The dyslexic engineer – issues for mathematics education

Author:

Glynis Perkin, Loughborough University, Leicestershire, LE11 3TU, UK, **G.Perkin@lboro.ac.uk**

Abstract *— In the academic year commencing October 2003, 113 of the 3388 students registered on engineering based undergraduate, taught postgraduate (Masters) and research postgraduate courses at Loughborough University in England had registered on application that they were dyslexic. A further 31 enginee ring students were diagnosed as dyslexic after their arrival at university: 6 in 2001/2002, 10 in 2002/2003 and 15 in 2003/2004. At the present time there is a widening participation programme in the UK; the government target is that 50% of young people be tween the ages of 18 and 30 will be entering higher education by 2010. It is expected that institutions will see a significant increase in the number of dyslexic students registered on their courses. Current legislation in the UK makes it unlawful for a un iversity to discriminate against a disabled person and universities must make reasonable adjustments to ensure that disabled students (this includes students with dyslexia) are not placed at a substantial disadvantage compared to non -disabled students. An investigation has been carried out to determine the problems encountered by dyslexic students reading for an engineering degree and to explore the ways in which dyslexia affected their learning of mathematics. By conducting interviews with students, from d ocumentary evidence and the provision of one -to-one mathematics support to a newly diagnosed dyslexic student the problems encountered in mathematics modules were investigated. Several exploratory case studies have been produced, from which a common list o f problems has emerged. This paper will give details of findings arising from the case studies and the student receiving one -to-one support, which provide a fascinating insight into the reactions of engineering students who discovered that they were dyslex ic after commencement of their university education. The nature of particular difficulties with mathematics as perceived by the students and by others will be described and the mechanisms that students or staff might put in place to alleviate them will be discussed. Once diagnosed as dyslexic, students have access to a range of general and mathematics -specific support. Details will be given of the support available in its various forms and an attempt will be made to evaluate the efficacy of its different co mponents. This paper will also distil emerging elements of good practice arising from these case studies. If adopted, in some cases by the student and in other cases by teaching and support staff, they will improve the chances of retention and progression and increase the level of achievement.*

Index Terms *— dyslexia, education, engineering, mathematics.*

INTRODUCTION

This paper has arisen as the result of an investigation carried out to determine the problems encountered by dyslexic students reading for an engineering degree in an English university and in particular to explore the ways in which dyslexia affects the learning of mathematics. The study focused on students who had been diagnosed as dyslexic after commencement of their undergraduate studies and therefore they had not previously received any form of dyslexic support. Most Universities in the UK have specialist units, which are responsible for students with disabilities and special needs. At Loughborough University the Disabilities and Additional Needs Service provides support to these students. The support includes external assistance such as liaising with social services and internal assistance such as ensuring the suitability of accommodation. The English Language Study Unit assists International students with study skills and English language problems. It also assists UK students who are having problems with the language needed for their studies and arranges for the implementation of recommendations such as increased library loan time.

When dyslexia is suspected, the procedure is that a member of the Disabilities and Additional Needs Service or the English Language Study Unit first talks to the student concerned, this is then followed by an interview. If the student wishes to proceed, a Dyslexia Adult Screening Test is administered to determine whether the student is considered to be dyslexic or not. Students who have either a positive or marginal result are then, if they wish, referred to an Educational Psychologist, the only person at the present time who may diagnose dyslexia in the UK. The Educational Psychologist will determine if the student is dyslexic or not and produce a detailed report, which includes the test results and recommendations such as extended time for examinations, assistive technology or the provision of one-to-one support. A member of the Disabilities and Additional Needs Service will then write a Needs Assessment, based on the report from the Educational Psychologist and

the course requirements of the student. Assistance is given to the student with the application to their Local Educational Authority to obtain the Disabled Students' Allowance, which funds the cost of any additional requirements that have been recommended in the report. Current legislation in the UK makes it unlawful for a university to discriminate against a disabled person and universities must make reasonable adjustments to ensure that disabled students (this includes students with dyslexia) are not placed at a substantial disadvantage compared to non-disabled students [1].

Many universities in the UK have introduced some form of mathematics learning support for students. A recent survey by Perkin and Croft [2] found that out of 106 universities in the UK, 66 offered some form of mathematics learning support, in addition to that provided by lectures and tutorials. This support ranged from postgraduates employed as student support assistants to dedicated learning support centres. At Loughborough University there is a dedicated Mathematics Learning Support Centre with staff available to assist students with their difficulties. If an Educational Psychologist recommends one-to-one support then it is tailored to the needs of the particular student. The English Language Study Unit provides support with report writing, time management and developing compensatory strategies. The Mathematics Learning Support Centre arranges one-to-one mathematics support where appropriate. An example of this is when it is believed that dyslexia is impeding progress in the mathematical or statistical elements of a student's course, in which case tutors with knowledge of dyslexia provide mathematics support.

