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Supporting Dyslexia in the Programming Classroom

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Abstract

Existing approaches to teaching in higher education continue, despite legislation, to be largely exclusive of the dyslexic population. In this report, the ICF classification of dyslexia, current legislation on disability, and the problems associated with dyslexia are investigated within the higher educational sphere, and specifically within the field of programming.

Dyslexic adults who study programming at university or college level could be better supported through the use of sequential assessments, multi-modal approaches to learning, assistive technologies, and appropriate tutor support. In consequence of these approaches, the standards set by the ICF, the DDA (1995), and the Equality Act (2010) should be met in the higher education programming classroom.

Keywords: Programming and Dyslexia, Dyslexia in Higher Education, Disability in Education, Accessibility in Programming, Models of Disability

1 Introduction

In this study, programming, which encompasses web development, games programming and all computer sciences, and the skills required of the programmer, will be analysed for the difficulties they may present to the dyslexic student. Suggestions for a revision of classroom methodology will be discussed so as to support the learning process of the dyslexic student in higher education.

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Dyslexia is a "hidden" disability that, to varying degrees, affects approximately 10% of the population. A form of specific learning difficulty, dyslexia negatively impacts information processing and retention, which can affect the individual's literacy skills and their ability to learn [1].

Dyslexic individuals lack distributed automatic processing of languages, and to compensate for this, they continually use their frontal, strategic parts of the brain [2]. As a result it may be beneficial to consider dyslexia as an alternative learning style rather than a disability [3]. The current societal constructs of education and assessment, however, continue to forward a traditional learning style, and it is those traditional teaching methods that present problems for the dyslexic student in higher education.

The difficulties associated with dyslexia in higher education are numerous, and may affect each dyslexic adult to a greater or lesser extent. General indicators of dyslexia, according to the national charity Dyslexia Action, may include:

- *Difficulties taking notes*
- *Difficulties planning and writing essays, letters or reports*
- *Difficulties reading and understanding new terminology*
- *Difficulties revising for examinations*
- *Struggles to communicate knowledge and understanding in exams*
- *Forgets names and factual information, even when familiar*
- *Struggles to meet deadlines*
- *Struggles with personal organisation*
- *Develops work avoidance tactics to disguise difficulties and/or worries about taking professional qualifications*
- *Difficulties become exacerbated when under pressure of time* [3]

While dyslexic, primarily right brained [4], students may experience weakness in processing analytical and sequential details, having difficulty "focusing and staying on task", and "passing standardized[sic] tests" [5], their brains work in such a way that they can make global or visual connections with greater ease [4][6].

As a "hidden" disability, dyslexia can often be mistaken for a lack of awareness or ability, but in reality, the dyslexic individual merely has an alternative means of negotiating the world that deviates from the societal norm.

1.1 Dyslexia from a Personal Perspective

The programming classroom can be a highly stressful and frustrating environment for the dyslexic student, where they are expected to effectively compete with their classmates on a daily and prolonged basis. As a former postgraduate web design and development student with dyslexia, one of the authors can certainly attest to those feelings of inability and frustration throughout their time in academia.

Dyslexia affords difficulties, but also advantages in the classroom. During their time in higher education, the dyslexic author frequently found that while poor working memory hindered their ability to recall recently acquired information in the classroom, strong visual skills helped them to construct complex databasing diagrams that helped other students to negotiate the processes required for effective database management during development. Dyslexia is, however, a complex disability that affects individuals in multitudinous ways; the affected author's dyslexic peers may experience other advantages or disadvantages that their dyslexia affords their learning process.

Dyslexic students, for example, can be highly creative and innovative in their thought and planning processes, and as a result of their often dominant right hemisphere, "stronger visual skills can often compensate for weaker phonological and auditory skills" [7].

1.2 Dyslexia in Education

As a result of their cognitive disability, dyslexic students may need to compensate for their inabilities by using alternative modes of learning both within and outside the classroom.

Dyslexic students typically have difficulties processing sequenced symbolic information. This can limit the dyslexic student's capacity for learning in a society that predominantly processes information and, more importantly, educates in this way [8]. It is, consequently, the responsibility of the institution to offer "a set of enabling arrangements which are put in place to ensure that the dyslexic student can demonstrate their strengths and abilities, and show attainment" [7] rather than relying on traditional teaching methods that only cater to the norm and leave the dyslexic student in a vulnerable position.

