Irish Learning Support Association

I.L.S.A.

LEARN

VOLUME 33, 2011

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LEARN is the Journal of the Irish Learning Support Association.

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Readers are invited to submit papers to be considered for inclusion in the 2012 issue of LEARN. Papers should reach the Editorial Committee, LEARN, ILSA, c/o Drumcondra Education Centre, Drumcondra, Dublin 9, by January 31, 2012. Papers should be relevant to some aspect of Learning Support and should not exceed 3,000 words. For information on electronic submissions please contact the administrator on our website at *www.ilsa.ie*

The Association is concerned with the education and support of children who experience difficulty in learning, whether in special or inclusive settings, and those for whom English is an additional language. Its aims include promoting co-operation between all involved in Learning Support and Resource Teaching and enhancing the quality of the service they offer, through the provision of resources, conferences, lectures and seminars.Besides the journal LEARN, a newsletter is published for members.

Application forms for membership of ILSA can be downloaded from our website at *www.ilsa.ie*

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Editorial

ILSA has become firmly entrenched over many years as the fourth largest teacher organisation in the country. Uniquely, ILSA represents Learning Support Teachers, Resource Teachers and EAL Teachers across both the primary and secondary sectors and continues to provide focused, classroom-oriented professional development for its members.

Learn is our annual research journal and it is a publication that we are immensely proud of. Its status and prestige are beyond repute. Copies of *Learn* are placed on the library shelves of each of our National Universities, Education Centres and Colleges of Education. Students of education, including Masters, Doctoral and Undergraduate students consult back copies of *Learn* for reference and to guide their research study.

A copy of *Learn* is given to each member of ILSA. It is to be hoped that the content of the journal will inform members' teaching experience and indeed, encourage them to submit their own research for publication in future editions of *Learn*. *Learn* has the potential to achieve several laudable objectives:

- The enhancement of the role of Learning Support
- The development of an additional dimension of professional development within Learning Support, where teaching might be perceived as research and research as teaching
- The advancement of opportunities for teacher professional development to take place within a teacher-driven action research domain
- The development of a new epistemology of Learning Support practice that would be grounded in teachers' knowledge, practical wisdom and insights.
- The de-construction of traditional pedagogical methodologies and their replacement by new modes of curricular delivery, new modes of assessment and improvement in the processes of teaching and learning that would evolve directly from teachers' research and teaching.

The publication of teacher research findings in *Learn* allows the teacher to impact on and contribute to current educational discourse. The recent Pisa Report indicated that there has been a decline in literacy and numeracy standards in Irish schools. The reverberations arising from this report have been deafening. The response from the Department of Education and Skills was to launch a National Strategy to improve Literacy and Numeracy entitled Literacy and Numeracy for Learning and life.

This Strategy aims to ensure that teachers and schools maintain a strong focus on Literacy and Numeracy skills. It sets out a wide-ranging programme of reforms in initial teacher education courses, in professional development for teachers, and in the content of the curriculum at primary and post-primary levels in order to achieve these vital skills.

Schools will be required to make greater use of standardised tests of reading and mathematics, in second and sixth class in primary school and for 2nd year students in post-primary. The test findings will be reported on a mandatory basis to parents, boards of management and to the DES. Schools will be required to develop and implement school improvement plans in accordance with guidance from the inspectorate.

Implementation of a number of measures in the Strategy is already underway. A circular has or will be issued to primary schools shortly requiring them to increase the amount of time available for literacy to 90 minutes per day and for mathematics to 50 minutes per day from this September.

Given that the country is currently basically bankrupt, it follows, as day follows night that the strategy has been developed in a way that keeps additional costs to a minimum. To ensure that costs are minimised or even reduced, the DES has cut back on the number of SNAs and EAL Teachers in our schools. Class sizes have been increased and are likely to increase further.

All of the above “financial constraints” will of course impact hugely on an already overstretched Learning Support structure. Reductions in Learning Support Teachers, Resource Teachers, SNAs and EAL Teachers, at the same time that class sizes are increased, will mean that more children than ever before will “fall through the cracks” and require the specialised help of the Learning Support Teacher.

This edition of *Learn* has an eclectic series of articles that deal with the problems of literacy and numeracy at both theoretical and classroom levels. There are also a number of articles that examine the level of usage of ICT by primary teachers in special needs and there are recommendations for programmes that studies have shown work very effectively with children who have special needs.

Dr Joe Travers in his article *Evidence Based Interventions in Primary Mathematics*, commenting on the recently published National Strategy for Literacy and Numeracy, highlights the use of computer assisted instruction as holding promise for raising the standards in both problem solving and computation. Travers says there is a key role for Learning Support Teachers to develop differentiated approaches to the teaching of mathematics, in collaboration with mainstream teachers. He also acknowledges that the “gold standard” for best practice would be teaching on a one-to-one basis; however in the current straitened times we may have to settle for second best and deal with small groups of three or four. Travers alludes to the key role of the teacher who focuses on targeted intervention. Travers analyses two programmes, *Maths Recovery* and *Numeracy Recovery*. In-class intervention using *Maths Recovery* might be as effective as withdrawing children to Learning Support.

Florence Gavin highlights ongoing tensions between theory and practice in mathematics teaching. She says that becoming a better teacher of maths is not an easy task. To remain effective, teachers up to recently upskilled themselves at their own expense. Gavin asks why the 1971 curriculum failed. She suggests three reasons:

- Lack of resources
- Lack of training
- Large class sizes

Inclusive education as enunciated by the DES means large classes that include more children with learning difficulties and physical difficulties and also more children with EAL. Faced with such large mixed ability classes, many teachers are conflicted between teaching maths the way they themselves were taught and teaching maths as endorsed by the DES.

Jerry McCarthy in an article entitled *Revisiting and Extending the Grand Narratives of Teaching* asks if the macro dualism of traditionalism and Constructivism are mutually exclusive. Enjoy the article and draw your own conclusions!

Mary Nugent compares five interventions for struggling readers in Ireland and she highlights approaches to reading that have been found to be effective, among them being:

- Structured systematic teaching
- Small group settings
- Teachers need to be well trained and have on-going professional development
- Co-operative learning, including peer reading approaches can be highly effective
- Students need to be taught new skills to the point of fluency
- Computer assisted learning has considerable potential but needs to be carefully matched to student need

Nugent also points out the implications for Learning Support Teachers in designing timetables. Short term intensive intervention is better than longer term, less frequent intervention.

A number of articles examine the use of ICT with special needs children. In particular John Phayer's article looks at the level of usage of ict, particularly at levels of access and usage. He highlights an astonishing amount of ignorance of the different types of special education technology that is now available on the market. The main reasons were:

- Lack of resources or funding
- Out-dated equipment
- Late adapters
- Lack of the right professional development courses.

The article highlights the fact that access to technology can result in meaningful learning experiences, can help to develop problem solving skills and higher order thinking skills and help a person to function in the world beyond the classroom.

I commend the 2011 edition of *Learn* to you. I also wish to thank our contributors to *Learn*. The publication of teacher research findings in Learn enables the teacher to contribute to current educational policy debate and commentary. It is important to inject some "meat" into the plenitudes of fluff that pass for serious debate on our airwaves. It is past time for practitioners on the ground to involve themselves in the current discourse taking place on education.

Finally, please remember that *Learn* is your journal and I am now calling for research papers and articles for next year's edition of *Learn*. I'm waiting!

Matt Reville
Editor of *Learn*
August 2011

The Ongoing Tensions Between Theory and Practice in Mathematics Education

Florence Gavin

(For the purposes of this article the term 'teacher' is generally meant to denote Irish Primary Teacher)

'To empower is to enable those who have been silenced to speak' (Smyth, 1991).

Becoming a better mathematics teacher is not an easy task, particularly during a time of change. Pedagogical theory, shifts in emphases and techniques, teacher behaviours, assessment tasks and changes in family and society values in general, must all be balanced with the primary mathematics teacher's main function, which is facilitating learning by motivation and assessing his/her pupils, giving them choices and scaffolding and guiding them towards procedural and conceptual understanding. It is almost impossible to state definitively what this exact balance is, yet, one main ingredient is the teacher's own ongoing developmental process which must be present if a teacher is to be effective. How can the teacher continue to be effective in a changing world? 'Today teachers still have to discover or adopt most of their own professional practices by personal preference, guided by neither the accumulated wisdom of seniors nor by practitioner-relevant research' (Hargreaves, 1996). To remain effective in the classroom, the teacher until very recently studied and upskilled largely at his/her own expense. In recent years some professional development has been available free of charge through the Support Services and through the DEIS and other initiatives. However, the education sector still compares unfavourably with other professions and industry in general.