For many people the term dyslexia is only synonymous with poor spelling. 'You know there are so many dyslexic people doing engineering and I hate getting in a group with them because they can't write' [3]. Difficulty with spelling, however, is just one manifestation of dyslexia. Other difficulties include problems with short-term memory, glare from text and text appearing to move, i.e. dance on the page. A computer simulation demonstrating visual difficulties, which may be experienced by some of the dyslexic population, can be viewed on the World Wide Web [4].

There are many definitions of dyslexia ranging from those using scientific terminology to brief statements referring to difficulties with reading and spelling. This definition is from The British Dyslexia Association, 'Dyslexia is best described as a combination of abilities and difficulties that affect the learning process in one or more of reading, spelling, writing. Accompanying weaknesses may be identified in areas of speed of processing, short-term memory, sequencing and organisation, auditory and/or visual perception, spoken language and motor skills. It is particularly related to mastering and using written language, which may include alphabetic, numeric and musical notation. Some dyslexics have outstanding creative skills. Others have strong oral skills. Some have no outstanding talents. They all have strengths. Dyslexia can occur despite normal intellectual ability and teaching. It is independent of socio-economic or language background' [5].

There has been a significant amount of research into dyslexia in the UK, especially during the last 20 years; however, most of this has been related to children under 16 years of age. There are publications, which specifically discuss mathematics and dyslexia. Chinn and Ashcroft [6] have authored a teaching handbook that details useful strategies for teaching mathematics to dyslexic students, it is, however, primarily written to assist pupils up to around 16 years of age. Other publications that discuss dyslexia and mathematics do not cover the subject at the level encountered in undergraduate education. Almost all the work relating to adults has been conducted from a psychological viewpoint, the subjects being those who had failed in mainstream education and overcome tremendous academic and emotional hurdles to obtain places in Higher Education (HE). This paper investigates students who performed well at school, achieved the necessary qualifications to enter university to read for a degree in engineering and only experienced difficulties after commencing HE. There has not been any in-depth research into the difficulties experienced by dyslexic students with mathematics modules in HE. Emerging work is that of Trott [7], detailing mathematics support for dyslexic students and ways to help facilitate the learning and understanding of mathematics at a level encountered in HE.

STATISTICS

The 1999 Report of the National Working party on Dyslexia [8] states that, dyslexia occurs in about 4% of the population, the incidence of dyslexia in HE is estimated at between 1.2% and 1.5% of all students and the incidence of dyslexia by gender is in the ratio of male: female between 3:1 and 5:1. Of these numbers, 57% are already known to be dyslexic on entry to university.

Statistics from The Higher Education Statistics Agency [9] in the UK show that the percentage of the student population stating that they are dyslexic on entry to university is rising, in 1994/95 it was 0.47%, in 1998/99 it was 1.10% and the latest available figures for 2001/02 show 1.84%. As many dyslexic people are visually gifted and choose to study in areas such as art, design and engineering, these figures make it extremely likely that most engineering courses will contain a dyslexic student or students. West [10] profiles 11 famous people including James Clerk Maxwell, Michael Faraday and Thomas Alva Edison who were visual thinkers and exhibited some of the traits that are associated with dyslexia.

In the academic year commencing October 2003, 113 of the 3388 students on engineering based undergraduate, taught postgraduate (Masters) and research postgraduate courses at Loughborough University had registered on application that they were dyslexic. A further 31 Engineering students were diagnosed as dyslexic after their arrival at university, 6 in 2001/2002,

10 in 2002/2003 and 15 in 2003/2004. The ratio of male: female students at Loughborough University in 2003/2004 was, undergraduates 1.6:1, postgraduate courses 2:1 and postgraduate research 2.5:1. The number of females in the 31 students who were diagnosed as dyslexic after their arrival at university was, 1 in 2001/2002, 3 in 2002/2003 and 4 in 2003/4.

At the present time there is a widening participation programme in the UK, the government target is that 50% of young people between the ages of 18-30 will be entering higher education by 2010. Statistics published in April 2004, from the Department for Education and Skills, report that for the academic year 1999/2000 the figure was 41% and had grown to 44% by 2002/2003 [11]. It is expected that institutions will see a significant increase in the number of dyslexic students registered on their courses as the population of students entering HE increases.