It is also the responsibility of the dyslexic student to inform the educational institution of their impairment, and to develop compensation strategies for traditional learning methodologies when no alternatives are offered.

A number of principles can be applied in the classroom to allow dyslexic students to compensate for their weaker phonological and auditory skills while supporting inclusivity for all students in the classroom. These principles include:

Table 1: Supporting Dyslexia and Encouraging Inclusivity in the Classroom

	Supporting Dyslexic Students	Supporting Inclusivity For All Students
Multi-Sensory Techniques	Kinesthetic activities, as a form of active learning where students actively participate in their education, will encourage the dyslexic student to use their strongest learning channels in the classroom.	Active learning is learner-centred, and allows students the opportunity to attain greater levels of abstraction in their learning process. The Analysis, Synthesis, and Evaluation levels within Bloom's Taxonomy of Cognitive Development, which represent the most complex and abstract mental levels, are fulfilled through this learning methodology [9].
Overlearning	Students should have the opportunity to overlearn through multiple differing and complementary learning modes to compensate for weak retention.	Driskell et al, in "Effect of Overlearning on Retention", discovered that the greater the degree of overlearning, the greater the effect of overlearning on retention. A 50% overlearning manipulation, therefore, would generate small improvements in performance, and a larger proportion of overlearning would encourage greater retention results for students [10].
Metacognition	Awareness of the learning process should be encouraged so that students can control personal goals, and effectively self-regulate their learning process. Discovery learning will also actively encourage the dyslexic student to map prior knowledge.	Metacognition strategies encourage self-awareness in the classroom. They encourage students to recognise personal goals and self-regulate their learning process. This process can aid retention and enable students to identify and compensate for problem areas in their learning process.
Personal Motivation	A real world context that is applicable outside the classroom will stimulate interest and motivate students.	It is important to foreground the professional relevance of skills learned in the classroom as a proportion of students will be interested in following a career which is relevant to the subject being taught.
Short Concentration Span	As the dyslexic student can lose concentration quickly, lessons should be compartmentalised into manageable segments that allow dyslexic students to concentrate for short periods of time.	In 1976 A.H.Johnstone and F.Percival observed adult students in more than 90 lectures, with 12 different lecturers, to record breaks in student attention. In 1985 Ralph A. Burns, who asked students to write summaries of presentations which noted the information retained in sequential half-minute segments, mostly corroborated their findings, which showed that a severe lapse of attention occurred 15 to 20 minutes into a lecture. As higher education lectures generally last between 50 and 70 minutes, the generality of students will struggle to retain information unless the lecture is appropriately segmented within the 15 to 20 minute attention span period with appropriate changes in learning methodology for each period to re-excite student interest [11].

The incorporation of these factors in the higher education classroom should allow students to adequately compensate for their auditory and phonological difficulties [7]. Should these factors not by encouraged in the classroom, the dyslexic student may continue to experience feelings of inadequacy, which may force them to hide their difficulties and actively avoid those subject areas that cause them such frustration.

It is currently the dyslexia assessed student's obligation to inform a tutor of any difficulties they may face and request support and allowances in higher education, but when the student feels vulnerable, which they so often do as a result of their impairment, they may not ask for such allowances, and consequently continue to struggle in higher education. Surely, then, it should be the obligation of the institution to meet with a student prior to course commencement to determine their specific learning needs so that they can be supported appropriately throughout. Through greater transparency in the classroom, feelings of inadequacy could certainly be tackled, and combined with the use of assistive technologies, tutor training, strategic assessments, and detailed and supportive feedback on assessments, feelings of inadequacy could eventually be eradicated in the higher education classroom. For those students who have not been assessed previously but who are demonstrating symptoms of

dyslexia, the institution could recommend that the student takes a dyslexia assessment which will allow the affected student to benefit, for example, from extra time in examinations.