A brief look forward, a brief look back

Currently the Irish Primary School Curriculum is undergoing change as the 1999 Curriculum is implemented. Many teachers will see this change as unnecessary. They may see it as something imposed on them, and so its implementation will not be as smooth had they been involved in the studies which sought to bring the changes about (Sugrue, 1997). Two mathematics books have been distributed to all primary teachers, Contents and Guidelines (DES, 1999). Theory is noticeably absent. Constructivism is mentioned but briefly in the eighty page Teacher Guidelines, which contain two pages on methodologies, various symbol and skills charts, large photographs of children at work, suggested equipment lists, committee membership lists, a glossary of mathematical terms and a reference list. Why so little emphasis on theory? Surely to facilitate change, debate and discussion is vital. Do the academics fear they might intimidate the primary teacher? Anne Watson, lecturer in mathematics at the University of Oxford and Mike Ollerton, senior lecturer in Mathematics at the University College of St. Martin, Lancaster have the same view. They state 'The approaches in this book are all supported by research but we have decided not to give references throughout the book except where we feel the reader might like to know about our sources and inspirations for mathematics teaching and learning. The text seemed to be complex enough without being interrupted by references' (Ollerton & Watson, 2001). Keeping quiet about the research and distributing the list of 'do's and don'ts', was not sufficient in 1971 when the previous curriculum was introduced and is not sufficient thirty years later, either.

Why did the 1971 Curriculum fail to be implemented in full?

The use of manipulatives in an enjoyable, child-friendly, child-centred mathematics classroom in which each child progresses at his/her own rate, making mathematical discoveries, making sense of what is being taught, all the while being guided by an understanding, competent and knowledgeable teacher is what we aimed for in 1971 with the implementation of the then new curriculum.

So what happened? Why are large sections of the population innumerate? The truth of the matter most likely is, that teachers had many obstacles placed in their way and that almost insurmountable difficulties prevented them from fulfilling their role, not least of which were (a) lack of resources (b) lack of training, (c) large class sizes. Resources by way of mathematical apparatus and teaching equipment were not readily available to the primary teacher until relatively recently unless the teacher financed them him / herself. Class sizes were enormous, of mixed ability and could contain fifty and above children to be taught. 'Most teachers strive for success, under difficult circumstances and would present another truth from the memories presented here' (Crook &Briggs, 1991).

The Reality Today

Researchers make assumptions about teachers which are unfair. 'The vast majority of such research is conducted by university-based academics involved in teacher education who do not teach in schools' (Hargreaves, 1996). Of course, as teachers we must take these findings on board, reflect on them and see what changes can be made 'We further suggest that research in mathematics education is of limited value unless it affects classroom practice and experience' (Hatch & Shiu, 1989).

Getting a perspective on the nature of mathematics can be difficult for teachers who have developed an interest in mathematics because they were good at solving text-book problems. Many teachers find it difficult to stress equal importance in the curriculum to, for example, shape and space and number, many equating arithmetic with mathematics. Other teachers consider experimenting by students as time wasting and believe mathematics to be a discipline composed of rigid rules and correct answers. Though classes are now reduced in number to closer to 35 children, teachers still face a difficult task daily. In any one day it is not uncommon for a primary teacher in an average class to have several children with learning difficulties, emotional and physical problems, speech and language difficulties, and behaviour problems. In some schools a very large percentage of children are EAL children. In discussing 'the availability of time to reflect' Eraut (1995) says a teacher has to be constantly assessing the situation, responding to incidents, deciding whether to change the activity, alert for opportunities to tackle difficult issues. (Eraut, 1995). The researcher on the other hand (unless specific to the research) is not involved in day-to-day problems concerning general matters of classroom management. The teacher *when s/he cares to look* has the bigger picture.

The relatively new inclusiveness policy in the Department of Education and Skills means that many teachers now have children with more severe learning / physical difficulties in his /her classroom. No matter how committed, how dedicated a teacher is, giving such children their just place in the classroom places further burdens on the busy teacher.

'Increasingly, professionals of all kinds (teachers included) are being confronted by situations in which the tasks they are required to perform no longer bear any relationship to the tasks for which they have been educated' (Smyth , 1991). and 'Teachers in particular are becoming increasingly engulfed in wrangles over conflicting and competing values and purposes and are often faced with pressures for increased efficiency in the context of contracting budgets, demands that they rigorously 'teach the basics', exhortations to encourage creativity, build citizenship … help students examine their value' (Smyth, 1991).

The 1999 Curriculum in Mathematics for the Primary School clearly promotes teaching for both conceptual and procedural knowledge. It stresses linkage and relationship in mathematical ideas and demonstrates when, why and how to use a variety of mathematical methodologies. Formulae must no longer be taught by rote. Calculators form part of the curriculum for 9/10 year olds upwards. Data plays a more prominent part in the curriculum and probability and chance are introduced for 8/9 year-olds. Tensions arise between teaching for conceptual knowledge and teaching for procedural knowledge. Many teachers may fear that the introduction of calculators will not allow pupils to develop basic computational skills. Tension arises from a belief that students who have difficulty with mathematics should only be expected to learn procedures. 'while Cruickshank and Applegate (1981) define reflection in terms of helping teachers to think about what happened, why it happened, and what else they could have done to reach their goals, it is clear that their conception of the reflective amounts to nothing short of prescribing what teachers ought to teach within tight guidelines, while co-opting one another into policing the implementation of pre-determined goals'.

For many teachers, the conflict arises between teaching mathematics the way they were taught themselves and teaching as endorsed by the Department of Education and Skills. 'Part of the problem is the way so much maths is presented. If your experience of maths as a child was of tedious, repetitive exercises to practise techniques that other people had already discovered, then it's hardly likely that you came out with a positive impression of the subject (Eastway & Askew, 2010). Many teachers are aware of the 'proceptual divide' (Gray & Tall, 1994) though they may not call it such. They are aware that some children are merely manipulating symbols. Conceptual knowledge often takes a back seat when teaching difficult procedures for example re-grouping for subtraction, multiplication of a two-digit number by a two-digit number and long division. More time is often spent teaching a procedure to find an answer than in facilitating understanding of a concept. Yet how much time is there realistically for fostering 'Multiplicative Thinking' as opposed to teaching multiplication (Kamii, 2000). But can we afford not to take that time?

But what is the teacher to do? The support for the child as a social being rather than as a lone scientist constitutes an attack on Piaget's views of learning which assume that genuine intellectual competence is a manifestation of a child's largely unassisted activities. But have teachers been told? Why have teacher journals and periodicals in this country not broadcast the matter?

The teacher with the very able maths student for example, in class must have a separate programme for this child. (The special programme may be needed in other areas of the curriculum also). The implications for planning for the class teacher are immense. This is just one pupil with special needs. 'It is rather that one begins to wonder if *everything* that goes on in classrooms or the world for that matter might take on that kind of complexity if one were to give it time, take it seriously'. (Jackson, 1992).

And we have not mentioned 'metacognition', yet. The teacher must guide her pupils so that they can assess their own learning, their own motivation and outcomes.

Special provision must also be made for underachieving pupils. Part of the summary from the (British DES) report 2004 makes remediation look positively simple. 'Research strongly suggests that children's arithmetical difficulties are highly susceptible to intervention. Individualized work with children who are falling behind in arithmetic has a significant impact on their performance. The amount of time given to such individualized work does not, in many cases, need to be very large to be effective'. A 'can-do' attitude is to be commended but this sounds like a magic wand!

The following is a hypothetical situation. The teacher has two 'visitors'. Paul who has been previously assessed as 'exceptionally able' is being observed.

Paul

We are constantly being told that able children who are not challenged will eventually became bored and disruptive. Children with behaviour problems are an extra burden on teachers. Take the story of Paul who never 'finished his work', the teacher observed. One visitor thought the observation 'uninteresting, bland and simple'. But to the teacher who knew Paul in the flesh it was different. Unfinished work is always a problem and Paul was breaking the fifth of Polya's '10 Commandments for Teachers'. 'Give them … attitudes of mind, the habit of methodical work' (Sinicrope, 1995). A student with a tendency to leave work undone, carries this bad habit into the workplace and into adult life. The teacher is thinking of the future implications of Paul's behaviour. But the visitor's analysis is that Paul is bored and wants to pace himself so that he does not have too much to do. One visitor in Paul's defence says '**we** continually leave work undone', in the real world. But is he correct? We may leave a book aside and not finish reading it or drop out of an evening class. New Year resolutions are quickly forgotten. But in Paul's case, day after day his leaving work unfinished was very worrying for the teacher. The occasional visitor to the classroom only sees a snapshot. We do not find it acceptable if a person fails in his/her duty or fails to honour financial or other commitments in adult life. Paul's duty at the time in question was school. Self-monitoring and reflective behaviours cannot be learned quickly and this was where Paul needed help most. Paul did not need someone to make excuses for his behaviour.

'Practitioner-derived knowledge is, in fact, trustworthy and relevant in and of itself (Smyth, 1991) and 'Until we can show that we do question the operations of our own professional routines, we can hardly ask teachers to listen to our theorisations of theirs (Tripp, 1987).

It is a daunting task to have the exceptionally able 'Paul' in class, alongside several children with an assessment result at or below the 10th percentile. Add to the class the usual group of children of mixed ability (intellectual and physical), creativity, behaviour and emotional development and we have some semblance of the primary classroom.

There is no doubt and teachers will agree, that a teacher's enthusiasm and energy can change depending on the class. 'Studies are needed to examine the stability of teacher's conceptions of mathematics and mathematics teaching, specifically whether or not teachers' conceptions are likely to change with changes in grade level, the students' academic aptitude and the mathematical content taught' (Thompson, 1984).