PRE-UNIVERSITY QUALIFICATIONS

In England and Wales the General Certificate of Secondary Education (GCSE) is taken at the end of compulsory education (16 years of age), in a variety of subjects. Students generally take up to nine subjects. Mathematics may be taken at higher, intermediate or foundation level. The highest grade is A* and the lowest grade is F. The General Certificate of Education Advanced Level (GCE A level) is usually taken at 18 years of age in three or four subjects. The highest Grade is A and the lowest pass grade is E. In addition to specific GCE A level qualifications, a minimum requirement of GCSE grade C in Mathematics and English are usually pre-requisites for obtaining a place at university. There are other entry routes to degree programmes, 1-year Foundation Courses may be undertaken at University and these are primarily for students who have A levels but wish to change direction from arts to science or vice versa. Access to Higher Education courses or Business and Technology Education Council (BTEC) courses may be undertaken at Colleges of Further Education and are recognized by universities in the UK for the purpose of entry to degree programmes.

METHODOLOGY

From conducting interviews, with engineering students who were diagnosed as dyslexic after commencement of their undergraduate programme, with members of staff who have been involved with these students and by analysis of the reports written by Educational Psychologists several exploratory case studies were produced. These exploratory case studies were conducted to determine whether these students experienced any problems with mathematics as a direct result of being dyslexic. The students were selected as they had not previously been taught any coping strategies or had any special arrangements made available to them. Summaries of four case studies are given.

The provision of one-to-one mathematics support to a newly diagnosed dyslexic engineering student on a weekly basis during the academic year 2003/2004 enabled problems encountered by him to be recorded. These problems are discussed in the section entitled one-to-one support.

The problems and difficulties, which emerged from both the case studies and the one-to-one support were investigated, as were the mechanisms that students or staff might put in place to alleviate them.

For reasons of confidentiality pseudonyms have been used for all the students who participated in the case studies and for the student receiving one-to-one support.

CASE STUDY 1: TOM – 2ND YEAR IN MANUFACTURING ENGINEERING

Interview with Tom

Tom was interviewed in 2003, during the 2nd year of his undergraduate studies in Manufacturing Engineering. For Tom it was at the commencement of his GCE A levels that he noticed a disparity between his knowledge level and what he could actually write down and additionally he noticed that he found short questions easy to understand but 'long winded' questions difficult. He described his Chemistry GCE A level syllabus as vague and he was unclear in the examinations what he was actually being asked. However, he obtained Physics Grade A, General Studies Grade A, Mathematics Grade B and Chemistry Grade E. Tom initially registered on a Mechanical Engineering programme and it was not until the 2nd year of his studies that, 'all hell broke loose and everything went pear shaped'. After being off sick for almost a month he had a lot of catching up to do, he obtained copies of the notes for the lectures he had missed but found that whilst he was reading large amounts of material he was not absorbing it. At this point he recognized that something was seriously wrong and realized that had he attended the lectures and heard the presentations then he would have retained much of the material. Tom started to panic, began to feel ill, was diagnosed as having depression and subsequently failed the 2nd year of his course. During his 2nd year of studies Tom was living in a shared house and noticed similarities between himself and his dyslexic housemate, 'we both had messy writing, contempt for written learning, thought off the wall not the page and had similar exam failure techniques'. Tom

described his exam failure technique as often writing what he thought should be said, not what the examination paper had actually asked for. Tom considered the possibility that he might be dyslexic and decided to investigate this when he returned to university after the one-year industrial placement that was incorporated into his programme of study. Tom had successfully obtained a placement and resolved that when he returned to university he would not retake the 2nd year of the course he had failed but would transfer to Manufacturing Engineering where it would be possible for him to enter at 2nd year level. After a successful year in industry, which helped to rebuild his confidence, Tom returned to University and visited the Disabilities and Additional Needs Service where he was tested for dyslexia. The results indicated that he may be dyslexic and in November 2003 he was assessed by an Educational Psychologist and diagnosed as dyslexic. He has now created his own 'systems' such as listing facts, flow charts and using diagrams to help him recall and understand material. He is adamant that if he were to be examined orally on a subject he would achieve far better marks than in a written examination. Difficulties experienced by Tom include:

- Memorising equations, learning proofs or theorems
- Poor short-term memory
- Not understanding what a question is actually asking
- Unable to listen and take notes at the same time
- Deciding what to write down
- Written examinations where he becomes tired and flustered, and often fails to answer the question fully

Report from the English Language Study Unit

A member of the English Language Study Unit stated that Tom appeared very anxious when she first met him and was worried about commencing his course in Manufacturing Engineering. Tom told her that he felt isolated and knew something was wrong but not what it was. She described Tom as having short-term memory problems and appearing very anxious, however, after being diagnosed as dyslexic he developed some coping strategies. Following the June 2004 examinations she reported 'he was glowing'.