2 Dyslexia and the Higher Education Programming Classroom

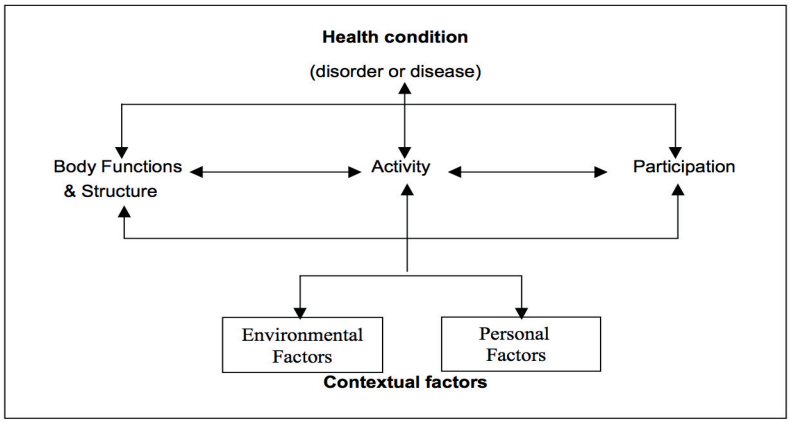
2.1 Legislation and Models of Disability

The International Classification of Functioning, Disability and Health (ICF) social model of disability "sees disability as a socially created problem and not at all an attribute of an individual"; it stipulates that "society...disables people, through designing everything to meet the needs of the majority of people who are not disabled" [12].

In this paradigm it is society that decides whether the student deviates from the norm, and thus it is society's responsibility to "reduce, and ultimately remove, some of these disabling barriers" for the dyslexic student [13]. In the social model of disability, the dyslexic student would expect the educational institution to accommodate for their learning needs, and they would never need to develop compensation strategies for traditional teaching methods in the classroom. This paradigm would constitute a major departure from traditional teaching methods that would be difficult to implement on a nationwide scale. The non-dyslexic student, who could respond positively to traditional teaching methods, may suffer as a result of such a departure, which mostly benefits a minority disabled demographic.

The medical model of disability stipulates that disability is a "feature of the individual, which requires medical care provided in the form of individual treatment by professionals" [12]. In this model, the disabled individual must exert themselves "to ensure that they do not inconvenience anyone else" [13]. In this model the dyslexic student will need to compensate for traditional teaching methods throughout their time in higher education. With a lack of support the dyslexic student will likely become vulnerable, as the pressure to compete with their non-dyslexic peers, especially under time constraints, may exacerbate the symptoms of their dyslexia.

Figure 1: Integrative Bio-Psycho-Social Model of Functioning and Disability [12]



The ICF advocates an amalgamation of the social and medical models of disability to create a bio-psycho-social model of functioning and disability. In this paradigm, disability is considered to be "a complex phenomenon that is both a problem at the level of a person's body, and a complex and primarily social phenomenon" [12]. The dyslexic student, in this model, will at times be supported in the classroom, but they will also have to develop compensation strategies for more traditional teaching methods.

While the social and medical models of disability are largely exclusive of the generality of students, the bio-psycho-social model of functioning and disability allows the student to find some support in the classroom and develop compensation strategies which will be beneficial in a real world context where they are less likely to find the support that they need.

In order to allow students to proactively develop compensation strategies, it would be beneficial to provide students with support not only in the classroom but also in cognitive disability support lessons, which will help them to develop compensation strategies that can be applied both inside and outside the classroom.

Examination boards currently offer special arrangements, in accordance with legislation set out by the Disability Discrimination Act (DDA) [14] and Equality Act (2010) [15], for the dyslexic populace during standardised testing, such as additional time, scribes, or the use of a computer, however support in the classroom, which the bio-psycho-social model of functioning and disability advocates, is still largely lacking for the dyslexic student in the higher education classroom [14].

Current legislation on disability in education states that "the responsible body for a school must take such steps as it is reasonable for it to have to take to ensure that — in relation to education and associated services provided for, or offered to, pupils at the school by it, disabled pupils are not placed at a substantial disadvantage in comparison with pupils who are not disabled" [15].

The Equality Act (2010) attests that in the provision of information "the steps which it is reasonable for A to have to take include steps for ensuring that in the circumstances concerned the information is provided in an accessible format", where "a person on whom the duty is imposed is referred to as A" [16], and thus the higher education institution.

In order to fulfill the obligations imposed by current legislation in the classroom, teaching methods should be adapted to satisfy not only the non-dyslexic student in a traditional teacher to student lecture methodology, but also the dyslexic student by implementing a variety of teaching methods which complement kinesthetic, auditory and visual learning styles. The combination of numerous learning styles in teaching methodology will not only benefit the dyslexic student, but will also be of benefit to the generality of students whose preferred learning styles may largely differ.