Conclusion

Although tension is uncomfortable, it is not necessarily a bad thing. Most teachers maintain an up-beat 'can-do' attitude. Philip Jackson learned over the two years to forgive the untidy Mrs. Martin her untidiness and admire her patience with her pupils. 'The clutter stayed. What disappeared was my concern over it' (Jackson, 1996). What was also different was the length of time Jackson studied the changes in the children. He had time to notice that 'they, too, grew more confident and self-assured as the year wore on' (Jackson, 1986) and 'What this means, I believe, is that those of us who study schools and classrooms need to develop a special sensitivity to the relatively benign forces, the educational equivalents of wind and rain that doubtless contribute to the slow weathering of the pupil's psyche'. (Jackson, 1986).

Teachers and researchers must learn to recognise, value and respect each others' work as different sides of the same coin. Both are concerned with the development of the fully rounded personality, the balanced citizen whose potential is fulfilled. 'Each researcher role gives access to information which is denied to the other and even the pooled knowledge can only tell a selective part of the story of any classroom' (Hatch & Shiu, 1998).

'Theory on its own is of little use. The route to 'successful' varies between lessons and teachers' (Ollerton & Watson, 2001). Teachers need to read, reflect, study and network in order to develop professionally. Therefore some of the problem of the tension between theory and practice and its resolution rests to a large part with the universities and colleges which train teachers and the DES, which guides and monitors them. But in the final analysis it rests with each individual teacher. 'Not to examine one's practices is irresponsible; to regard teaching as an experiment and to monitor one's performance is a responsible professional act' (Rudduck, 1984).

Smyth puts it even stronger when he talks about teachers bargaining away their educational power (Smyth, 1991). 'the gap between researchers and practitioners, while unavoidable, must be narrowed, or else we run the risk of education research becoming 'barren dry swimming' and the practice of teaching becoming 'naive, narrow-minded, and inefficient' (Morgens Niss, 2000).

Perhaps closer links between the two communities, researchers and practitioners will lead eventually to the enlightened, independent thinker quoted here. 'Most far-reaching is the idea of a completely autonomous teacher, who, with the help of reflection, is able to see through all political, social, historical and other ideological factors embedded in every educational situation and from this elevated position chooses freely and consciously, in order to take full responsibility for his or her actions' (Bengtsson, 1993).

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FLORENCE GAVIN

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Revisiting and Extending the Grand Narratives of Teaching

Jerry McCarthy

> *"The approaches available to teachers are not unlimited. The craft and art of teaching comprehends a finite range of pedagogical action. The repertoire is nourished by a reservoir of knowledge which is freely shared within the teaching profession and which is very similar in every country. Within that repertoire, the most important resources are teachers' understanding of how students learn, of how teaching works and of the most effective settings for education".*
>
> (Black and Myron Atkin 1996)

Any in-depth trawling of educational research literature, which is focused on pedagogy and the epistemology of teaching, will almost certainly uncover and encounter multiple references to the existence of a macro and invasive dualism that dominates and informs the cultures and practice of teaching. The binary components and polarities of this dualism are conventionally referred to in research literature as Traditionalism / Didacticism and Progressivism / Constructivism. The ideology of dualism holds and infers that many physical and social constructs consist of two basic categories or polarities that are incommensurable. Sugrue (2007) refers to the two epistemological and pedagogical polarities as "the two grand narratives of teaching". As with most dualisms, these two dominant pedagogical orientations and philosophies have universally been represented and defined, in research literature, as polar-opposites, mutually-exclusive, insular and adversarial. Each polarity is depicted as emphasising and attempting to compensate for what the other allegedly does not possess and therefore cannot provide (Sugrue 2007). There is ample evidence, in educational research literature, to suggest that the schism and divide, that separates these two pedagogical polarities, is un-retrievable and permanent. A situation would appear to exist where "ne'er the twain shall meet".

Investigating Didacticism

Sugrue (2007) states that didactic teaching and practice evolved and blossomed at a time when the paradigm of modernity dominated and scripted most public and educational discourse. Kalantzis (2005) agrees and states that didactic education mirrored and was "right" and appropriate for a society where the work environment was hierarchically structured, where strict compliance and subservience to managerial edicts and chains of command were required and demanded from employees and where exemplary citizenship was exclusively defined by unquestioning loyalty to society's edicts, norms, mores and structures.

The earliest forms of modern, mass and institutionalised education employed the didactic mode of teaching and knowledge transfer. The term "didactic" has been assimilated into the English language from Greek; the generic and seminal meaning of the term was "to teach". Kalantzis (2005) states that, over a period of time, a diversification of root metaphors, descriptors and phrases have been used in research literature to summarise or describe the key dynamics and processes of didacticism or to highlight perceived shortcomings and inadequacies that have been identified within the nuances and tenets of didacticism. It is interesting to note that many of these negative descriptors and phrases have been coined by advocates of the rival theses and epistemologies of progressivism and constructivism. Bullough (1992), Hargraves (1994), Goodson and Ball (1984) and Sugrue (1997) have studied and investigated the range and diversification of root metaphors, phrases and descriptors that have been used, in research literature, in association with didacticism. The following phrases, descriptors and root metaphors were frequently employed: "talk and chalk", "student as an empty vessel", "teacher-led interactions", "rote learning ", "reproductive learning", "student as a blank slate (tabula rasa) ", "lecture-based teaching ", "uniform, narrow and content driven", "the transmission and transplant model of teaching", "the classical model of teaching", "teacher dominated classroom", "traditional teaching", "teaching by telling", "pragmatic", "the Socratic model of teaching and learning", "to present a view of what is true or right or morally correct but in a way which might at times appear dogmatic", "back to basics", "reliance on textbooks", "rigid", "rote memorisation", "seat-bound", "disciplinarian", "the teacher directing his teaching at the middle-ability centre of the class", "whole class instruction", "teacher-directed learning", "the banking model of education", "learning things off by heart", "using tests which only told of one way of knowing", "pragmatism", "social determinism", "factory model of learning", "centrally prescribed texts and syllabus which allow for very little discretion on the part of teachers", "training rather than teaching", "passive learning", "spelling things out explicitly – but perhaps a little too laboriously", "systematic testing at regular intervals to measure student progress", "tailored to examination questions", "teaching by rote" and "the prescribed textbook telling the one permitted narrative, one chapter at a time".

Black and Myron Atkin (1998), Pogrow (2006) and Kalantzis (2005) identify and describe the following tenets, maxims and assumptions as the core of the normative structure that underpins and defines the traditional and didactic model of teaching:

- "Knowing that" must come before "knowing how"

- Human learning is a linear and predictable process that can easily be "systematised and manipulated" (Pogrow 2006). Pogrow also states that, as long as there is consensus and shared understanding about the existence of an "assembly line" of learning outcomes and learning objectives in formal education - and an awareness of the rewards that are attainable through success in education, together with the specified consequences for failure - "a renaissance of achievement", for students, can be consistently attained and realised through didactic teaching.

- A core orientation and tenet within the didactic epistemology is to conceptualise and treat every student as being "on the same page" and not to make or implement any concessions, differentiation or flexibility in pedagogical practice for individual student difference or needs.

- The most effective sequence and progression, to attain the maximum and optimum learning outcomes is: first to receive and memorise, then to use and practise in routine exercises so as to develop familiarity and understanding before attempting to apply.

- It is better to teach at the abstract level first and to leave the business of application, in many different contexts, to a later stage.

- John Locke conceptualised and depicted the human mind of a child (student) as a "blank tablet" which was genetically endowed with certain faculties such as memory, reasoning and imagining.

- Motivation is achieved by external pressure on the learner, not by changes in the mode of teaching and presenting the subject content.

- Student failure to learn, by the didactic and traditional route, exclusively arises from an innate lack of ability in the student, or from inadequate effort, by the student, rather than from any mismatch between the teacher's preferred learning and communication style and the student's. The formula for succeeding in the didactic classroom is: Effort + Ability = Success.

- Verbatim and rote internalisation and memorisation of multiple facts, rather than the development of understanding, are prioritised so that appropriate amounts of information and detail can be regurgitated and reproduced in examinations (Sugrue 2007).

- Silcock (1996) states that "successful education will follow from firm control by teachers over what pupils do, and an associated firm control by governments, over what teachers do".

- "Good students" (docilis) – those who are "teachable" – are those who adopt a passive, docile attitude towards the teacher (Sugrue 2007).

- Silcock (1996) suggests that "children cannot have the main role in their own learning; development occurs, largely, in ways prescribed by others".

- Bruner (1970) claims that cognitive development is as much from the "outside in as from the inside out".

- O'Hare (1987) claims that it is knowledge which empowers individuals. He contends that knowledge, even acquired through didactic methodologies, gives individuals control over events, and he rejects claims, from advocates of progressivism, that particular progressive and constructivist strategies are exclusively needed to achieve effective knowledge transfer and transmission as false and erroneous. O'Hare states that autonomy is not comprehensible outside of a knowledge-context, and also that the "process-product" distinction, which is prioritised in constructivist and progressive epistemologies, presents a false and biased dichotomy.