Report from the Educational Psychologist

The Educational Psychologist report revealed that Tom had an IQ on the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) greater than 87% of the general population in his age range. It described Tom as having relative (to himself) strengths in vocabulary development, verbal reasoning, general knowledge, reading comprehension, spatial problem solving, non verbal Matrix reasoning, basic number skills and mental arithmetic. Tom's relative weaknesses are with working memory, processing speed and efficiency of retrieval of phonological information from long-term memory. The report grouped Tom's results into 4 cluster groups (a grouping of scores which fall into the same category) showing what percentile of the population he was in for each cluster group.

Cluster Group	Percentile
Verbal Comprehension Index	97th
Working Memory Index	47th
Perceptual Organization Index	95th
Processing Speed Index	5th

The report recommended Tom be given; individual specialist support on a weekly basis, technological support, 25% additional time for timed assessments and examinations, additional time to complete written coursework, a note taker in situations where there is a heavy writing requirement, additional loan times from the library. The purchase of personal copies of some books was also recommended.

CASE STUDY 2: RYAN – FINALIST IN SYSTEMS ENGINEERING

Interview

Ryan was interviewed in 2003, during the 4th and final year of his Master of Engineering programme in Systems Engineering. At school Ryan realized that, compared to his peer group, his reading pace was slow and he also had a tendency to make silly mistakes, however, he was not aware that he was dyslexic. At GCE A level Ryan achieved grade A's in Chemistry, Mathematics and Physics but a grade E in General Studies where he had difficulty in absorbing material, discussing topics

and producing written reports. It was during the third year of his undergraduate studies that that he began to feel frustrated. During a group project he realized that he was unable to explain and communicate his ideas to other members of the group. They believed he was being stupid and laughed at his written work. While he was in the Mathematics Learning Support Centre in the second semester of his 3rd year at university he saw the leaflets and checkpoint lists for dyslexia, felt that many of the points applied to him and discussed his situation with a dyslexia-dedicated member of staff. An appointment was made for Ryan to attend the Disabilities and Additional Needs Service where he was provisionally tested for dyslexia. The result of this testing indicated that Ryan may be dyslexic, two weeks later he was assessed by an Educational Psychologist and in his final year diagnosed as dyslexic. Ryan finds modules that have a diagrammatic representation 'user friendly' and now hand draws himself mind maps saying that he absorbs the material better this way than by using the software with which he has been supplied. Difficulties experienced by Ryan include:

- Problems understanding a topic if he has missed a lecture
- Spelling and sentence structure
- Problems absorbing material from text alone
- Coping with more than one form of media delivery i.e. printed notes and lecturer talking
- Essay writing, especially under exam conditions

Report from the English Language Study Unit

A member of the English Language Study Unit states that initially Ryan was worried about being dyslexic and writing his final year project. Additionally he was concerned that he was wasting her time as his average mark was indicative of him obtaining a 1st class honours degree. After being diagnosed as dyslexic he attended workshops, met other students and developed coping strategies. She now describes him as being happier and more confident. Ryan had always chosen modules that suited his strengths and realized that the compulsory final year project was going to be difficult for him. Whilst he had chosen a creative subject for his project, a written report was still obligatory; a member of the English Language Support Unit provided help and support with his written English.

Report from the Educational Psychologist

The Educational Psychologist report revealed that Ryan had an IQ (WAIS-III) greater than 70% of the general population in his age range. It described Ryan as having relative strengths in vocabulary, alertness to visual detail, spatial problem solving and non-verbal matrix reasoning and relative weaknesses with working memory, auditory analysis skills and efficiency of retrieval of phonological information from long-term memory. The report grouped Ryan's results into 4 cluster groups, showing what percentile of the population he was in for each cluster group.

Cluster Group	Percentile
Verbal Comprehension Index	68th
Working Memory Index	37th
Perceptual Organization Index	86th
Processing Speed Index	58th

The report recommended that Ryan be awarded extra time for examinations, given tutorial support and assistive technology.

Final Result

Ryan obtained his Master of Engineering degree and was awarded a first class honours classification.

CASE STUDY 3: ROBERT – FINALIST IN ELECTRONIC AND ELECTRICAL ENGINEERING

Interview

Robert was interviewed in 2003, during the 3rd and final year of his BSc programme in Electronic and Electrical Engineering. At school Robert found Science and Mathematics based subjects easy but English and language based subjects difficult. Robert commenced studying for his GCE A levels with a need to re-sit his GCSE English which he subsequently passed, however, after 1 year of study he began to experience difficulties and decided to leave school. He commenced a 4-year apprenticeship in an electrical electronic engineering company where he obtained Ordinary National Certificate (ONC) and

