2014

Teaching Mathematics to Students with Neurodevelopmental Conditions

Milena Venkova
Dublin Institute of Technology, milena.venkova@dit.ie

Sean McGarraghy
University College Dublin, sean.mcgarraghy@ucd.ie

Recommended Citation

Venkova, M. & McGarraghy, S. (2014) Teaching Mathematics to Students with Neurodevelopmental Conditions, 17th SEFI MWG Seminar Mathematical Education of Engineers Dublin, Ireland, June 2014.

TEACHING MATHEMATICS TO STUDENTS WITH NEURODEVELOPMENTAL CONDITIONS

SEÁN MCGARRAGHY AND MILENA VENKOVA

1. Introduction

This work investigates the awareness among mathematics lecturers in Ireland of certain neurodevelopmental conditions, and what strategies they use to address such conditions. To this end, we carried out an online survey, "Teaching Mathematics to Students with Neurodevelopmental Conditions", through `www.surveymonkey.com`, inviting responses through the Irish mathematics lecturers' MATHDEP mailing list. This survey consisted of six questions, covering three main topics: awareness of the existence of these conditions and their implications for learning; institutional provision of information on these conditions to lecturers; and teaching strategies directed towards students with these conditions. In this paper, we discuss these three main topics; for each, we first give necessary background, then give the results of the relevant survey questions with analysis and comments.

We conclude by commenting on the significance of the results, and suggest some future avenues on the use of smartphones and modern technologies to provide improved teaching and learning strategies.

2. Neurodevelopmental conditions and awareness of them

In this section, we first describe the conditions, giving their official definitions, including what is a learning disability and what is a sensory disorder. We then discuss awareness of them among mathematics lecturers in Ireland, as indicated by our survey results.

The conditions we cover are

- Autistic Spectrum Disorder (ASD). People with ASD tend to have communication deficits, such as responding inappropriately in conversations, misreading nonverbal interactions, or having difficulty building friendships appropriate to their age; in addition, people with ASD may be overly dependent on routines, highly sensitive to changes in their environment, or intensely focused on inappropriate items (APA, 2013). The symptoms of people with ASD will fall on a continuum (spectrum), with some individuals showing mild symptoms and others having much more severe symptoms. It is believed that 1 person in 150 is on the autism spectrum, although there are some estimates that claim it is 1 out of 80. In DSM-5, ASD now includes the previously separate Asperger's Syndrome (AS) (APA, 2013).
- Attention Deficit Hyperactivity Disorder (ADHD). ADHD symptoms are divided into two categories of inattention and hyperactivity and impulsivity that include behaviors like failure to pay close attention to details, difficulty organizing tasks and activities, excessive talking, fidgeting, or an inability to remain seated in appropriate situations. ADHD affects about 6–7% of children when diagnosed via the DSM-IV criteria (APA, 2013).

Date: May 6, 2014.

- Dyspraxia is a neurological disorder beginning in childhood that can affect planning of movements and co-ordination as a result of brain messages not being accurately transmitted to the body. People with dyspraxia have problems with both gross motor skills (difficulty remembering the next movement in a sequence, problems with balance, problems with spatial awareness) and fine motor skills (slow writing speed, problems with establishing the correct pencil grip).
- Dyscalculia is a learning disability which involves such difficulties as understanding and using basic mathematical concepts (such as number, quantity and time), which in return bring difficulties with manipulating numbers or number facts (e.g., the multiplication tables) (Butterworth, 2010). Estimates of the prevalence of dyscalculia range between 3% and 6% of the population (Butterworth, 2010).
- (Developmental) dyslexia is defined as a specific and significant impairment in reading abilities, unexplainable by any kind of deficit in general intelligence, learning opportunity, general motivation or sensory acuity (WHO, 1993; Habib, 2000).

Dyscalculia and Dyslexia are *learning disabilities*. When a student's cognitive ability is much higher than his or her academic performance, the student is often diagnosed with a learning disorder. Many of these conditions are co-occuring. Approximately 25–75% of individuals with ASD also have some degree of learning disability (O'Brien, 2004). A quarter of children with dyscalculia have ADHD (Shalev, 2004). Learning disabilities have been found to occur in about 20–30% of children with ADHD. Although each disorder occurs in approximately 5% of children, 25–40% of children with either dyslexia or ADHD meet the criteria for the other disorder.