- The "Concept to Classroom" web page (http://www.thirteen.org/edonline/concept2class/constructivism/index) provides the following insights into the components, processes and nuances of the traditional or didactic classroom: the curriculum begins with the parts of the whole; the primary emphasis is on basic skills development; strict adherence to the fixed curriculum is mandated; classroom materials and resources are primarily textbooks and workbooks; learning is based on repetition; teachers disseminate information to students and the students are passive recipients of this knowledge; the teacher's role is directive and authoritarian; assessment is through written testing and exams require regurgitation of memorised facts; credits in test and exams are provided for the one correct answer to each specific question; knowledge is conceptualised as inert, hierarchical and fixed; students primarily work independently in the classroom.

In her thesis and investigative typology, Kalantzis (2005) identifies and describes the following strands as core dynamics and dimensions of didactic philosophy and epistemology:

- Architectonic Dimension. The classroom environment and setting consists of a large number of students facing in one direction and towards the teacher, who is generally positioned at the front of the classroom for a considerable proportion of each lesson. In this scenario, the teacher is the focus of all classroom instruction, a situation given emphasis through the serial arrangements of the students' tables or desks and the placement of the blackboard / whiteboard at the front of the room, behind the teacher's desk. The student's gaze is constantly drawn towards this central point within the classroom environment. This physical arrangement and spatiality is conducive to the implementation of didactic teaching and the maximising of the impact and outcomes of teacher performance. The teacher literally creates an ambience “on the stage of learning” and is the star performer (Watkins 2007).

- Discursive and Pedagogical Dimension. The focus is on teacher talk and teacher activity rather then on what the learner does. The balance of agency, and locus of control and empowerment, weighs heavily towards the teacher’s side. The teacher is in control of knowledge selection, classroom discussions, selection of text and assignments, knowledge transmission and modes of assessment. It is mandated and demanded that the learner sits silently during the lesson and passively absorb the knowledge laid before him or her by the teacher. The students learn what they have to learn, primarily by rote, by concentrated and focussed listening, by practice and repetition and by memorising key lists of the presented facts, theories, “truths and civic values”. Kalantzis describes this prioritisation of rote learning and of the processes of imitating, copying, reproduction, repetition, practice and replication as an epistemology of “mimesis”. Kalantzis states that mimesis underpins and permeates throughout all didactic education.

- Intersubjective Dimension. The culture of the didactic classroom is grounded in authoritarian systems, rules, regulations and procedures. The hegemony of the prescribed syllabi, textbook and forthcoming assessments and examinations is unquestioned. In the classroom, the teacher is the sole agency for interpreting, sub-dividing and transmitting the official syllabus. The teacher’s subjectivity, experience, selection and interpretation of curricular priorities dominate the web of classrooms activities, priorities and interactions; the students’ interests, learning styles and specific learning needs are subservient and not investigated in this classroom.

- Socio-cultural Dimension. The concepts of individual readiness, individual learning styles, multiple intelligences, specific learning needs, individual student interests and individual student needs are not countenanced, recognised or incorporated into the tenets and philosophy of didacticism. In essence, for practical, organisational and operational purposes, all learners are conceptualised and treated as the same, within didacticism. The underpinning pedagogical and philosophical orientation is that “one size fits all”.

- Proprietary Dimension. The norms of “privacy”, “private spaces”, “control”, “discipline”, “silence” and “ownership” predominate in the didactic classroom. Teachers refer to “my classroom” and “my desk”. Students refer to “my homework” and “my assignments”. Students sit silently in seats during lessons. Teacher talk dominates this classroom environment.

- Moral Dimension. A major tenet of the didactic philosophy is that discipline, obedience and conformity lead to success. By extension, this thesis also infers that the learner should exclusively blame himself or herself for not being able to succeed in exams or learn the presented content of the prescribed syllabi.

Sugrue (1997) and Murphy (2006) both contend that many teachers, who endorse child-centred teaching methodologies, rationale and rhetoric and who consistently declare and profess their allegiance and adherence to the tenets and values of progressivism and constructivism, when faced with the rigours, strains, realities and complexities of classroom interactions, together with on-going curricular change, inconsistencies in resource provision, the press of multiple educational policy stipulations and the presence of regular high-stakes student assessments and examinations, have regularly opted to embrace didacticism and to implement didactic practices and methodologies in their classrooms. The appeal of didacticism, for many under-siege practitioners, is that didacticism appears to work; it can contribute to the development of a controlled learning environment in the classroom and it can deliver successful learning outcomes in terminal exams where retention and reproduction of knowledge is prioritised. Consequently, behaviourism and didacticism, with their prioritisation of drill and practice methodologies, remain the dominant norms that operate in many classrooms. This is highly understandable because both approaches are deemed effective in making the student "exam-smart" and "competent" in the reproduction and application of well-drilled procedures in exam contexts. In an evaluative scenario, where a teacher's effectiveness is predominantly judged by his or her ability to get students through the exam marathon, this didactic reality will remain uncontested and unrivalled. Sugrue (1997) describes classrooms as "sites of struggle" where teachers, on a daily basis, grapple with many complexities and conflicting realities "as they seek to give meaning and coherence to contemporary versions of teaching traditions: where back-to-basics, in its various guises, is pitted against more humane, just and equitable versions of classroom practice which is frequently located within a progressive ideology of schooling". Black and Myron Atkin (1996) suggest that the no-frills and pragmatic tenets and edicts of didacticism will always have an appeal for teachers and, consequently, will remain firmly rooted in classroom practice in many schools. Black and Myron Atkin (1996), Hargraves (1992) and Lieberman (1990) claim that didactic practices have systematically evolved and advanced to become core, implicit and embedded norms within the cultures of teaching.

Other than the critiquing of specific shortcomings of didacticism, that are encapsulated within the suite of associated root metaphors and descriptors which I have previously referred to, the wider landscape of educational research literature also contains many additional critiques of the inadequacies and inefficiencies of the didactic epistemology. The following is a brief selection of some of these additional critiques:

- Within the dogma and philosophy of didacticism, there is no in-built or underpinning conceptual understanding of the complex nature and dynamics of learning and teaching. Within the didactic philosophy, teaching is conceptualised as a "pounding into them process" (Pogrow, 2006).
- Bowen (1979) states that the philosophy of didacticism is grounded in a profound and holistic acceptance of the existence of absolutes and "absolute truths" within the educational domain. The ideologies of pragmatism and "streams of experience", which were embedded within the tenets of progressivism and constructivism, meant that this ideology of absolutes and absolute truths was severely challenged and eventually rejected.
- Draper (2002) contends that, within the tenets of didactism, knowledge is perceived as being discreet, hierarchical, sequential and fixed.

Interrogating Constructivism and Progressivism

Some educational researchers and historians state that the emergence and development of progressivism and constructivism occurred as a direct response and reaction to the fundamental inefficiencies, inadequacies and deficits of didactic epistemology and pedagogy to consistently deliver successful learning outcomes for an inclusive and heterogeneous student population. The following statement from Froebel is certainly scripted by a profound and oppositional reaction to didacticism: "I want the exact opposite of what now serves as educational method and as teaching-system in general". Rousseau also articulated his negativity towards didactic approaches: "reverse the usual practice and you will almost always do right".

There is also an alternative cohort of educational researchers, social commentators and historians, including (Reese 2001), who suggest that constructivism and progressivism have evolved, as independent and distinct epistemologies and theses, from the cloisters of European Enlightenment or, in particular, from the twentieth century psychological canons and theses of Thoreau, Pestalozzi, Froebel, Herbart, Montessori, Bernstein, Piaget and Dewey.

Irrespective of where the genesis and roots of the progressive and constructivist epistemologies and theses lie, in essence and de facto, these dual child-centred epistemologies significantly and fundamentally challenge and critique the traditional and didactic epistemology and its underlying conceptual assumptions and orientations. Hartley (2009) claims that the original advocates of progressivism and constructivism did not desire fundamental or radical rupture or upheaval in the didactic structure and processes of education. Bowen (1979) claims that progressivism and constructivism primarily sought to establish a conservative tradition of education and did not question or critique the metaphysical assumptions and theories of didacticism. Their primary focus was to bring about change in the process of education and to succeed in getting consensus on the locus and status of the child as the primary focus of all education. Most advocates and exponents of progressivism and constructivism claim that didactic methodologies are a barrier to the development and implementation of experiential and constructivist learning opportunities for students in schools. Black and Myron Atkin (1998) state that advocates of progressivism contend that teaching based on didactic methodologies "will achieve successful learning with only a minority of pupils, while failing to tap the motivation and the learning potential of almost all the rest".