Higher National Certificate (HNC) qualifications, HNC being roughly equivalent to GCE A level. Robert was made redundant before the end of his apprenticeship and decided to enter university, his qualifications being acceptable criteria for entry into HE. He found most of the first year of his course reasonably easy and felt that the time he had spent in industry was helpful to him, however, he struggled with the two mathematics modules and failed both of them. Whilst his qualifications were science/maths/computing based, there were certain areas in the Mathematics GCE A level syllabus that had not been covered in the HNC. It was during his 2nd year that he began to experience difficulties with his course and whilst working in the Mathematics Learning Support Centre he saw the dyslexia checklists and discovered that many of the points listed applied to himself. Robert contacted the Disabilities and Additional Needs Service and was provisionally tested for dyslexia. The result of this testing indicated that Robert may be dyslexic. He was assessed by an Educational Psychologist and in the second semester of his 2nd year diagnosed as dyslexic. Once he had been diagnosed as dyslexic, Robert initially felt shy about it and additionally thought that it was 'bad' that the school system had failed to discover his dyslexia and he had, in effect, had to diagnose himself. In his 2nd year, Robert failed his 'wordy' examinations and his mathematics module but obtained passes at the re-sit session. Robert described the one-to-one support, which he received for mathematics as a great help, saying 'the tutor slowly explained the where, how and why aspects of a topic in a way which enabled me to see the whole picture'. Difficulties experienced by Robert include:

- Difficulty in deciding what to write down
- Difficulty in following information when presented on slides with the lecturer expanding on the subject
- Final year project
- The need to rewrite his notes

Report from the Mathematics Learning Support Centre

Members of the Mathematics Learning Support Centre staff described Robert as having short-term memory difficulties and requiring more time than his peers to absorb new material. He was seeking help from the Mathematics Learning Support centre during the 1st year of his studies but failed both his mathematics modules. They observed that he needed to read examples several times and experienced great difficulty in listening and then writing down what he had been told. After being diagnosed as dyslexic during the 2nd year of his studies, he benefited from one-to-one support given by a dyslexia-dedicated member of the Mathematics Learning Support Centre. She reports that he obtained over 50% in his mathematics re-sit examination and now appears happier and more confident.

Report from the Educational Psychologist

The Educational Psychologist report revealed that Robert had an IQ (WAIS-III) greater than 77% of the general population in his age range. It described Robert as having relative strengths in verbal comprehension and perceptual organization and relative weaknesses with working memory, processing speed, sequential ability and phonological processing. The report grouped Robert's results into 4 cluster groups, showing what percentile of the population he was in for each cluster group.

Cluster Group	Percentile
Verbal Comprehension Index	82nd
Working Memory Index	73rd
Perceptual Organization Index	30th
Processing Speed Index	32nd

The report recommended Robert be given; an individual programme of support, technological support, special examination arrangements of 25% extra time, extra time for coursework and a tape recorder.

Final Result

Robert failed the final year of his degree programme.

CASE STUDY 4: KEITH – POSTGRADUATE RESEARCH IN CHEMICAL ENGINEERING

Interview

Keith was interviewed in 2004, prior to submitting his Ph.D thesis to the Department of Chemical Engineering. Keith states 'I had all the signs of dyslexia, I was a slow reader, misread lines and experienced problems with text appearing to move on the page but didn't realize that I was dyslexic'. Keith was deported from his country of birth when he was 12 years old, after spending 4-years in country B, he then moved to country C where he continued his education and commenced a BSc in Agricultural Engineering; however, he did not complete this as he then moved to England. He had learnt some English during his schooling but mainly vocabulary rather than sentence structure and grammar. He now needed to learn English and obtain qualifications that would enable him to enter a University in the UK. He enrolled at a London college and completed a BTEC in Science followed by a 1-year Access Course to Science and Technology. These qualifications satisfied university entry requirements and he was accepted at an English university to read for a BSc in Food Technology. Keith recalled that during his undergraduate studies, whenever he encountered any report writing or essay style work, he became extremely stressed and used to think 'Am I so stupid that I can't understand what is required?' He described the problem he had after missing a lecture, he borrowed the notes but couldn't understand them, then realized that, if he missed a lecture, he couldn't grasp the material, whereas if he had attended the lecture he could recall and understand the material. Regarding mathematics he states that if he has been shown how to solve something he will not remember it, however, if he works through a problem himself he will remember it. He describes himself as being much better at dealing with abstract mathematics than elementary number work, where he was sometime unsure what he was supposed to be answering. Keith states that he hates text-based reading but is good at mathematics, figures, and the interpretation and understanding of graphically represented material. He describes himself as creative and good at idea generating but hates group work and other people seeing his written work. He also states that he needs the whole picture, including why we do it and what it is. He found his undergraduate thesis to be an area of great difficulty, but at this time he attributed his difficulties to working in English rather than his native tongue. During his undergraduate studies his tutor suggested that he go for English Support in the Medical Centre. Keith was puzzled by this and didn't go, his tutor hadn't mentioned dyslexia and Keith did not realize that this was dyslexic help being offered. He graduated with a 2:1 honours degree classification and came to Loughborough in 2000 to undertake a Ph.D in the Department of Chemical Engineering. Whilst having a discussion with a dyslexic friend it occurred to Keith that he might be dyslexic. Subsequently in June/July 2003 he made an appointment with a member of the English Language Study Unit who administered testing for dyslexia, the result indicated that he might be dyslexic. In October 2003 an Educational Psychologist assessed Keith and diagnosed him as being dyslexic. After being diagnosed as dyslexic he felt frustrated, it was the final year of his Ph.D he was struggling to write his thesis and needed a quick solution but realized that it was too late for him to start learning new coping strategies. Keith knows that he needs to read things more than once to understand the concept and has developed the strategy of first reading for key words then reading again and remembering the concept. Difficulties experienced by Keith include:

