions
- Word Wizard word finder that combines dictionary and thesaurus to help when you are lost for words.
- Text-to-Speech functionality with natural sounding digital voices
- Homophone Checker - Sounds Like
- Word Prediction
- Study Skills Toolbar (highlighting and collecting of text)

Penfriend

Company name:

Penfriend Ltd

Web page:

http://www.dyslexic.com

Description

Penfriend XL is a word predictor, screen reader and on-screen keyboard. It is a comprehensive literacy aid which can boost confidence and increase reading and writing skills across a range of abilities and ages. It contains a wealth of features to support learners with reading and writing difficulties, particularly those people with dyslexia or physical/sensory disabilities including visual impairment and motor difficulties.

Penfriend XL works with your word processor and accurately predicts the word you are typing. For example, when you enter the first or second letter, words will appear in the prediction window, one key press will finish the word for you. If you want it will offer you the next word as well.

It XL offers flexible screen reading which reads menus and dialogues on your desktop, web pages (in most browsers), spell checker, thesaurus and dictionaries in Microsoft Word. It will screen read in most European languages for which voices are available.

Penfriend XL is a powerful tool for those learning Foreign Languages (MFL) or English as a second language (ESL). It offers prediction and on-screen keyboards in English, Gaelic, French, German, Spanish, Italian, Portuguese, Dutch and Swedish.

Features

- A Homophone option in the prediction window to support literacy
- Type on hover to help mobility for the on-screen keyboard
- Speak on hover to support typing with the on-screen keyboard
- A transparency option so you can see all your desktop Windows and icons when Penfriend is running and discretely use Penfriend without anyone knowing!
- Display - horizontal and rounded display in Prediction Window. The function or number keys can also be greyed out to increase the contrast with the predicted word.
- Predicted words sorted alphabetically with rounded background and function key signs differentiated from the predicted word making it easier to see.
- Learns words in inverted commas and after tabbing.
- Empty Lexicon for simplifying the production of topic lexicons.
- It accepts unlimited length and number of abbreviations. Up to 12 can be displayed at one time.
- Switch access: Abbreviation expansion with 12 expansions for each abbreviation can be very valuable for those using switches. By typing two letters they can have sets of 12 expansions greatly reducing the effort of writing common phrases.
- Word Predictor in English, and 8 other languages
- Predicts next words
- Completes existing words
- Learns personal vocabulary patterns and new words
- Colours and fonts are fully customisable to suit the user
- Includes more than 30 word lists or lexicons
- Accessible by mouse or keyboard; output on screen and in speech
- Speaks and highlights words in the prediction list
- The prediction window can follow the text caret or be positioned anywhere on the screen and at any size
- Add new topic words from files, web pages, or by typing
- Review new words, delete inappropriate ones
- Ban words that should never be predicted
- It is easy to edit and personalize word lists and preferences
- Speech in Scottish, English and US accents; high quality voices from a British supplier

- Screen reader for dialogue boxes, MS Word documents, PDF, web pages and other content
- Highlights words as they are spoken, in customized colours and at any size
- The clipboard viewer can be positioned in any suitable place and for the visually impaired this allows everything spoken on the screen to be shown in one place and the font size is only constrained by the screen size
- On-screen keyboard for mouse access
- Easy to use and does not require extensive training or support
- Integrates with Clicker grids

Lexion

Company name:
Frölunda Data Försäljning AB
Web page:
http://www.dyslexic.com
Description

Lexion combines extensive, tailored literacy exercises and in-depth assessment suitable for use with a wide range of pupils with specific learning difficulties. This assessment and literacy training package is based on one of the most popular programs in Swedish schools. *Lexion* provides all the tools needed to identify areas of weakness, create tailor-made exercises to suit the individual's needs and track pupils' progress.

Lexion Assessment

Lexion uses standardised testing data for an in-depth assessment covering the cognitive language processes. Simply select an age-appropriate test for the area of difficulty and *Lexion* will analyse the answers given and display the results in easy-to-follow figures and charts.