Many researchers, including Blyth (1965), Ashton (1975), Blenkin and Kelly (1981) and Bennett (1976) have identified and investigated the range and diversification of root metaphors, phrases and descriptors that have been used in association with progressivism and constructivism in research literature. Many of these root metaphors are directly informed by Piagetian developmental psychology. The following phrases and root metaphors were frequently and commonly employed: "child-centred teaching", "interactive teaching ", "authentic learning and teaching", "individualistic teaching" "inquiry-based teaching", "teaching that facilitates independent learning", "participatory teaching", "providing flexible learning opportunities", "discovery teaching and learning", "providing and incorporating first-hand experiences of subject matter", "collaborative and cooperative teaching", "activity-based teaching", "learner-centred teaching", "the constructivist classroom", "productive teaching", "reflective teaching", "discovery-based classrooms", "negotiating the curriculum with learners", "originality and creativity", "readiness", "activity and guided discovery", "process teaching and learning rather than product", "of relevance to the lives of learners", "integrated and holistic", "activity based learning and teaching", "developmental teaching and learning", "emphasis on classroom talk and orality", "emphasis on problem-solving", "student-directed learning", "drawing out what's already there", "student needs". "pluriformity of approaches", "non-directive teaching", "dispositional", "enthusiastic learning", "real learning opportunities", "learning with immediate relevance", "experimentalism", "pragmatism", "learner-centred", "respect for individual capacities, interests and experiences", "using activity as the stimulus and centre of learning", "full and harmonious development of the child", "respect for individual difference", "exploratory", "students learning from each other", "improving the student's self image", " negotiated learning ", "teacher as coach", " broadly based, balanced curriculum", "curriculum-as-process", "environmentally-based learning", "hands on experiments", "reflective teaching and learning", "accommodating the natural curiosity of learners", "dialogue focused classrooms ", "focused on the development of understanding", "tailored teaching", "pedagogy of personalisation", " marrying the fostering of individual autonomy to a structured teacher-intervention", "conscious agency of cognition" and "active learning environment".

Educational research literature identifies and describes the following as key tenets and assumptions that underpin and define the progressive and constructivist model of teaching:

- Constructivism and progressivism are unique epistemologies which exclusively prioritise the child as the primary focus and concern in the web of educational processes. Darling (1986) states that progressivism and constructivism advocate pedagogies and a curriculum, which is based on the student's needs and interests and which take proper account of the nature of the child and the way he or she develops. The Plowden Report is clearly embedded in the progressive and constructivist ideology: "at the heart of the educational process lies the child. No advances in policy … have their desired effect unless they are in harmony with the nature of the child, unless they are fundamentally acceptable to him". Kelly (1999) states that within these child-centred pedagogies, the planning and designing of the mode and content of the lesson always evolves from "a concern with the nature of the child and with his or her development as a human being". Ross (2000) also suggests that the constructivist and progressive pedagogies and epistemologies are grounded in a desire and orientation to ensure that "the curriculum should enable the student to understand the world in his or her own terms, through his or her own enquiries". Walshe (1981) claims that in progressivism and constructivism "the teacher does not prompt or prescribe …. explicit direction is avoided". Walshe also states that in these child-centred pedagogies, teachers are required to step back, talk less and let the students get on with their own learning.

- Constructivism and progressivism are based on the assumptions and beliefs that we are all agents of our own learning, that knowledge is constructed from within and that we are constantly involved in the construction of meaning for ourselves. As learners, we are all "meaning-makes"; we have to make sense of the world for ourselves. We continue to develop and extend this capacity and understanding throughout our lives. Orton (1994) states that knowledge is actively constructed by the learner, not actively received from the environment. Von Glasersfeld (1991) states that "knowledge cannot simply be transferred ready-made from parent to child or from teacher to student but has to be actively built up by each learner in his or her own mind". Received knowledge, no matter how insistent and dogmatic the source, is always open to some degree of reflection and reinterpretation prior to internalisation and assimilation. Kress (2000) contends that all representation and processes of meaning making are transformative. Orton (1994) argues that "nothing can inject or transplant into the mind from without". All understandings are private and individual constructions. Bolton (1977) contents that all cognitive structures are products of intentional acts, human consciousness itself being a structured web of intentions".

- All students will learn spontaneously as long as they are motivated to learn and are provided with individualised, experiential and child-centred teaching.

- Collaboration, social interaction and social communication are critical components in supporting the individual to construct his or her own understanding.

- The development of relational understanding enables the student to make connections between prior knowledge and incoming new knowledge and new experiences. Black and Myron Atkin (1996) state that learning is effective only when it starts from, and builds on, the previously-acquired and existing learning, ideas, experiences, interests and perceptions that students carry with them to their studies. Only by this route can students build knowledge into coherent and meaningful structures of their own. This is a central message of constructivism.

- Learning becomes enhanced and extended when the student is provided with opportunities, and sufficient time, to contextualise, connect and assimilate new in-coming information into his or her existing cognitive matrix of knowledge, perceptions and expectations. The gradient of the learning challenge significantly increases when the student is presented with disjointed, atomised and unconnected components of knowledge.

- Sugrue (1997) states that there is a "seductive and a seamless attractiveness to the rhetoric of child-centred teaching". He also contends that progressive and constructivist teaching is focused on the creation of a planned and strategic level of "cognitive dissonance" within students, so as to extend and enhance their conceptual development.

- In the theses of progressivism and constructivism, little value is ascribed to rote learning or to the development of the skills and competencies of automaticity. Orton (1994) argues that the understanding and knowledge, that have been acquired through constructivist and progressive approaches, are more likely to be retained as a permanent fixture in our intellectual storehouse, whereas knowledge arrived at by rote learning and by didactic approaches is more likely to be segmented, disjointed and superficial and hence more difficult to anchor and retain in our cognitive schemata.

- Sugrue (1997) claims that constructivist and progressive teaching often includes whole class a teaching rather than being unremittingly opposed to it. Sugrue also states that child-centred teaching pushes students to the limits of their learning rather than merely allowing them to follow their own interests or rest on their laurels.

- Kelly (1977) states that it is the process of meaning making and the development of understanding that matters most in the epistemologies and pedagogies of constructivism and progressivism.

- On occasions, students are encouraged to self-evaluate, rather than being continuously evaluated by the teacher.

- Brehony (2001) states that progressivism and constructivism has four distinct dimensions: moral, ideological, social and discourse / language. Brehony also claims that the protracted ideological debate, that underpinned the evolution and development of the concepts of progressivism and constructivism, delayed the emergence of child-centred teaching as a realistic alternative to didactic approaches and practices. The ideological debate and discussion began by being primarily focused on what progressivism and constructivism were opposed to, rather then on what were the integral and essential dynamics of these epistemologies. This protracted ideological debate identified various dichotomies and obstacles that needed to be parsed and investigated before shared understandings and consensus could emerge: e.g. the nature of the relationship between the "particular" and the "general", "intellect training" v "development of emotional life", "facts v initiative", "conformity" v "freedom", "acquiescence" and "passivity" v "activity", "knowledge for knowledge's sake" v "knowledge for use", "control" v "reason", "continuity" v "discontinuity", "social structure" v "symbolic interactionism" and "before" v "after".

- Silcock (1996) suggests that progressive and constructivist teaching and cultures prioritise three core and interconnected procedures: the teacher attends to individual need, the teacher utilises and exploits the individual experiences of the student in the learning context and the teacher facilitates and promotes individual student autonomy.

- Hartley (2009) states that, in the theses of progressivism, play is recognised as an important learning medium. While at play, children should feel secure, free and happy.

- Halsey and Sylva (1987) state that, in child-centred theses and tenets, children are considered to be naturally motivated and agents of their own learning. Consequently, these researchers contend that education should always start with the needs of the child.

- In his theses on progressivism and constructivism, Bernstein (1975) introduced the concept of the "invisible pedagogy" whereby role-demarcation – between the teacher and the student – would be less rigid, the structuring of time and space would be more flexible and the classroom order, regulations and rituals would be negotiated rather then imposed. The teacher retains implicit, not explicit, control over the student. The teacher still primarily structures the learning context and the student is empowered to "rearrange and explore" this learning context. Within the learning context, the student has wide powers over what he or she selects, over how he or she structures the learning tasks and over the timescale of his or her activities. The modes of assessment are "multiple and diffuse". There is a reduced emphasis upon the transmission and acquisition of specific skills.

- Richardson (2007) states that, in the progressive and constructivist classroom, regular opportunities are provided "for students to talk and listen, read, write, reflect, and build mental models".
- Silcock (19976 contents that "human beings are innately in charge of their own cognitions and behaviour. In other words, we are individuals before we are anything else". Silcock also contends that unless pupils are capable of managing their own learning, progressivism cannot work.
- Wells (1986) states that the theses and tenets of progressivism and constructivism advocate and recommend collaborative learning "because talk endows meaning".
- Draper (2002) states that, in progressive and constructivist classrooms, multiple opportunities are provided for students to interact with peers, become active, think, pose questions and problems, solve problems and analyse the solutions, work within cooperative groups, use manipulatives and mobiles to help them solve problems and arrive at solutions, work on projects that require them to think about interesting problems for longer than the typical forty minute class period so that they can construct their own specific meaning, understanding and knowledge. Draper states that progressive and constructivist teachers get the balance right between permitting students sufficient time to construct their own meaning and making direct, selective and judicious inputs in order to model and clarify some new strategy, to provide scaffolding, shepherding and contingency when deemed necessary, to manage and provide structure for the student's learning, to provide feedback when required, to instruct, to provide assistance and to ensure that the student is acquiring the correct terminologies and vocabulary, to prompt students to formulate their own questions, to allow and encourage multiple interpretations and expressions of learning and to ask key questions so as to reinforce, clarify and extend the student's thinking. Draper states that progressive and constructivist pedagogies and epistemologies require that "the teacher takes into consideration what students know, what they want to know and how to move students towards desired knowledge".
- The "Concept to Classroom" web page (http://www.thirteen.org/edonline/concept2class/constructivism/index) states that the concept of constructivism has its roots in classic antiquity, going back to Socrates's dialogues with his followers, in which he asked directed questions that led his students to realise for themselves that they possessed weaknesses in their thinking.