- Understanding what a question is asking
- Deciding what to write
- Structuring written work

Report from the English Language Study Unit

A member of the English Language Study Unit stated that, when she first met Keith, he was worried about a report due to be submitted in one to two months, which he had not commenced writing, he explained to her that he was unable to get the words from his head onto the page. Time was spent showing Keith how to use 'tree diagrams' and bullet points, thereby breaking down what was for him, a monumental task into small manageable sections Additionally she noted that Keith required help with organization and planning.

Report from the Educational Psychologist

The Educational Psychologist report revealed that Keith had an IQ on the (WAIS-III) greater than 63% of the general population in his age range; however, it must be noted that English is not Keith's native tongue. It described Keith as having relative strengths in reasoning skills (very superior), non-verbal reasoning (superior), spatial problem solving, working memory, long-term memory (general knowledge) and basic number skills. Keith's relative weaknesses are with processing speed, grapho-motor fluency (handwriting), alertness to visual detail, short-term auditory sequential memory, efficiency of retrieval of information from long-term memory and vocabulary development. Again, the weakness in vocabulary

development may be related to English not being Keith's native tongue. The report grouped Keith's results into 4 cluster groups showing what percentile of the population he was in for each cluster group.

Cluster Group	Percentile
Verbal Comprehension Index	79th
Working Memory Index	73rd
Perceptual Organization Index	68th
Processing Speed Index	8th

The report recommended Keith be given; specialist dyslexia support, additional tutorial support from his academic department, additional time of 25% within timed assessments and examinations, additional time to complete written coursework, specific help with English and technological support.

ONE-TO-ONE SUPPORT: PATRICK – 1ST YEAR IN CIVIL ENGINEERING

Observed Difficulties

During the academic year 2003/2004 one-to-one mathematics support was given to a Civil Engineering student who had been diagnosed as dyslexic after commencing his undergraduate studies. Although a case study has not been conducted the areas where he experienced difficulty were witnessed. This student is mathematically competent, however, he has encountered several problems directly related to his dyslexia.

- For lengthy mathematical procedures the delivery speed in lectures was often too quick for Patrick to follow, unless it was a topic he had previously encountered. In methods such as Cramer's rule this resulted in him not being able to follow through the whole procedure.
- Solving systems of equations using row operations. Whilst the student fully understood the procedure he consistently produced incorrect answers. The problem here was related to lining up the numbers.
- Finding the inverse of a matrix using the formula,

  $$A^{-1} = \frac{1}{|A|} adj(A),$$

  involves the use of two distinct operations, finding the determinant and the adjoint. Initially the problem was for him to recall that there were two distinct operations involved and that they both required the correct usage of an + - + - array of signs. Again he encountered problems with the visual aspect of one row and column being ignored and operations being performed on the remaining rows and columns. Subsequently he then had difficulty in linking the correct procedure to each of terms, determinant, adjoint and inverse.
- Problems encountered by 'rushing headlong' into answering a question before reading it correctly. This has sometimes resulted in his answering what he thinks is being asked rather than doing what is actually required or missing out part of a question.
- Particularly in statistics questions he encountered problems extracting the essential part of the question from the often lengthy and descriptive text. Additionally he often failed to notice key words such as *continuous* or *discrete*, which resulted in him failing to correctly answer a question.
- With introductory vector work he encountered problems moving from a 2-d representation to a 3-d conceptualisation.

ANALYSIS OF CASE STUDIES AND ONE-TO-ONE SUPPORT

The exploratory case studies were conducted to determine whether the students had experienced any problems with mathematics as a direct result of being dyslexic. It has been determined that dyslexia impeded these students, in a variety of ways, in their learning of mathematics. The case study student who received specialist mathematics support was enabled to overcome or minimise his particular difficulties.