2.2 The Novice Programmer

Shigley and Mitchell [3] provide a generic model for the cycle of design or problem-solving; when writing a computer program, this model can be summarised in the following steps:

Recognition of a Need This step involves the acknowledgement and definition of what the function of the program will be following evaluation of its necessity [17].

Problem Definition In this step the program will be evaluated as a method to solve a problem [18].

Synthesis This step involves conceiving what the program, class or method requires at different levels of abstraction. [3]

Analysis This step involves the individual classes, methods or code that are required to create whole functionality at different levels of abstraction.

Implementation This step involves coding, testing and debugging so that the program eventually compiles and functions as expected.

Evaluation The final step involves user trials of the program, which may render refinements or re-conceptualisation necessary.

Programming in general demands certain requirements of the individual, and these include:

Concept Acquisition There are no habitual intellectual activities that can effectively form the basis for construction of mental models in some programming concepts such as variables, in contrast with mathematical concepts such as velocity [19]. Novice programmers, as such will struggle to quickly understand and appropriately use such concepts in their work.

Underlying System Knowledge The 'notional machine' [19], which comprises the changing representation of the whole system when moving from one system to another and adapting to new constraints, is a necessary function of the programmer when designing, understanding or debugging a program. Novice programmers may encounter difficulties with the relative complexity of the command device in the acquisition process or may demonstrate erroneous representations of the notional machine.

Communication Errors Laborde et al, Samurcay and Rouchier, and Bonar and Soloway [19] have noted misconceptions in simple iterative programs designed by novices. One common error consisted of writing operations in the order 'description of actions/repeat mark'. In this example the novice programmer has credited the computer with semantic abilities such as presupposition and interpretation of the content communicated by the user. The novice programmer will need to reevaluate their understanding of the computer as a non-sentient device.

Abstract Thought The programmer needs to be able to think on several levels concurrently. Tasks should be compartmentalised to avoid information overload on the programmer. Hierarchies, for example, help the novice programmer to compartmentalise information into organised and manageable processes [20].

2.3 Programming in Higher Education

The British Computer Society held a conference in March 2004 [Grid and Cooperative Computing GCC 2004], which focused on the grand challenges in computing. In computing education, seven grand challenges were identified, one of which, "Programming Issues", was described in the following terms:

"One can generally observe that a strong correlation exists between programming ability and other computing skills, reflecting, as it does, skills in abstraction, conceptualization, design and evaluation. However, major concerns exist among the academic community internationally that when we set out to teach programming skills to students, we are less successful than we need to be and ought to be [...].

Given the situation described above, the computing challenge for this area is as follows: Understand the programming process and programmer practice to deliver effective educational transfer of knowledge and skills" [21].

Effectual transferral of skills is of paramount import for the student programmer, as programming is a continually evolving field. The tutor should always be able to provide students with current information, to ensure that the subject matter they cover is usable outside of academia.

To ensure that relevant skills and real world experience is brought to the programming classroom, it would be advisable for institutions to source part-time tutors who remain active in their field, or to allow full-time tutors adequate research and development time within their working hours to ensure that they are always passing useful and current skills onto their students. It is also important to encourage students to work in a real-world paradigm during their projects, as this will allow them to see how the skills they are learning can be applied in a relevant and usable context.

In order to understand the programming process and programmer practice, institutions need to encourage tutors to understand the learning methodology of the student in the higher education classroom. By understanding of the diverse learning needs of the classroom, and encouraging multi-modal teaching practices that support those needs, skills can be transferred in the most intuitive manner.

2.4 Accessibility Guidelines for Dyslexia in Programming

The Special Education Needs and Disability Act (SENDA, 2011), and the DDA, provide no specific guidelines for the provision of electronic based materials, however their advocation of "reasonable adjustments" in education does provide an impetus for other standards providers in the field of accessibility on the web [22]. The most notable of these standards providers are:

IMS Global Learning Consortium (IMS, 2002) The IMS has developed guidelines pertinent to accessible learning applications. These guidelines are designed to "advance technology that can affordably scale and improve educational participation and attainment" [23].

The W3C's Web Accessibility Initiative (WAI) The WAI has developed the Web Content Accessibility Guidelines 2.0 (WCAG) that "covers a wide range of recommendations for making Web content more accessible...[to] make your Web content more usable to users in general" [24].