Available tests cover:

1. Phonological awareness
2. Blending and segmentation
3. Single word decoding
4. Reading comprehension
5. Spelling
6. Short-term memory
7. Sequencing skills

Lexion Assessment provides a written summary of the results and once the assessments have been completed, it will automatically create appropriate exercises to address the area of difficulty.

Features

Lexion's exercises cover all areas of reading and writing and includes:

- Phonological awareness
- Letter-to-sound correspondence
- Syllable and morpheme segmentation
- Blending
- Grammar
- Spatial skills
- Arithmetic
- Understanding the clock

Lucid CoPs

Company name:
Lucid Research Ltd
Web page:
http://www.dyslexic.com
Description

Lucid CoPs is diagnostic screening for children of all abilities, for ages 4 to 8 years. A computerised screening system which can accurately predict dyslexia and other learning difficulties in young children. Lucid CoPS is administered to each child in the form of nine games with attractive graphics and cartoon characters. As the child plays the games the computer records his or her cognitive skills, such as short term memory, phonological awareness, auditory and colour discrimination. Lucid CoPS (Cognitive Profiling System) is for children aged 4 - 8 years.

Areas covered:

- Visual Memory
- Auditory/Verbal memory
- Phonological skills

Kidspiration

Company name:
Inspiration Software Inc
Web page:
http://www.dyslexic.com
Description

Kidspiration helps to develop literacy, numeracy and thinking skills through visual learning making it ideal for pupils with dyslexia. It is used to strengthen word recognition, vocabulary, comprehension and written expression at Key Stage 1 and Key Stage 2. The maths tools will encourage reasoning and problem solving skills. Ideal for dyslexic learners who benefit from visual learning tools to explore and understand words, numbers and concepts. Kidspiration will also support personalised learning, allowing pupils to express their creativity and thinking with pictures, words and numbers.

Projects can be quickly generated using this concept mapping software to allow students to organise their thoughts using the library of over 3000 symbols for use for literacy skills. The math section includes 5 tools to explore number sense, spatial reasoning and conceptual understanding of the four basic operations.

Features

- Kidspiration uses the proven principles of visual learning to help readers and writers learn to develop and organise their ideas
- Picture view provides a graphical way for pupils to represent their ideas using symbols (includes a library of over 3000 symbols)
- Writing View allows pupils to begin the writing process, by expanding their visual thoughts
- One mouse click transition from Writing View to Picture View to Picture View and vice versa
- SuperGrouper tool allows pupils to interactively group and arrange thoughts and symbols
- Audio gives pupils the chance to hear their work read aloud, or record their own voice
- All buttons, menus and other text are text-to-speech enabled, helping pupils to read and navigate

- Symbol maker - create customised symbols with this new drawing tool
- Includes thumbnail of images in the outline view to support emerging readers and writers
- Super grouper template allows creation of VENN diagrams to categorise and sort information
- Interactive whiteboard enabled (except on Mac OS Classic)
- **Maths View** with 5 visual maths tools develop pupils number sense, spatial reasoning and conceptual understanding of the four basic operations
- **3000+ symbols** offer visual support for concepts taught in the primary curriculum
- **Symbol search** makes it easy to find the right picture, image or symbol to express thoughts and ideas
- **Word Guide** - a combination dictionary and thesaurus, builds pupils vocabulary and reading comprehension
- Teaches emerging readers/ writers to clarify thinking, and to process, organise and prioritise information
- Visual representation deepens the pupils understanding of concepts and identifies misconceptions
- Intuitive interface helps keeps pupils focused on their ideas, not on the process of constructing the mind mapping diagram
- Stimulates creative thinking
- Build conceptual understanding in maths

13.1. Scally's World: Verbs & Actions

Company name:
Topologika Ltd
Web page:
http://www.dyslexic.com
Description

Scally's World of Verbs and Actions helps make sense of how verbs work. Learning vocabulary and understanding tenses is difficult for many children, particularly those with dyslexia and other Specific Learning Difficulties. *Scally's World of Verbs and Actions* improves listening, vocabulary, word recognition, spelling, sentence building, sequencing, modelling, and ICT skills. Verbs and tenses (past and present) are illustrated through fun animations as Scally, a small alien, learns English. Contains five engaging activities.

