# LEARNMATHS: A CASE STUDY OF THE DEVELOPMENT OF LEARNING SOFTWARE TO SUPPORT SOCIAL INCLUSION

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Abstract: This paper discusses the role of technology in overcoming existing barriers to education and employment faced by people with specific learning disabilities and illustrates the discussion by the example of the Learnmaths toolbox for people with specific learning disabilities in mathematics. The context of the toolbox is respect for equality and diversity and consequently the recognition that different approaches to learning are equally valid and that the cognitive processes of people with specific learning disabilities can lead to creativity and innovation. 

Keywords: mathematics, specific learning disability, assistive technology, user involvement, empowerment.

## 1. BACKGROUND AND CONTEXT

A prerequisite of social stability is a stable environment in which people can live together in peace. This paper takes the view that social inclusion at the margins is a particularly important aspect of social stability. From the point of view of engineering researchers this means prioritising the needs of people who are marginalised by existing social structures, as well as involving them in the design process.

The term "social inclusion" is being increasingly used in European and other policy to express a belonging to and involvement in society and an ability to access goods and services and educational and employment opportunities. It is important because many people experience social exclusion and marginalisation due to a range of factors, including poverty, disability, sexual orientation, gender, ethnic origin and immigration status. This has costs to society as well as the individual, as people are forced into a position of dependency rather than being empowered to obtain education, training and employment and contributing to society. Many industrial societies have falling birthrights and ageing populations (Hersh, 2006), giving a need for an influx of younger people to work. However rather than welcoming asylum seekers, many of whom are of working age and have good qualifications, the richer and less unstable countries which are a minority destination for asylum seekers (Hersh, 2006), detain and deport them. At the individual level, excluded and marginalised individuals experience poverty and discrimination, as well as diminished feelings of self-respect and self-worth.

Diversity contributes to the wealth of society and there is even recognition that having a diverse workforce will contribute to a firm's profitability and competitiveness (Bertuglia, 1994). One aspect of diversity is differences in skills and abilities, learning strategies and cognitive processes, as well as areas of learning disability. There is increasing recognition of the learning disability dyslexia, despite some controversy as to whether or not it really exists () and some progress has been made in developing learning approaches and technologies to support people with dyslexia. However less attention has been given to mathematical learning disabilities.

Many everyday activities such as shopping, budgeting and decorating a room require basic numeracy skills. Adults who experience difficulties in telling the time or knowing what coins and notes they need to pay for something may feel inadequate and isolated, considering the fault to be in themselves rather than society. Numeracy skills also facilitate access to computers and the internet. More advanced mathematical skills are required for many careers and scientific and technical education at all levels. Particular difficulties in acquiring these skills are encountered by people with (specific) learning disabilities, such as dyscalculia and dyslexia, leading to potential disadvantage both with regards to

everyday activities and education and career opportunities.

## 2. LEARNING DISABILITY IN MATHEMATICS

An estimated 5-8% of school-age children have specific learning disabilities in one or more areas of mathematics (Geary, 2004). Empirical studies have found that children with specific learning difficulties in mathematics often use strategies which do not require mental retrieval of number facts (Gersten et al, 2005). This supports theories that they have poor short term memory retrieval skills (Dowker, 2005). There is also empirical evidence that one of the main distinguishing features of children with dyscalculia is difficulties with multistep arithmetic (Bryant et al, 2000). Since the term mathematics encompasses diverse topics which make different cognitive demands, specific learning disabilities may impact on some areas of mathematics, but not others (Geary, 2004). However most research in the area has concentrated on arithmetic and number skills.

A relatively small number of both computer-based and other tools have been developed to support people with (specific) learning difficulties. However most of the commercially or freely available tools focus on children, rather than adults or the full age range. A study of the literature indicates that coverage of mathematics topics is also relatively limited and generally related to basic numeracy skills rather than more advanced topics and concepts.

There is therefore a need for further research on tools, methodologies and learning approaches to support mathematical and numeracy learning by people with dyscalculia of all ages and stages of education. There are also questions as to the role of (computer) technology in this process, whether and in what circumstances in can be an enabler rather than a further hurdle to be overcome and the appropriate balance between the computer based resources and other types of support. The authors attempt to address the following proposition:

Proposition: is it possible to design a support system which can enable people who experience social exclusion as a result of mathematical learning difficulties?