Section 508 of United States accessibility law Section 508 provides standards for accessibility for technologies, software and

Web resources. These guidelines aim to "make...electronic and information technology (EIT) accessible to people with disabilities [3]

In addition to these standards providers, numerous bodies, such as WebCT, and TechDis, endorse the standards set out by the aforementioned providers. [25]

The following guidelines were selected from generic accessibility guidelines and correlated against symptoms of dyslexia:

Controlling styles The dyslexic programmer should be able to control font sizes and styles, and colours in backgrounds and text [26]. Contrasting colours may aid the student when reading text, and certain fonts can be problematic for the dyslexic populace [27][28][29]. Cascading style sheets allow the student to customise a webpage to suit their preferred visual learning style [30][31].

Active Avoidance Strongly coloured or patterned background may distract the dyslexic programmer and obscure text [26.] [31].

Structuring Left justified paragraphs will provide a clear structure for the dyslexic programming student [31] [32].

Linguistics Language should be clear and concise, and graphics should be intuitive [31] [32].

Design for Assistive Technologies Web pages should be designed to work with assistive technologies such as screen readers, as they may aid the dyslexic student when confronted with a large body of text [26] [33]. The student will be able to compensate for poor reading skills and receive information through a more accessible channel [31] [34].

Switching Off Elements Distractions, such as animated or timed elements, blinking or scrolling text could be difficult for the dyslexic student who experiences difficulties reading text [31] [30].

Consistency Consistent layouts and formats will reduce cognitive load, allowing students to focus their attention [30][26].

Context Information should be contextualised and oriented to provide a basis of knowledge for the dyslexic student [30].

White Space Text should not appear cluttered on the page as it will hinder the student's ability to process information [31] [32].

Front-Loading Hyperlink sentences should provide a brief description of the page they lead to and why it is important [26][31]

In following these guidelines, the accessibility of web pages can be ensured, and improved clarity will allow the student to focus on content rather than distractions in the programming classroom. [7]

2.5 Programming and Dyslexia in Higher Education

The most common misconception about dyslexia is that it merely affects the individual's ability to construct sentences and spell words correctly. In order to understand the considerable challenges that the dyslexic student faces in the programming classroom, we need to revisit the some of the skills required of the programmer during a project life cycle in higher education.

Synthesis Dyslexic individuals, who tend to be right-brained [4], and thus tend to think holistically, may find their dyslexia is an asset when considering the program as a whole and how elements interact. The dyslexic students could aid non-dyslexic students in the classroom by working in small groups which allow them to share their ideas and work in a real-world programming context where they will likely work as members of a team.

Analysis Dyslexic people may have difficultly breaking down the system into component parts, and viewing these parts in a logical sequence, as these are primarily left-brained activities [3][4]. If the educational institution provides compartmentalised lessons that sequentially cover the necessary steps for analysis of the program, the dyslexic student and the generality of students will be able to focus for short periods of time in logical sequences which will aid retention and encourage organisational skills.

The dyslexic student could also request prior knowledge of the system that will be under discussion in the classroom and some

examples of component parts, which will allow them to develop their ideas prior to the time pressure of the lesson environment. Dyslexic students could use mind maps, system diagrams and brainstorming sessions which should help them to see correlations between the system and component parts, helping them to develop their ideas prior to the lesson. In order for dyslexic students to create these helpful tools, the lecturer should encourage the use of such diagrams by creating them in the lesson environment based on student feedback, which will help all students to actively assimilate their own knowledge of the system with appropriate lecturer criticism and further explanation.

Implementation Specific programming tasks may be hindered by symptoms of dyslexia such as syntax and spelling weaknesses, which are due to phonological processing problems [3] [4]. The multitude of processes that need to be considered when program writing will also place considerable load on the dyslexic student's short term memory, as dyslexia primarily causes difficulties when attempting to remember the order of successive elements and sequences [4]. Organisational skills are also necessary in this stage of development which can be especially difficult for the dyslexic programmer [3].

The dyslexic student should be responsible for overcoming their weaknesses in the classroom by controlling styles, actively avoiding strongly coloured backgrounds or patterns, structuring their code with left-justification, switching off elements which are distracting, using consistent layouts, ensuring that text is uncluttered on the page, and front-loading their hyperlinks. The lecturer should use clear and concise language and encourage design for assistive technologies in the classroom. They should also provide a clear context for programming tasks which will provide a basis for knowledge for the dyslexic and non-dyslexic student.