The provision of one-to-one mathematics support to a newly diagnosed dyslexic engineering student on a weekly basis during the academic year 2003/2004 revealed particular problems, which were directly related to his dyslexia.

EMERGING THEMES

The reasons for students requesting that they be tested for dyslexia does not have a common theme, it includes a student who having missed lectures found himself unable to understand the material from the notes alone, a student experiencing problems with group work and another student failing modules. Other reasons that have been encountered but not discussed here include a student being unable to take comprehensive notes in lectures and a student who failed a computer on-line test even though he had a good understanding of the topics that were being tested. However, there were common difficulties that emerged from the case studies, these involved problems with note-taking, getting lost part way through a lengthy problem, not answering the question that had actually been asked, difficulty in transferring subject knowledge into written work and problems with isolated information or facts.

Work with the one-to-one student enabled not only the problems he experienced to be witnessed but also what was causing the problem to be examined. In addition to the speed of delivery of material in lectures the main difficulties experienced by this student were visual difficulties giving rise to problems when working with rows and columns of figures, extracting the required information from the question, getting lost part way through a problem and not reading the question properly, thereby failing to answer the actual question that had been asked.

DISCUSSION OF IDEAS

It transpired that all of the case study subjects and the student receiving one-to-one support had either been re-working their lecture notes into colour coded mind maps or using a diagrammatic depiction of topics. Colour coded concept diagrams had been used by Trott [12] when giving one-to-one dyslexic support in the Mathematics Learning Support Centre and had been found to assist students with multi-stage mathematical operations. The feasibility of using specialist software to produce colour coded mind maps, which could then be converted into text, was investigated. It was discovered that whilst mathematical formulae are available, they are inadequate for the mathematics encountered at undergraduate level in engineering courses. Word equation editor could be utilized, however, once an equation had been placed into the concept diagram, it could not be changed at a later date. This prompted the question, ‘do we really need to convert the mind map to text’? After all, the students already have text, what we are looking for is a more visual representation of a process or different methods which come under one umbrella i.e., differentiation. Alternative software was investigated and SmartDraw found to be both adequate and user friendly. The next question was ‘do students actually want to use software to draw their mind maps’? The answer from the small sample (5), of students asked this question, was a unanimous ‘No’. However, they all stated that they would like to be given a visual representation of a method or process, to help in gaining an understanding of the whole picture, but the mind maps they produce for themselves are unique and part of their learning process.

The use of squared paper has been seen to assist dyslexic students, in particular, a remarkable improvement in accuracy was observed with Patrick, the one-to-one student, when it was used for matrix operations enabling him to correctly align rows and columns of numbers. There is a web site [13], where it is possible to design your own graph/squared paper, allowing both the colour of the lines and the colour of the paper onto which you print to be chosen. This enables the design to be ‘tailor made’ to suit individual requirements and preferences, thereby reducing the glare experienced by the student.

The extremely simplistic idea of using two matchsticks to cover up the row and column, which were not being used in matrix operations, such as finding the determinant, has proved greatly beneficial to Patrick, significantly minimising his errors.

The introduction of a simple 3-d model enabled Patrick to move from a 2-d representation of vectors to a 3-d conceptualisation.

SUPPORT

The Mathematics Learning Support Centre

The Mathematics Learning Support Centre at Loughborough University opened in October 1996. It is a dedicated room, which is open 5 days a week. It contains a large collection of mathematics textbooks, computers, self-study handouts, study skills material and on-line resources. The centre is open to any Loughborough University student and in particular aims to assist students in the early stages of their undergraduate studies. During term time a ‘drop-in’ surgery is in operation with academic members of staff on duty to assist students with any mathematical problems or difficulties they are having.

One-to-One Mathematics Support For Dyslexic Students

Once a student had been diagnosed as dyslexic and identified as needing one-to-one mathematics support the Mathematics Learning Support Centre then arranges for this to take place. This support differs significantly from that which is available at the drop-in sessions. One particularly beneficial aspect of this support is that the students see the same person each week enabling them to build up a comfortable working relationship with their tutor. The tutor has time to explore areas where the student is experiencing difficulty, and to develop techniques to overcome these difficulties. These techniques may involve encouraging the student to draw a mind map, giving a diagrammatic representation or using colour coding to help the student separate different terms in an equation. Other ways of assisting are splitting up lengthy procedures into several smaller steps. Additionally, seeing a student regularly enables the speed of delivery and the length of time spent studying to be tailored to the needs of the student.