## 3. THE NEED FOR EDUCATION SUPPORT SOLUTIONS

Changes in theories of learning from behaviourism to cognitive psychology and social constructivism have had a limited impact on the approaches used with students with specific learning disabilities. There has been a tendency to focus on behavioural approaches and rote learning of maths facts, rather than problem solving or imparting skills embedded in understanding (Woodward et al. 2002). Some curriculum aims may also unintentionally disadvantage people with learning disabilities. This has been discussed in the context of calculator use, where it has been suggested that present approaches should be modified to appropriate calculator use in combination with an ability to estimate approximate answers. This would reduce short term memory demands, which can be a problem for people with specific learning disabilities, without reducing the need for understanding. Other issues relate to whether the currently used algorithms, which have evolved historically, are the most appropriate for students with learning disabilities or whether they would benefit from having the option to choose between several different algorithms (Woodward et al, 2002). Studies have also shown that the media chosen can affect learning outcomes and that there are advantages in a multi-sensory as well as a multi-media approach. However, multi-media and multi-sensory approaches need to be treated sensitively to avoid sensory overload (Beacham, 2002).

There has been some progress in understanding the learning processes of people with (specific) learning difficulties. However, a taxonomy of mathematical learning difficulties has not yet been developed. Neither has a categorisation of the different areas of mathematics, correlated to the different types of mathematical learning difficulties. Consequently, the assistive technologies available to people requiring support in this area tend to be narrowly focussed and relatively inflexible. What is needed is a comprehensive assistive technology solution which provides a coherent set of tools for the user. The author's call this the 'LearnMaths Toolkit'.

### 3.1 End-User Involvement

The Learnmaths Toolbox and Learning Environment is intended to support students with dyscalculia in acquiring skills and understanding from basic numeracy to advanced mathematical techniques. Since it is only end-users of a system who really understand their own needs and what is likely to work for them, the content of the toolbox will be finalised after consultation with end-users with dyscalculia.

End-user involvement will be organised according to the principles of human centred technological systems development and the principles developed in the EU FORTUNE Project (Bühler, 2000). The FORTUNE concept of user participation is based on the following principles:

1. Partnership as a basis.
2. Users as members and/or representatives of organisations.
3. Users should receive payment on the same basis as other participants.
4. Guaranteed accessibility of all relevant materials and premises.
5. All partners guarantee confidentiality, respect and expertise.
6. Detailed project plan, including time and resource planning for user participation.
7. Partnership is implemented from the start of the project.

This will be combined with a human centred approach based on the H-CAD (Human Centred

Assistive Technology systems Development) methodology (Duffy et al, 2004; Stapleton et al, 2004). T his methodology has been applied successfully to the design and implementation of assistive systems for adult learners with dyslexia. It has been shown with adult learners with dyslexia in Ireland that the use of a human centred approach reduces the likelihood of the learners having increased feelings of isolation. This can often be a problem in assistive technology projects for people with specific learning difficulties. The H-CAD methodology significantly reduces the likelihood of this problem by careful management of user involvement and contextualisation of the work.

### 3.2 Learnmaths Philosophy: Diversity and Difference

The philosophy of the Learnmaths Toolbox is based on the social model of disability and a respect for equality and diversity. According to the social model of disability it is social barriers and oppression which disable people rather than their impairments. For instance it is the steps not the wheelchair or the lack of large print books not the visual impairment which are the problem. Therefore it is society rather than disabled people which needs to be 'rehabilitated'. A philosophy based on equality and diversity recognises both the importance of diversity or difference and the entitlement to equal rights and opportunities. However, access to these equal rights and opportunities may be obtained by different groups of people or individuals in different ways.

In the context of learning and learning disability this implies that there are different approaches to cognition, organising information and learning. Some approaches may seem to be more effective than others, but no approaches are intrinsically 'better' and increased effectiveness may be the consequence of a social context which privileges some approaches over others. Individuals who have cognitive and learning approaches which are not privileged are likely to experience disadvantage and discrimination. To avoid this educational tools are required which provide different approaches and aim to communicate with users on their terms rather than trying to mould them to meet norms. This will have some effect on changing attitudes so that different is not considered less or not socially acceptable. However full discussion of changing attitudes is beyond the scope of this paper.

## 4. THE LEARNMATHS ASSITIVE TECHNOLOGY SOLUTION

### 4.1 The Learnmaths Toolkit

The initial version of the Toolbox will focus on tools for the 16+ age range, with further work to develop and extend the tools to younger people. The Toolbox will cover a wide range of different mathematical and numeracy skills. Some of the tools will be specific to particular areas of mathematics, whereas others will be more general. There will also be multimodal, multi-sensory and multi-media capability, including the choice of output modes and the option to configure the system to meet user preferences. This is in-line with research evidence that people with specific learning disability can benefit from multi-sensory and multi-media capacity, but that care is required to avoid sensory overload. The customisation facility will enable users to choose the optimum learning environment to meet their needs, including when they are fresh and when they are tired. Attention will be given to making all the LearnMaths tools fully accessible, so that they can be used by students with additional impairments as well as dyscalculia. The Toolbox may also be of interest to a number of students who do not have any recognized learning disabilities, but who encounter difficulties with current learning and teaching approaches or who find them uninteresting. Unlike many existing assistive systems, the Toolbox will be designed to support both the acquisition of practical skills and the development of understanding of basic concepts.