- Draper (2002) states that progressive and constructivist teachers are fully aware of the importance that language plays in the acquisition of new knowledge. Hence, these teachers rely on and use teaching practices that are rich in conversations.

- The National Council of Teachers of Mathematics (U.S.) (2002) state that: "students, who have opportunities, encouragement and support for speaking, writing, reading and listening in mathematics classes, reap dual benefits: they communicate to learn mathematics, and they learn to communicate mathematically".

- The "Concept to Classroom" web page (http://www.thirteen.org/edonline/concept2class/constructivism/index) provides many insights into the various orientations, processes and nuances of the progressive and constructivist classroom: ab initio, the focus is on "big ideas" and "interconnected concepts" within the curriculum; student generated questions are encouraged in these classroom; classroom resources include primary sources, manipulatives and mobiles; learning is interactive - building on what the student already knows; conversations and dialogues are emphasised in this classroom because they are primary conduits by which students construct and formulate their own knowledge; the teacher's multifaceted role-set is interactive and rooted in negotiation; assessment includes written work, portfolios, observations, tests and oral expressions of points of view; process is conceptualised as being as important as product; knowledge is seen as dynamic and constantly changing with the student's experiences; cooperative learning is prioritised and students work primarily in co-operative groups.

In her investigative typology, Kalantzis (2005) identifies and describes the following strands as core dynamics and dimensions of the progressive and constructivist epistemologies and theses:

- Architectonic Dimension. The classroom environment and furniture is arranged so as to allow for maximum student face-to-face and toe-to-toe engagement and activity. Walshe (1981) states that progressivism and constructivism encourage a "dispersed placement" of groups of tables and desks within the learning space. The didactic stipulation, that every student's eyes should be constantly on the teacher has been eroded and discarded. The teacher no longer possesses or occupies a central position within the classroom; rather he or she functions more as a roving monitor, motivating students and checking student's progress and assignments. There is less opportunity for "teacher performance" and for whole-class instruction.

- Discursive and Pedagogical Dimension. The focus is on learning how to learn, on the provision of hands-on, experiential, constructivist, investigative, cross curricular and reflective learning opportunities and on the nurturing and development of a web of focused conversations and discussions between all participants within the classroom environment.

- Intersubjective Dimension. The progressive and constructivist classroom culture are firmly grounded in the values and norms of child-centred teaching and learning, in the use of multiple modalities and differentiated approaches to cater for individual difference and individual needs of students and in the provision of learner-centred experiential activities to support teaching and learning.
- Socio-cultural Dimension. The underpinning pedagogical orientation is scripted by the concepts of inclusion, social integration and participation, respect for difference, heterogeneity, personalisation, , individual readiness, individual learning styles, cooperative learning, multiple intelligences, paired-activities and group work, self-paced learning, social integration, ownership and differentiation.
- Proprietary Dimension. The norms of “privacy”, “private spaces” and “ownership” are diluted and minimised. Classrooms are “opened-up” and conceptualised and planned as collaborative learning spaces. Social engagement and cooperative learning opportunities are prioritised in these classrooms. Learning priorities are regularly negotiated between teacher and students and choice in selection of assignment is regularly provided to the students. An increased level of responsibility and accountability for learning outcomes is vested in – and required of - the student.
- Moral Dimension. The underpinning ethical and moral philosophy is that by providing multiple opportunities for collaborative and self-directed learning to occur, our educational system will successfully produce cohorts of students and graduates who possess inquiring minds and who will fully participate as citizens in our society.

Advocates and exponents of constructivism and progressivism consistently claim the moral high ground and superiority for their epistemology over the much maligned and oft-harangued epistemology of didacticism. However educational research literature also contains multiple critiques of the epistemologies of progressivism and constructivism. Among this suite of critiques are:

- Kalantzis (2005) claims that, within constructivism and progressivism, an excessive emphasis is placed upon the concept of “receptivity” and, in particular, on the specific level and extent of receptivity that may exist at a particular cognitive stage of an individual learner’s cognitive development. Kalantzis states that, in this flawed thesis of invasive receptivity, the raw materials of “intelligence” are “biologised” and individual variations are conceptualised and explained exclusively in terms of “individualised capability”.

- Kalantzis concedes that the epistemologies of progressivism and constructivism shift the balance of agency towards the learner, by allowing him or her choice in the selection of assignment and by providing opportunities to reflect and assimilate knowledge at his or her own pace, but this researcher is adamant that this perceived student empowerment is bounded, constrained and controlled.

- Kalantzis also concedes that in the constructivist classroom the student is provided with opportunities to discover new insights and realities by making connections between different pieces of information, but, in essence, the student's synthesis and discovery is fundamentally constrained by having to be embedded in the knowledge, details and resources that had been originally presented to the student by the teacher. Whereas it appears that the student is de-constructing old knowledge and re-constructing his or her own new knowledge, he or she is merely reconstructing existing meta-narratives within the constraints of existing paradigms.

- Watkins (2007) states that progressivism and constructivism have resulted in the marginalisation and erosion of the teacher's role in many classrooms. Watkins claims that the teacher's role has been regulated and reduced to that of "facilitator". She further contends that the teacher's overall "affective and intercorporeality" presence and impact in classrooms has been greatly reduced. Sugrue (1997) also refers to the peripheral role of the teacher, in the progressive and constructivist classroom context, where learners are allowed to pursue their own interests at their own pace.

- Lockhead (1991) suggests that "to date, constructivist thinking has been more effective in describing what sorts of teaching will not work then in specifying what will".

- Because the introduction of a constructivist epistemology into classrooms cannot be mandated, forced or fast-forwarded, and because it primarily involves establishing classroom cultures and environments where learning is permitted to take place gradually, incrementally and at the student's own pace, constructivism is perceived, conceptualised and evaluated as being completely out of synch with an educational system that is dominated by the compulsory coverage of lengthy syllabi and by a terminal exam ethos. Consequently, there is every likelihood that constructivism will remain an avis rara in classroom contexts in the near and distant future.

- Walshe (1981) advises us, that because the progressive and constructivist epistemologies are predominantly grounded in the principles of student empowerment and in the establishment of democratic and egalitarian relationships in the classroom, we should not conveniently or automatically conclude that these child-centred epistemologies are the only epistemologies that can enhance the learning environment and bring about successful learning outcomes in students. Walshe contents that the didactic epistemology has, over many decades, also consistently produced successful learning outcomes.

- Pogrow (2006) critiques both the constructivist and didactic epistemologies. He states that neither epistemology is informed by a holistic and comprehensive conceptual understanding of how students learn; consequently, each of these epistemologies is grounded in erroneous and spurious conceptual premises and assumptions. Pogrow also states that, over a lengthy timeframe, in the ebb-and-flow of fluctuating educational policy priorities, official preference has been periodically bestowed on each of these two epistemological polarities. On occasions, the voices calling for "back to basics" and a prioritising of the 3Rs in education have been in the ascendancy. On other occasions, the pursuit and implementation of child-centred approaches have informed and dominated the current educational narratives and policy directives. Historical evidence and records suggest that, inevitably and in cyclical rotation, the rival epistemology is always elevated into hegemonic ascendancy as the failure of the other epistemology becomes increasingly apparent and publically critiqued.

- Alexander (1992) contends that the classroom teacher, who exclusively employs child-centred approaches to script his or her teaching, needs to possess a unique range of professional competencies and interpersonal skills to remain continuously successful in cultivating and nurturing developmental interest in all learners within the realities and complexities of contemporary heterogeneous classrooms.

- Darling (1986) critiques progressivism and constructivism by stating that "subjectivism" was widely practised within these dual ideologies. However Darling now accepts that today's child-centred theories are more based on the bedrock of scientific and empirical fact rather than on the uncertainties, spuriousness and inconsistencies of subjectivism.

- Sugrue (1997) contends that progressivism and constructivism are often clearer about what they are against, rather than what they are for. Sugrue also states "there is nothing intrinsic to these constructivist methodologies that suggest that they should fill the pedagogical repertoire of practitioners to the exclusion of other teaching skills".

- Cox and Boyson (1975) suggest that progressivism and constructivism can be critiqued for fragmenting and trivialising the content of curriculum and for continuously prioritising process over content.

- Sugrue (1997) suggests that the principles of child-centredness are inconsistent, ambiguous and imprecise and he states that there is no evidence in research literature to confirm that direct instruction is less valuable or effective in supporting and enhancing the development of understanding and meaning in students.