One common theme for these conditions is difficulty in sensory processing. Sensory processing was defined by Ayres (1972) as "the neurological process that organizes sensation from one's own body and from the environment and makes it possible to use the body effectively within the environment". Sensory processing problems are suspected to be the root of many of the conditions we listed: for example, many people with dyslexia describe the letters of a written text as moving on the page. There are different known techniques which can alleviate such problems, and we will concentrate on them in Section 4.

Although these conditions are usually diagnosed in children under 10, they are lifelong conditions and (for example) the child with ASD becomes an adult with ASD. They also may have behavioural aspects (Hughes *et al.*, 2007), but this is outside our scope.

Table 1 gives the responses to Question 1 of the survey.

TABLE 1. Responses in numbers and percentages to Question 1: "*Which of the following neurodevelopmental conditions are you aware of?*"

	Yes	I've heard of it	No	Total
Autistic Spectrum Disorder (ASD)	43	8	5	56
	76.79%	14.29%	8.93%	
Attention Deficit Hyperactivity Disorder	48	6	2	56
(ADHD)	85.71%	10.71%	3.57%	
Dyspraxia	19	29	8	56
	33.93%	51.79%	14.29%	
Dyscalculia	24	19	12	55
	43.64%	34.55%	21.82%	
Dyslexia	50	6	0	56
	89.29%	10.71%	0.00%	

Table 2 gives the responses to Question 2.

TABLE 2. Responses in numbers and percentages to Question 2: "*Are you aware of the implications these conditions have for students' learning of mathematics?*"

	Yes	Vaguely aware	No	Total
Autistic Spectrum Disorder (ASD)	12	33	11	56
	21.43%	58.93%	19.64%	
Attention Deficit Hyperactivity Disorder	20	28	8	56
(ADHD)	35.71%	50.00%	14.29%	
Dyspraxia	4	23	29	56
	7.14%	41.07%	51.79%	
Dyscalculia	17	22	15	54
	31.48%	40.74%	27.78%	
Dyslexia	27	22	6	55
	49.09%	40.00%	10.91%	

Although awareness of conditions, especially ASD, ADHD and dyslexia, was high, awareness of implications for learning of mathematics was noticeably lower.

3. INSTITUTIONAL PROVISION OF INFORMATION ON THESE CONDITIONS

Neurodevelopmental conditions are commonly encountered at the college level, as more and more students with such conditions are incorporated into mainstream secondary education and are better prepared to enter third level (Moon *et al.*, 2012, p. 94). Webb (2011) points out that ASD and ADHD are "invisible" disabilities: educators, especially at third level, may not be aware that students have these conditions unless they identify themselves. Statistics are hard to come by, but Hibbert (2004) states that in the Engineering faculty at the University of Nottingham, from 2000-2003, between 8–10% of students had a declared disability, and out of those, almost half were "invisible" disabilities. It has been stated (Hughes *et al.*, 2007) that 1–4% of Physics undergraduates have AS, and it seems reasonable to assume that a similar proportion of Engineering undergraduates have the same condition. It is also possible that students may never have obtained a formal diagnosis and so may not be registered with Disabilities Support. It thus seems reasonable to assume that in a class of 50 or more, there will be at least one or two students with neurodevelopmental disorders.

Questions 3 and 4 of the survey sought to establish the degree of institutional support and provision of information on these conditions, and the timeliness of this information.

There were 56 responses to Question 3, '*Have you been contacted by Disabilities Support Centre to inform you of one or more students with neurodevelopmental conditions in a class you teach?*' Of these, 30 (53.57%) answered "yes, at the beginning of term", ten (17.86%) answered "yes, notified just before the examination" and 16 (28.57%) answered "no".

This would appear to indicate a reasonable degree of provision of information by institutions to lecturers, though there is some room for improvement.

There were 32 responses to Question 4, '*If you answered "Yes, at the beginning of term", were you. . .*'. Of these, two (6.25%) answered "offered training about the nature of the condition and how to accomodate it in your teaching"; 14 (43.75%) answered "given on-line or other materials and guidelines"; and 16 (50%) answered "not offered assistance".