### 4.2 Benefits of the Learnmaths Toolbox

The development of the Toolbox will take place in the context of research on how people with learning disabilities learn with regards to both understanding concepts and the acquisition of skills. This could have a wide range of benefits with regards to improving understanding of cognitive processes and the particular skills of people with dyscalculia. However the main benefits will be improving the opportunities of people with dyscalculia and dyslexia in education and employment, increasing their autonomy and encouraging their participation in and contribution to society. Improved numeracy skills, leading to independence and autonomy in areas such as budgeting and shopping. People with specific learning difficulties in mathematics, who are an estimated 5-8% of the population will benefit in the following ways:

- Improved educational outcomes and qualifications.
- An increased ability to participate in the Information Society.
- An increased ability to participate in policy debates about technology. As the role of technology increases, the general public will require a better scientific education in order to understand the issues. It is important that people with learning difficulties are not left behind.
- An increase in self-esteem and more enjoyable educational experiences as a result of appropriate strategies being used to avoid (repeated) failure.
- Access to a wider range of (professional) careers, including in the sciences and

engineering (for people with milder mathematical learning difficulties.

There will also be benefits to the following groups of people:

- Teachers of numeracy skills, who will benefit from additional tools to support their work.
- Learning support tutors, particularly those supporting students with dyscalculia and dyslexia.
- Schools, colleges and universities, which will benefit from increased success rates in mathematics and subjects dependent on it.
- Society as a whole, which will benefit from the increased contribution made by people with dyscalculia and dyslexia.

Although the main aim of the LearnMaths Toolbox is to support people with dyscalculia and dyslexia, the multi-sensory and accessible nature of the tools in the Toolbox will mean that many of the tools will also be useful to blind and visually impaired people. Therefore there will also be subsidiary benefits in terms of improving the opportunities of blind and visually impaired people in the areas of education and employment, increasing their autonomy and encouraging their participation in and contribution to society

## 5. CONCLUSION

The final version of the paper will discuss the contribution of the Learnmaths Toolbox as well as the educational and other benefits of providing assistive technology in a context of equality and diversity. It will provide a brief overview of the value of research in assessing usability in various educational contexts. Thus the paper demonstrates a technical solution to social stability by providing an assistive system for people marginalised by society's lack of flexibility with regards to different approaches to learning and different learning needs.

## REFERENCES


Beacham, N., (2002). Dyslexia-friendly computer-based learning materials. In: *Access All Areas: Disability, Technology and Learning*, Phipps, L., Sutherland, A. and Seale J. (eds.), JISC TechDis Service and Alt.

Bertuglia, L.E. (1994). An exploration of the glass ceiling, *Women Eng.*, May/June, 27-29.

Bühler, C. (2000). *FORTUNE Guide Empowered Participation of Users with Disabilities in Projects*, Evangelische Stiftun volmarstein.

Bryant, D., Bryant, B.R. and Hammill, D.D. (2000). Characteristic behaviors of students with learning disabilities who have teacher-defined math weakness. *J. Learning Disabilities*, **33**, 168-179.

Dowker, A. (2005). Early identification and intervention for students with mathematics difficulties, *J. Learning Disabilities*, **38(4)**, 324-332.

Duffy, D., L. Stapleton, M. Jordanova, D. Lakov and M. Lyng (2004). From assistive technologies to assistive systems: total solutions for the learning disabled, *Proc. MEDeTEL Int. Conf*, Luxembourg.

Geary, D.C. (2004). Mathematics and learning disabilities. *J. Learning Disabilities*, **37(1)**, 4-15.

Gersten, R., Jordan, N.C. and Flojo (2005). Early identification and intervention for students with mathematics difficulties, *J. of Learning Disabilities*, vol. **38(4)**, 293-204.

Hersh, M.A. (2006). *Mathematical Modelling for Sustainable Development*, Springer Verlag.

Stapleton, L., D. Duffy, M. Jordanova, D. Lakov and M. Lyng (2004). From assistive technologies to assistive systems: human centred support for the learning disabled, Int. *Multitrack Conf. of Advances in Control Systems*, TU Wien.

Woodward, J. and Montague, M. (2002). Meeting the challenge of mathematics reform for students with LD. *J. of Special Education*, **36(2)**, 89-101.