- Watch and Say – watch Scally act out up to 400 verbs
- Click and Watch – click on a verb and watch Scally 'do' it
- Watch and Click – watch an action, then click on the verb
- Watch and Write – watch an action, then type the verb
- Write and Watch – type verbs Scally knows to make a sequence

Word lists can be created making this software suitable for children of all abilities. With the built-in help, clear interface and optional speech-supported feedback this software program can be tailored to suit the individual's need. Scally's contains a fun talking story which can be printed out, as well as within the pack, work cards and the sheet music of the sing-along song in Scally's World: Verbs and Actions.

Nessy Learning Programme Deluxe

Company name:

Nessy

Web page:

http://www.dyslexic.com

Description

Nessy Learning Programme is an interactive literacy development suite to encourage positive, independent, learning for pupils of all ages. It has been developed at the Bristol Dyslexia Centre and is designed for pupils of all ages and abilities to learn how to read, write and spell confidently. It is also ideal for teachers who need to provide a complete literacy scheme for dyslexic students.

The **new** Nessy Learning Programme Deluxe won the Education Resources Award (ERA) 2010 in the category of "Special Educational Needs Resources or Equipment - Involving ICT".

Nessy's humorous approach combines structured incremental phonics linked with language, writing skills and vocabulary development, to create a highly effective multisensory learning environment; which is both fun and effective.

Students take on more responsibility for their own learning with encouragement to mark their own work. They quickly get involved in monitoring their own record-keeping and progress. Their efforts are rewarded with Nessy Nuggets, which can be spent at an interactive Fairground. This game-based learning approach has proved extremely effective for motivating learners and building self-esteem. Time saving resources for teachers include: guided lesson plans, teaching tips and strategies, as well as integrated planning, monitoring, record keeping and assessments.

Nessy provides a comprehensive resource of learning material to enable the pupil to practise the same skill in many different ways, so there is little chance of getting bored.

Features

- Integrated electronic record keeping with group monitoring
- Users create their own profile and all progress is automatically saved
- 10 new games include titles such as Jig Sore, to build up phonemes, and Chimp Fu, for syllable division
- 25 animated rules
- 120 lesson plans with strategies for learning
- 70 animated phonemes
- Library of interactive mnemonics and word endings
- 40 interactive worksheets
- Provided a teaching manual full of information about dyslexia and how to use Nessy's resources
- Interactive comic explains 'What's it like being dyslexic?'
- The Fair - 9 games to maintain motivation
- Lessons for Punctuation, Thinking Skills and Past Tense
- Revision games linked to printable certificates
- 5000 words and many more sentences all professionally re-recorded
- Favourite games have been recreated and improved so that timer is an option
- Extended early stage resources
- Facility to record and play games with your own words
- Every worksheet has been recreated and every illustration redrawn
- Worksheets and card games display in a carousel (Mac style cover flow)

StarSpell

Company name:

Fisher-Marriott Ltd

Web page:

http://www.dyslexic.com

Description

Starspell is a spelling program for all ages. Using a "Look-Cover-Write-Check" strategy, *Starspell* helps learners at all ages to improve their spelling. Designed to be both easy and fun to use for all ages, it can help teach spelling for beginners at KS1 right on through to spelling lists appropriate for Key Stages 3 & 4 (up to age 15). Every word is spoken and also given in a spoken sentence for an example of context, making this program very accessible for dyslexic users.