This finding appears to show that although faculty may be informed of the presence of students with particular needs, they are not well informed on how to accomodate them, particularly in terms of mathematics teaching.

4. Teaching and learning strategies addressing these conditions

In this section, we address the various in class techniques that could help students with such disorders. Various authors have suggested a range of such techniques, including

- Providing lecture notes, especially in electronic form, in advance of the class, helps students mitigate the effects of poor handwriting skills (Webb, 2011); Moon *et al.* (2012) discuss this in the context of ASD but it will also apply to cases of dyspraxia. Electronic formats are particularly helpful, as students can read them using accessibility software (Moon *et al.*, 2012) and "listen" to print materials as a learning strategy. Further, Trott (2003) recommends this approach for students with dyslexia.
- Using different colours to highlight different parts of text or of mathematical expressions. Webb (2011) suggests such highlighting, e.g., within multiple integrals.
- Using mind-maps in lecture notes. Webb (2011) suggests this may improve accessibility and flexibility and gives an example of solving two-dimensional linear systems with complex eigenvalues. Trott (2003) gives an example of how use of a mind-map helped a student better organise the process of partial differentiation.
- Using visuals (sketching graphs, Venn diagrams, etc.) whenever possible. Friend and Bursuck (2006) point out that this provides additional ways to reinforce important concepts. However (Moon *et al.*, 2012, pp. 97-98), clear explanations should be provided with such graphics, and students with ASD benefit from clear precise directions, especially if given both orally and in writing. Students with ADHD were challenged by tasks primarily using symbolic, analytic and verbal representations and showed a preference for graphical or pictorial approaches to problem solving (Judd, 2008).
- Allowing students to use their laptops in class. Moon *et al.* (2012, p. 95) suggest that this can mitigate the effect of poor handwriting skills, which (Webb, 2011) is a major problem for students with these conditions. Draffan (2001) describes the benefits of other technologies such as tactile technology and speech to maths formatting.

Table 3 gives the responses to Question 5, while Table 4 gives the responses to Question 6. We see that use of visuals and allowing laptops are almost universal, while pre-class provision of notes, use of different colours and permitting photographs are widely used; however, mind-maps are hardly used at all. Together, these responses show that although 54 respondents use such strategies, at most 24 use them specifically to aid students with neurodevelopmental conditions; of these, the majority used pre-class provision of notes and allowing laptops.

5. Discussion

The broad findings from this work are that although mathematics lecturers are mostly aware of the existence of neurodevelopmental conditions, and are informed by Disabilities Support of the presence of students with such conditions, they are less aware of in class strategies, particularly as used to aid students with these conditions. At the same time, many of the strategies suggested in the literature are already being used in the classroom, while some others are fairly easy to implement, e.g., using mind-maps instead of a numbered list of points.

With the advent of technology such as smartphones/tablets, the authors have experience of cases where students ask permission to photograph boards with notes and/or worked examples.

TABLE 3. Responses in numbers and percentages to Question 5: "*Which of the following do you use in your teaching? (Select all that apply.)*". Total number of respondents: 54.

Answer Choices	*Responses*	*Responses* (%)
Providing lecture notes in advance of the class	31	57.41%
Using different colours to highlight different parts of text or of mathematical expressions	27	50.00%
Using mind-maps in lecture notes	3	5.56%
Using visuals (sketching graphs, Venn diagrams, etc.) whenever possible	46	85.19%
Allowing students to take a photograph of the board before cleaning it	25	46.30%
Allowing students to use their laptops in class	41	75.93%

TABLE 4. Responses in numbers and percentages to Question 6: "*Of the teaching strategies, if any, that you selected in the previous question, which do you use specifically to aid students with neurodevelopmental conditions? (Select all that apply.)*". Total number of respondents: 24.

Answer Choices	*Responses*	*Responses* (%)
Providing lecture notes in advance of the class	19	79.17%
Using different colours to highlight different parts of text or of mathematical expressions	5	20.83%
Using mind-maps in lecture notes	1	4.17%
Using visuals (sketching graphs, Venn diagrams, etc.) whenever possible	11	45.83%
Allowing students to take a photograph of the board before cleaning it	12	50.00%
Allowing students to use their laptops in class	16	66.67%

We posit that allowing this may be particularly helpful to students with neurodevelopmental disabilities, as they are not then under pressure to assimilate the information and reproduce it in their own notes before the board is cleaned; they may do so at their own pace. We believe that this can go some way to mitigating the effect of poor handwriting skills (as discussed in (Moon *et al.*, 2012, p. 95)), and inability to quickly process and reproduce detailed information.