With Patrick, one-to-one support provided an opportunity to work through procedures at a speed that enabled him to absorb the material. Time was also spent trying to prevent him rushing headlong into questions. Whilst this is a difficult area to overcome, the practicing of exam style questions, which he completes in far less time than that which he is allowed, has given him confidence in his ability to complete an exam paper. He has been awarded 25% extra time in examinations, which has helped to alleviate his panic of not finishing in time. In text based questions highlighting the numbers and looking for key words such as *continuous* and *discrete*, *with replacement* or *without replacement* was practiced, this helped to ensure that he answered the actual question posed. Again the knowledge that he has been awarded extra time in examinations has helped. The best use of this extra time was also discussed, it transpired that for Patrick it was best for him to use half the extra time to read through the paper, highlight key words and decide which questions he would answer and use the remainder of the extra time for checking through his work.

SUGGESTIONS

Mind maps could be designed and made available for the most commonly encountered multi-stage mathematical operations / topics and during support sessions students encouraged to produce their own mind maps after seeing examples. Provision of squared paper for students undertaking examinations. At Loughborough University, this is now available on request in extra time examination halls. However it is important that students are familiar with the usage of this paper prior to encountering it in an examination.

The addition of serifs to fonts helped facilitate reading for most people; however, for those dyslexic students who experience 'moving text', these fonts are particularly difficult to read. Any sans-serif font is extremely helpful to dyslexic students; however, many non-dyslexic students will find sans-serif font takes slightly longer to read. Whilst text can be typeset in sans-serif font, it is not always conventional or appropriate for mathematical symbols. From 2004, Loughborough University has introduced the standard usage of a sans-serif font for text in examination papers. It is recommended that where possible sans-serif font is used, provisional to it not proving detrimental to non-dyslexic students. Justified or blocked text also presents problems for some dyslexic students making it more difficult for them to determine which line they have just read. The worst possible representation of material encountered by dyslexics is the standard black text on a white background. Whilst many dyslexic students use a coloured overlay (the colour used varies from student to student) to reduce glare from the text they are reading, producing black text on an off-white background would also be beneficial. Once diagnosed as dyslexic, students in the UK are entitled to a range of facilities and provisions as recommended in the report from the Educational Psychologist, it is good practice to ensure that these recommendations are implemented as quickly as possible.

FUTURE LINES OF INQUIRY

There are many possible areas for future research; Riddick writes 'There is, as yet, little systematic published research into dyslexia in higher education' [3]. An area of research arising from these cases studies is why were these students not diagnosed as dyslexic during their compulsory schooling? Other areas, which could be explored, include investigating whether dyslexic students are disadvantaged when completing an on-line computer test and whether multi-choice papers discriminate against dyslexic students. An interesting comparison would be the performance in HE of dyslexic students who were diagnosed at school compared to those who were diagnosed after commencing HE.

ACKNOWLEDGEMENT

The author is grateful for the award of an International Travel Grant from the Royal Academy of Engineering. Special thanks to Clare Trott for sharing her knowledge of dyslexia and her ideas with me, to Abigail James, Product Manager (Software), Iansyst Ltd., for her advice on the use of mind maps and to members of the Disabilities and Additional Needs Service and the English Language Study Unit for the provision of data. Contributions from Dr. A. C. Croft and the students involved in this study are also acknowledged.

REFERENCES

[1] The Special Educational Needs and Disability Act 2001, The Stationery Office, London.
[2] Perkin, G, and Croft, T, *Mathematics Support Centres – the extent of current provision* , MSOR Connections, Vol 4, No.2, pp14-18.
[3] Riddick, B, Farmer, M, Sterling, C, *Students and Dyslexia,* Whurr Publishers Ltd., London, 1997, p175, p183.
[4] http://www-staff.lboro.ac.uk/~cvnb1/dyslexsim/dyslexsim.htm
[5] The Dyslexia Handbook, The British Dyslexia Association, London, 2002, p67.
[6] Chinn and Ashcroft, *Mathematics For Dyslexics (A Teaching Handbook), Whurr Publishers Ltd., London, 1993.*
[7] Trott, C, *Mathematics Support for Dyslexic Students,* MSOR Connections, Vol 3, No.4, pp17-20.
[8] Dyslexia in Higher Education: policy, provision and practice. The National Working Party on Dyslexia in Higher Education, The University of Hull, UK, 1999, pp 1-18.
[9] http://www.hesa.ac.uk/holisdocs/pubinfo/stud.htm
[10] West, T, G, *In The Mind's Eye* , Prometheus Books, Buffalo, New York, 1991, pp 101 – 141.
[11] http://www.dfes.gov.uk/rsgateway/DB/SFR/
[12] Trott, C, in *LTSN Engineering Guide: Working with Students with Disabilities* , LTSN Enginering, 2002, p27.
[13] http://incompetech.com/beta/plainGraphPaper/