Starspell contains around 800 word lists, which complement every term of the Literacy Hour Framework and individual National Curriculum subjects (KS 3/4). Users can create and maintain personal word lists, use multi-sensory activities and print word list worksheets. It also includes 'onset & rime' for beginner readers and spellers, plus diagnostic Pupil Records of all spelling attempts.

Features

- Uses the "Look-Cover-Write-Check" strategy
- Approximately 800 word lists, providing a unique and graded progression to English spelling
- Every word is spoken. Many words have pictures and every word has a spoken sentence for context
- Create and maintain your own lists of words
- Lists tie in with every term of the Literacy Hour Framework, and there are extensive lists for individual National Curriculum subjects (KS 3/4)
- Includes "Onset & Rime" for beginning readers and spellers
- Diagnostic Pupil Records of all spelling attempts
- Uses a variety of multi-sensory activities and a worksheet can be printed for every list
- Speaking Starspell features in the British Dyslexia Association's list of useful software

Lucid Memory Booster

Company name:

Lucid research Ltd

Web page:

http://www.dyslexic.com

Description

Lucid Memory Booster is an activity based program for developing memory skills. Many children with dyslexia find it difficult to acquire memory strategies and skills due to poor working or visual memory. *Memory Booster* provides a multi-sensory environment for learning and developing memory through challenging activities. Designed to be used at home or in the classroom, it can be configured for each individual user.

Memory Booster is presented in the form of an adventure game set in the castle of Pooter the Master Computer, who has lost his memory and needs the users help to recover it. With six levels of increasing complexity, the program automatically adjusts the difficulty according to the progress of the child, which helps to maintain the right degree of challenge. Aimed at children aged 5 to 14, *Memory Booster* uses colourful characters and cartoons to provide a fun working environment.

Memory Booster incorporates many features to motivate children and ensure that they get the most from the activities. It has been designed so that children can work independently, requiring little

or no adult involvement. It provides graphs and certificates of achievement so that progress can be monitored.

Mastering Memory

Company name:
CALSC Ltd
Web page:
http://www.dyslexic.com
Description

Mastering Memory is a training scheme to improve memory skills and strategies. People who have dyslexia often have problems with memory, particularly short-term memory. *Mastering Memory* is a PC program to improve visual and auditory memory. Improved memory helps people with dyslexia gain many skills, but particularly literacy.

It was created by Jane E Mitchell, a speech and language therapist and dyslexia teacher who lectures on the practical applications of memory theory, and is aimed at teachers and therapists who wish to work with pupils on memory improvement.

Although the program uses colourful icons, it is not an ordinary computer game and requires supervision in order to achieve good results.

The Complete Version contains symbols appropriate for both children and adults.

Mastering Memory helps to:

- Improve short term memory
- Enhance transfer of information to long term memory
- Transfer new memory skills to other situations

Wordswork

Company name:
Alphabetics Ltd
Web page:
http://www.dyslexic.com
Description

Wordswork is a powerful multi-sensory study skills package. There have been a number of programs to teach study skills, but the classic one is *Wordswork.* It is packed with useful advice for dyslexic students. It is written primarily for dyslexic undergraduates but is very relevant for students in upper secondary, tertiary, further and adult education. In addition dyslexic adults wanting to improve their skills before embarking on formal study will benefit. Its excellent use of sound and pictures make it dyslexia friendly and a must for dyslexia Resource Centres and a great training and reference tool for individual students.

Wordswork uses graphics, 'voice-overs', colour and humour to develop a variety of language skills which dyslexic students (and others) need to address. Using a 'learning styles' approach, students are encouraged to identify and use their strengths to overcome areas of weakness. The program includes many exercises to involve users in interactive learning. The wide attraction of the programme results from the sophisticated, yet amusing, approaches used. The program is not intended to teach basic reading skills, but all printed screens are accompanied by 'voice-overs', reducing the need for excessive reading.

Features

- Essay writing
- Exam revision
- Grammar
- Handwriting
- Memory
- Oral presentation
- Punctuation
- Reading
- Spelling
- Time management
- Vocabulary building