Use of such technology by lecturers may also be beneficial in that colour overlays may be used to reduce screen glare of black type on white background, which is known to cause problems for students with dyslexia, ASD and other conditions (Trott, 2003). We suggest that a non-white background colour on presentation slides may benefit such students.

One respondant suggested use of online tests as a form of assessment; this reduces many of the issues experienced by a student with neurodevelopmental disorder, such as sensory overload, distraction, noise and inability to concentrate.

6. CONCLUSIONS AND FUTURE WORK

The significance of this work is that, for the first time we know of, it investigates the awareness among Irish mathematics lecturers of neurodevelopmental conditions, the support and information provided by third level institutions and the teaching and learning strategies used to address these conditions. It finds that awareness is high in a general way, but that specifics of how to address the conditions are less widely known. Many of the specific strategies that may be used do not require great effort, but may still make a difference to the student. Our hope is that this work may lead to a wider understanding of what can be done, and more effective and thorough provision of information to lecturers on useful strategies.

This piece of work has concentrated on the topic of neurodevelopmental conditions from the perspective of mathematics lecturers. Future work aims to extend to the perspective of the student with one or more neurodevelopmental conditions, and the use of new technology such as tablets and smartphones in improving the student's learning.

Further investigation is required into smartphone/tablet apps which convert speech or handwritten text into print, particularly for the kind of formulae encountered in mathematics education, where the positioning of elements (e.g., superscripts) is not well represented by common speech: this makes these formulae especially difficult to convert.

REFERENCES

American Psychiatric Association (2013). *Diagnostic and Statistical Manual of Mental Disorders (DSM-5)*, fifth edition. Arlington, VA: American Psychiatric Association. url: `dsm.psychiatryonline.org` [access date: 1 June 2013].

Ayres, A. J. (1972). *Sensory integration and learning disorders*. Los Angeles: Western Psychological Services.

Butterworth, B. (2010). Foundational numerical capacities and the origins of dyscalculia. *Trends in Cognitive Sciences*. **14**(12):534–541.

Draffan, E. A. (2001). Accessing Maths and Stats by other means. *MSOR Connections*. **1**(3):10–12.

Friend, M., and Bursuck, W. (2006). *Including students with special needs: A practical guide for classroom teachers*. Boston, MA: Pearson Education.

Habib, M. (2000). The neurological basis of developmental dyslexia: An overview and working hypothesis. *Brain*. **123**(12):2373–2399.

Hibbert, S. (2004). MELEES — an environment to support dyslexic students? *Engineering, Maths and the Dyslexic student: DDIG event*.

Hughes, M., Pepper, S., McCall, A. and Milne, V. (2007). Supporting students with Asperger's Syndrome in the Physical Sciences. HEA supporting material.

Judd, A. D. (2008). *Function visualization and mathematical thinking for college students with Attention Deficit Hyperactivity Disorder*. PhD thesis. University of Northern Colorado.

Moon, N. W., Todd, R. L., Morton, D. L., and Ivey, E. (2012). *Accommodating students with disabilities in science, technology, engineering, and mathematics (STEM): Findings from research and practice for middle grades through university education*. Atlanta: Center for Assistive Technology and Environmental Access, College of Architecture, Georgia Institute of Technology. url: `http://www.catea.gatech.edu/scitrain/accommodating.pdf`, [access date: 30 April, 2014.]

O'Brien, G. Pearson (2004). Autism and learning disability. *Autism*. **8**(2):125–140

Shalev, R. S. (2004). Developmental Dyscalculia. *Journal of Child Neurology*. **19**(10):765–771.

Trott, C. (2003). Mathematics support for dyslexic students. *MSOR Connections*. **3**(4):17–20.

Webb, S. D. (2011). Accessibility of University Mathematics. *MSOR Connections*. **11**(1):42–47.

World Health Organisation (1993). *ICD-10. The international classification of diseases, Vol 10: Classification of mental and behavioural disorders.* Geneva: World Health Organisation.