- Brehony (2001) claims that there has been a deliberate effort, within the ideological debate on progressivism and constructivism, to create an impression of continuity, constancy, status and legitimacy for these emerging epistemologies by regularity referring to the founding fathers of child-centred approaches in their literature. Foucault (1972) describes this pursuit of continuity and constancy as "the search for silent beginnings" and "the never-ending tracing back to original precursors".

- Darling (1986) states that progressivism and constructivism have, in effect, maintained and reinforced an essentially conservative thesis of education in society. Darling also states that these two child-centred philosophies have been highly instrumental and significant agencies, for introducing heightened levels of control over students in classrooms. Darling describes these child-centred approaches as providing "greater effectiveness for social control and structuring aspirations" in classrooms.

Constructing a New and Inclusive Epistemology of Teaching

Few would disagree with Hartley (2009) when he contends that, despite the fact that profound and deep upheaval has occurred in the foundation disciplines of education – sociology, psychology and philosophy - since the 1970s, there has been very little knock-on or down-stream change in the practice and dynamics of teaching and pedagogy. Bowen (1979) agrees and describes the following "compelling paradox" that now exists in contemporary education: "at the end of twenty five years of the most intense educational research and theory formulation ever seen in the history of mankind, we are now more divided and confused than ever. Our vast accumulation of data has given us, contrary to expectations, no clear path to follow in the future".

A new, inclusive and integrated epistemology is required to respond to the multiple challenges and realities of postmodernistic classrooms. Pogrow (2006) states that education cannot live by either progressivism, or didacticism alone. Both of these pedagogical and epistemological philosophies are only partially correct; however, each epistemology possesses important pieces of the solution to the puzzle for creating better schools. Without progressivism and constructivism, our schools would be grim, unfriendly and sterile places. Without didacticism and traditionalism we possibly would not have the comprehensive system and infrastructure of public education that we have today or would not have created the bedrock system of existing curricula and standardised assessment processes. Aronowitz and Giroux (1991) correctly claim that "no tradition … can speak with authority and certainty for all of humanity". Sugrue (1997) claims that the arbitrary categorisation of teaching methodologies, into the dualism and dichotomy of progressivism and didacticism, has failed to adequately recognise and cater for the complexities and multiple realities of modern classrooms. We need multiple approaches and a new epistemological paradigm to cater for the realities, challenges and complexities of contemporary classrooms.

In the final section of her seminal thesis, Kalantzis (2006) recommends and advocates the establishment of a new, holistic and inclusive macro epistemology, which she describes as "Transformative Education". This innovative epistemology will incorporate, synthesise and extend best practice from both didacticism / traditionalism and progressivism / constructivism. The following strands should be included as core dynamics and dimensions of this emancipating Transformative Education:

- Architectonic Dimension. The transformative classroom environment and layout will be flexibly arranged so as to allow for maximum student engagement, project work, enquiries and experiential activities. Learning will not be restrained within the physical classroom environment and can extend, as required, to include many off-site learning opportunities. The period of compulsory schooling will be conceptualised as being firmly grounded and anchored within the spectrum of lifelong and life-wide learning.

- Discursive and Pedagogical Dimension. The focus will be on learning how to learn and on the development of enhanced understanding and meaning among students. This new and synthesised epistemology will also focus on the provision and availability of regular experiential, cross-curricular, constructivist, investigative and reflective learning opportunities in the classroom, the utilisation of various modalities and technologies to enhance teaching and student learning and the nurturing and supporting of networks and webs of conversations and discussions between the different players within and outside the classroom environment. The role and agency of the teacher will be re-balanced and re-conceptualised to incorporate and emphasise the multifaceted role-set of "learner", "designer of pedagogy and the learning environment", "action researcher and social scientist", "evaluator of the effectiveness of the current learning environment" and "autonomous manager of student learning". A primary role, which will be performed by each student, will be that of "co-designer of learning". Students will be encouraged to bring their own, diverse and unique knowledge, experiences and interests into the learning environment. Students will be provided with regular opportunities to encounter new information and new experiences, but only within a predetermined "zone of intelligibility and safety" which will be carefully planned and designed, to be sufficiently close to the student's current life's experiences, so as to be "half-familiar" – but sufficiently new and challenging to necessitate and require focussed concentration and new learning. This new and synthesised epistemology will also provide alternative pathways, and multiple entry points, for student learning to occur. A new partnership between teacher and student will be prioritised. Every student will matter; every student will be facilitated to meet his or her full potential.

- Intersubjective Dimension. The transformative classroom culture will resonate with self-directed, cooperative and integrated learning opportunities. The quality of teacher-student relationships will be prioritised. An expansive culture of care will permeate throughout all classroom interactions.
- Socio-cultural Dimension. The underpinning pedagogical orientation will be scripted by the concepts of inclusion, pluralism, collegiality, collaboration, social integration, respect for difference and heterogeneity, differentiation, personalisation, individualisation, individual readiness, individual learning styles, cooperative learning, multiple intelligences, paired-activities and group work and self-paced learning, when required.
- Proprietary Dimension. Cooperative learning opportunities will be prioritised and can occur anywhere or at any time. Learning priorities will be regularly negotiated, between teacher and student, and choice in selection of assignment will be regularly provided to the student.
- Moral Dimension. The underpinning philosophy will be that the provision of multiple opportunities, for collaborative, enquiry, research and self-directed learning to occur, will produce students and graduates who can successfully navigate through the rhythms of life, discern, change, negotiate deep diversity and create and innovate in society.

The amalgamation, integration and synthesising of diverse epistemologies within a new Transformative Epistemology will be challenging and difficult to achieve. However, insights acquired from many research findings to date, including Surgue (2007), Bennett (1976) and Bassey (1978), clearly suggest that teachers have no difficulty in “synergizing teaching traditions”, in implementing “a pluriformity and diversification of approaches” in their classrooms on a daily basis, in developing a harmonious “co-existence” between rival teaching traditions and in moving fluidly and freely between child-centred epistemologies and didactic teaching methodologies. The teachers, in Surgue’s research, successfully reshaped and re-visioned spurious child-centred approaches to teaching into a dynamic pedagogy in their classrooms.

Because teachers’ pedagogical practices are primarily and predominantly influenced by “their deeply-ingrained personal beliefs and understandings rather than by the principles of the curriculum”, Murphy (2006) recommends that the provision and prioritising of ongoing, relevant and dynamic continuing professional development for teachers, which provide opportunities for reflection and discussion, as the most effective conduit for enabling teachers to re-constructed and advance their understandings of child-centred teaching methodologies.

Brehony (2001) states that in order to keep the dynamics of any epistemology current and relevant to the complexities and realities of modern classrooms, the original tenets and edicts will have to be systematically and regularly reworked, reformatted and reconstructed. Dewey revisited and amended his original writings on many occasions and, in so doing, extended his original theses and proceeded to develop multiple new insights. The pursuit of a new synthesised epistemology will provide multiple opportunities for the revisiting of original and seminal theses and the reworking and assimilation of these theses into a new macro and inclusive epistemological paradigm.

Sugrue (1997) states that opportunities and resources will have to be consistently provided for teachers to work and plan collaboratively and to reconstruct themselves and their practices - if the prospect of introducing and implementing a new epistemology of teaching and learning into schools is to be successfully achieved. Hargraves (1992) also pinpoints the importance of the agency of the teacher in implementing change at the school level: "It is what teachers think, what teachers believe that what teachers do at the level of the classroom that ultimately shapes the kind of learning that young people get".

Brehony (2001) claims that the epistemologies of traditionalism / didacticism and progressivism / constructivism have much in common: both are teaching methodologies which require the intentional action of teachers and both are aimed at the transformation of those being educated. These similarities and common ground can serve as the launch-pad for the development of the new integrated epistemology.

Silcock (1996) also advocates a marriage of ideologies and suggests that any new amalgamated epistemology will have to be grounded in current insights into how children learn and develop, be conscious of the importance of ensuring learner-autonomy, seek to facilitate the empowerment of individual students in context and be aware of constraints and obstacles that exist within the education system.

Hartley (2009) claims that in primary schools classrooms in Britain, education has come full circle; progressivism and constructivism are now aves rarae in these classrooms. Didactic norms and methodologies, together with whole-class teaching, have been reinstated in these schools as the practitioners' preferred mode of teaching and classroom management. Hartley strongly recommends the planning and development of an innovative educational philosophy and epistemology, which he calls "personalisation".

The conceptualisation and representation of pedagogical choice as a dualism, which embraces and incorporates two distinct epistemologies, may have significantly prevented and delayed the investigation of alternative and additional pedagogical approaches and methodologies. Given the complexities, realities and challenges of modern classrooms, there has never been a more appropriate time to engage in an investigation of pedagogical and epistemological reconstruction and innovation.

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Four Years Later

Yvonne Mullan

This article relates to an examination in 2009 of the mathematical progress made by children who took part in a mathematics intervention during the school year 2004- 2005 when they were in Junior Infants. In general terms most of the children's 2009 attainments were reassuring with regard to arithmetic ability. However, children who failed to make significant progress during the intervention, continued to have difficulty with certain mathematical skills four years later. The research indicates that several factors impact on arithmetic ability and confirms that numeracy failure starts early and becomes entrenched if not tackled early. This is an abridged version of a research report which was presented at the Third Research in Mathematics Conference in 2009

INTRODUCTION

Understanding basic mathematics is an important life skill. Children who master mathematics in their early years are in a good position to go on to further studies and those who do not are likely to be disadvantaged in the labour market (NAO, 2008). This study, like many that preceded it, identifies a strong link between succeeding early and continuing to succeed.