Evaluation Organisational skills, which often put the dyslexic student at a disadvantage, and the burden on short term memory when finding the cause of erroneous behaviours in a program, will likely hinder the dyslexic programming student [3]. Lecturers should encourage good organisational skills in all students, and may need to evaluate the effectiveness of these skills for the benefit of the dyslexic student. Where organisational skills are lacking, the lecturer should give appropriate guidance to the dyslexic student whose responsibility it is to manage their own work process. Some requirements of the programmer may also negatively impact the dyslexic student in the higher education programming classroom.

Concept Acquisition S.Vacari et al in their 2005 paper on developmental dyslexia and implicit learning deficit [35], found evidence of reduced procedural abilities in dyslexic test subjects, which suggests a general deficiency in implicit learning, which comprises acquiring and executing new motor, perceptual, and cognitive skills, in dyslexia. Priming is an effect of implicit memory where prior exposure to perceptual, semantic or conceptual stimulus influences a response to later stimulus [36]. If priming techniques, such as introducing dyslexic students to lesson plans or summaries of content prior to a lesson, are used for the dyslexic students in higher education, affected students will be able to map their prior knowledge with content discussed in the lesson to help them to build new mental models in programming concepts without pressure of time in the classroom.

Underlying System Knowledge With the abundance of programming languages and systems in use today, the dyslexic student will be expected to retain the knowledge of more than one language or system, and its constraints, at any time. Memory, cognitive, and compensation learning strategies can be applied in the higher education programming classroom to help students "store and recover information...even when there is a gap in knowledge" [37].

Abstract Thought It is the duty of the tutor to ensure that student practices good programming techniques, such as indented hierarchies, to ensure that complex processes are made more manageable. Regular code formatting assessments could prove helpful for the dyslexic student, and such assessments would ensure that the tutor is made aware of any problems the student encounters; tutors should also be able to offer the student advice about improved formatting and assistive technologies that would help them to negotiate complex code.

Strategies to be Adopted by the Lecturer in the Higher Education Programming Classroom Memory strategies encourage students to perceive information in a logical order and in a multitude of formats through sequential ordering, association making using multi-modal techniques, and reviews. Repeated processing of the same information in multitudinous formats encourages learners to find their preferred learning style and commit information to memory.

Cognitive strategies actively engage the mind of the student through repetition, analysis and summary through practice, receiving and sending messages, analysing and reasoning, and by creating structures for input and output [37]. Compensation strategies allow students to use their powers of assumption around a context to discover information. In this strategy, recall and interpretation skills are tested when knowledge of a subject is incomplete.

As the dyslexic student commonly experiences a limited working memory capacity, cognitive load can negatively impact working memory as the student attempts to hold and process information synchronously. Compartmentalised lessons that build on knowledge should be employed to limit cognitive load [38].

While dyslexic programmers may develop compensation strategies for organisation, when faced with another student's code, the dyslexic student will likely feel overwhelmed. The strategies they have developed to help them negotiate their own code will not be used universally and, with the prospect of a future career in programming as a part of a team, these students will need to learn to adapt to the frustrations inherent in such situations. Team projects are thus advisable within the classroom to ensure that the dyslexic student learns to negotiate these situations.

Tutor training in managing dyslexia in the classroom will ensure that students are offered the support they require, and, in combination with frequent and strategic assessments, and detailed and supportive feedback, the dyslexic student and the generality of students should be appropriately supported by the tutor, and consequently rendered less vulnerable in higher education.

3 Conclusion

The difficulties that the dyslexic student faces in the programming classroom are numerous; it is the duty of educational institutions to make the reasonable adjustments advocated by the DDA, the ICF and the Equality Act to help these students to circumnavigate their difficulties. It is also the responsibility of the student to ensure that they are attempting to meet the requirements of their programming course despite their disability. Where dyslexic students fail to meet course requirements despite working continually to overcome their impairments, the educational institution should be informed to ensure that reasonable adjustments have been put into effect for the affected student.

The following table provides a summary of the skills required to program, any difficulties the dyslexic programmer may face when attempting to gain those skills, specific recommendations for the dyslexia, reasonable adjustments that are advocated for the institution, and the effect of those adjustments on the non-dyslexic demographic. The application of such recommendations and adjustments should help the affected student to overcome their difficulties and gain the skills required to program.

Table 2: Recommendations for Dyslexic Students and the Institution

Skills Required in Programming	Difficulties /Advantages For Dyslexic Students	Recommendations for the Dyslexic Student	Reasonable Adjustments in the Classroom	The Effect of Such Adjustments on the Non-Dyslexic Community
Project Life Cycle				
Synthesis	As primarily right brained, holistic learners, the student should find that their dyslexia is an asset during this process.	Working in small groups with non-dyslexic students will allow students to share their ideas and work in a real world context.	Lecturers should advocate working in small groups during the synthesis process with adequate supervision and refinement of ideas	Working in small groups will allow the non-dyslexic community to work with dyslexic students who are primarily holistic learners. This will allow them to refine their ideas of the system as a whole and its component parts.
Analysis	Dyslexic students may have difficulty breaking down the system into component parts in a logical sequence.	The dyslexic student should request prior knowledge of what will be discussed in the lesson to allow them to create system diagrams that will help them to develop their knowledge before the time pressure of the lesson.	Lessons should be compartmentalised into manageable and logical sections that limit cognitive load and encourage organisational skills. System diagrams, brainstorms and mind maps should be encouraged in the lesson based on student feedback with appropriate refinement of ideas.	A segmented lesson structure with 15 to 20 minutes sections will allow all students to focus on tasks to a greater extent.
Implementation	Dyslexic students may have difficulty with syntax and spelling, short term memory load and organisational needs.	Dyslexic students should control styles, actively avoid strongly coloured backgrounds, structure code, switch off distracting elements, use consistent layouts, ensure that text is uncluttered, and front-load hyperlinks	A minimalistic strategy which reduces cognitive load by using clear and concise language should be used, design for assistive technologies should be encouraged, and a clear context for programming tasks should be provided. Overlearning will also encourage students to build on knowledge while retaining previously acquired knowledge.	All students should benefit from the advocated adjustments.

Evaluation	Dyslexic students will likely find that the organisational skills required for this process and the burden on short term memory renders them disadvantaged.	Dyslexic students will need to manage their own work process which will allow them to compensate for a limited working memory during complex processes.	Lecturers should encourage good organisational skills and evaluate the effectiveness of student organisational skills periodically. Where organisational skills are lacking, the lecturer should provide guidance.	Non-dyslexic students may not understand the need for organisational supervision, however where organisation is lacking, these students should benefit from advice.
Skills Required in Programming				
Concept Acquisition	Deficiency in implicit learning will hinder the students ability to acquire new concepts.	Priming techniques will benefit the dyslexic student. They will need to request information about the concept prior to the lesson to develop their ideas and map prior knowledge on the concept without the time pressure experienced in the classroom.	Lecturers should actively encourage metacognition techniques which map prior knowledge and assumption on new concepts by eliciting feedback from students prior to refining knowledge.	N/A
Underlying System Knowledge	Dyslexic students will find it difficult to retain the knowledge of more than one language or system without confusion due to their limited working memory.	Periodic revision of systems or languages with tools such as mind maps or system diagrams should help the dyslexic student to visualise each system, as mostly strong visual learners.	Memory, cognitive and compensation strategies should be encouraged in the classroom to help students to store and recover information even when there is a gap in knowledge.	N/A
Abstract Thought	Dyslexic students may experience difficulties when managing complex processes due to limited working memory.	Dyslexic students should manage their work process to compartmentalise the necessary steps in any given process. They should also use assistive technologies which help them to navigate complexity.	The lecturer should offer regular code formatting assessments which will make them aware of any student problems. Lecturers should also be able to offer students advice about how to improve formatting and use assistive technology which will help them to negotiate complex code.	Non-dyslexic students may not appreciate the need for code formatting sessions, however where there are problems with code formatting, these students should benefit from advice provided by the lecturer.

The use of these guidelines in combination with the accessibility guidelines stipulated in this report, namely: *controlling styles, active avoidance, structuring, linguistics, design for assistive technologies, switching off elements, consistency, context, white space,* and *front-loading*, and with the use of assistive technologies, and appropriate tutor support, the dyslexic student should be able to negotiate their difficulties and excel in the higher education programming classroom.

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