The question of how best to help children succeed early in mathematics is the subject of much debate. In recent years, mathematics curricula have been developed that draw from children's understandings, build on those understandings and progressively move towards abstract and formal mathematical processes – a movement referred to as "progressive mathematisation" (Zevenbergen, Dole and Wright, 2004, p.4). However, despite the best efforts of teachers and a constructivist approach to learning (NCCA, 1999), many children in our schools get left behind in mathematics early on in their school lives. There is a particular concern here in Ireland about the children who get left behind in low-income communities (Sheil and Kelly, 2001; Weir, 2003; Surgenor, Shiel, Close and Millar, 2006).

One of the problems faced by teachers, when attempting to build on the understandings of children, is that within one class group, children's understandings and mathematical experiences vary enormously. Evidence suggests that there can be a three year differential in achievement levels between children's early mathematical knowledge, as they begin school (Griffin, Case and Siegler, 1994; Mullan and Travers, 2007). Recent research suggests that the best way to address this differential is good quality early intervention that lasts for at least a term, that is given by a specially trained teacher and that addresses number concepts, verbal reasoning and literacy skills (Williams, 2008; Dowker 2009). Mathematical Reasoning and knowledge of arithmetic make independent contributions to children's achievement in mathematics and research suggest that mathematical reasoning is more important (Nunes, Bryant, Sylva and Barros, 2009).

Since 2005, the Social Inclusion programme *Delivering Equality of Opportunity in Schools* (DEIS) (Department of Education and Science, 2005) has supported the mathematics' interventions *Mathematics Recovery* (Wright, Martland and Stafford, 2000) and *Ready Set Go Intervention* (Pitt, 2001) in DEIS schools. However in 2004 there were few specifically mathematical interventions available to the children in this study. The intervention, which was monitored in 2004, when the children were in Junior Infants, was called *Number Worlds* (Griffin and Case, 1997). It is based on Central Conceptual Structure theory (Griffin et al., 1994) and has been used successfully to close the number knowledge gap between children in schools in low-income, high-risk communities and their more affluent peers in Massachusetts (Griffin and Case, 1997) and in Dublin (Mullan and Travers, 2007). The intervention involved teaching mathematics differently to the way mathematics is normally taught in Junior Infants. It included a mixture of whole-class teaching and scaffolded small-group games. There was no written work. There was a heavy emphasis on counting and language skills. All activities aimed to help children to gain a representation of number akin to a mental counting line. Observation of children's pre and post test scores on the Number Knowledge Test (NKT) ((Griffin and Case, 1994) was one of the methods used to assess the impact of the intervention in the original study and these scores can be seen in Table 2 below along with the children's 2009 test scores.

METHOD

School

The school had almost 1000 children on campus. Prior to 2005 the school had disadvantaged status. In 2005 the school did not qualify for DEIS (DES, 2005) status. Over 50% of the children attending the school were international children.

Subjects

The subjects were 9 children in 3rd class, 4 boys and 5 girls. The breakdown of nationalities seen in Table 1 is typical of the current school population. The children ranged in age from 8 years 8 months to 10 years 6 months.

Table 1: Age, gender and nationality of children

	Boys					Girls			
Child	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Age	9'5	9'7	9'2	9'9	10'6	9'8	9'2	8'9	8'8
Nationality	Nigerian	Nigeria	Ghananian	Lithuanian	Philipino	Irish	Irish	Irish	Irish

Tests

The Numerical Operations subtest of the Wechsler Individual Achievement Test Second UK Edition (WIAT-II 2) (The Psychological Corporation, 2005) was administered in order to observe children's written arithmetical skills. Unlike most standardised mathematics' tests which require certain language and literacy abilities, Numerical Operations is a test of ability to work with numbers and symbols only. Thus, it was hoped that children's literacy or language skills would not affect their scores and that a clear picture of children's arithmetic ability would evolve. The MICRA-T standardised test of literacy Level 2 (Wall and Burke, 1990) and the SIGMA-T standardised tests of mathematics Level 3 (Wall and Burke, 1992) were administered by the class teacher and were collected by the author.

Questions

Children were asked individually to add two numbers between 10 and 20 e.g. 17 and 15, without use of paper or pencil, and were then asked about the strategies they used to add the two numbers.

Interview

The class teacher was interviewed to get her opinions about child's concentration skills, progress in mathematics, and learning support at home.

Limitations of Study

The movement of children to different schools meant that only 9 of 21 children from the original study continued to attend the school in which the intervention took place. Ideally the progress of all 21 children from the original study would have been monitored. More information from children about mental arithmetic strategies could have given a given a greater insight into the children's understanding of number.

RESULTS AND OBSERVATIONS

WIAT-II Numerical Operations:
All 9 children achieved standard scores of 85 or higher and of these
1 child achieved a score in the High Average range (110-119)
6 children achieved standard scores in the Average range (90-109)
2 children achieved scores within the Low Average range (80-89).

SIGMA-T:
2 of the 9 children scored higher than the Average range (>109)
4 children scored in the Average range (90-109)
3 children scored in the Low range (70-79).

MICRA-T
All scores apart from one (Child 3) were in the Average range or higher (≥90).
Child 3's score was in the Low range (79).

Table 2. Test Scores 2004, 2005, 2009

Pre-test Nov 2004				Post-Test April 2005			June 2009 Standard Scores			
Child	Actual Age	NKT score	Age Equivalent	Actual Age	NKT score	Age Equivalent	Age	SIGMA-T T	MICRA T	Numerical Operations*
1	4'10	6	3-4	5'3	13	5-6	9'4	73	91	98
2	4'8	2	2-3	5'1	8	4-5	9'2	77	97	89
3	5'1	1	2-3	5'6	7	4-5	9'7	78	79	85
4	5'3	10	5-6	5'8	-	-	9'9	114	99	101
5	5'11	9	5-6	6'4	17	6-7	10'5	>130	116	98
6	5'2	7	4-5	5'8	13	5-6	9'8	93	104	107
7	4'8	2	2-3	5'1	14	5-6	9'2	92	100	100
8	4'5	5	3-4	4'9	12	5-6	8'9	91	114	104
9	4'2	7	4-5	4'8	14	5-6	8'8	92	110	114

Children's 2004 (pre-test) and 2005 (post-test) scores on the NKT can be seen in the shaded columns to the left of Table 2. Children's 2009 test scores on the Numerical Operations, SIGMA-T and MICRA-T can be seen on the right of Table 2.

Children's Strategies

All nine children gave correct answers when asked to add two numbers mentally. Eight children (all except Child 5) reported that when they added two numbers such as 15 and 17 mentally, they first added the tens and held the 1(ten) +1(ten) = 2 (tens) in mind somewhere and then added the units. The children did not mention the words tens or units. Instead they referred to the digit on the left or the right side. When the sum of the numbers on the right side added up to more than ten, children reported that they then added the 1 (ten) to the 2 (tens) which had been stored in mind. Child 5 reported that when she added 15 and 17, she firstly thought about 17 being 15 + 2. She knew that 15 + 15 added up to 30 and then she added on the 2 which she had removed from the 17 before adding the 15's.

Teacher's Views

Children 1, 2 and 3 had poor concentration and Children 1 and 3 did not appear to receive support for learning at home. Children 1, 2 and 3 needed a lot of help with mathematics and Child 3 had serious literacy difficulties. Child 4 was a very good student who got anxious when he was not completely sure of things. Children 5 and 6 were very good students. Child 7 was unsure of mathematical concepts at the beginning of the year but had improved during the year. Child 8 was an independent worker. Child 9 was competent enough and seemed to grasp concepts once they had been explained thoroughly.

DISCUSSION

Children's strategies for the mental arithmetic addition problems were insightful. All but one child began their mental addition by adding the tens. This method appeared to the author to be quite logical since the (tens) numbers were smaller and thus easier to add. However, this method of adding tens first is the opposite direction to the way in which children are taught column addition. Child 5 who used a "doubles" approach was the eldest in the class and had scored highest on SIGMA-T and MICRA-T tests. During the presentation of this paper at ME13, one of the audience expressed bewilderment that in this study, children's understanding of number should be tested using *written* column addition. The speaker was from the Netherlands where the teaching of (formal) place value and written algorithms is postponed in order to build first on children's (informal) mental strategies (Beishuizen and Aghileri, 1998). We may need to take a leaf from their book.

It was reassuring to see that all nine children achieved standard scores of 85 or higher on the WIAT-II test of arithmetic ability; that six of the children scored in the Average range and that one of the children scored in High Average range. It was less reassuring to see the SIGMA T scores (Low range) of Children 1, 2 and 3. The SIGMA-T tests arithmetic ability *and* mathematical (verbal) reasoning, and thus requires certain levels of literacy and language skills. Child

3's lower SIGMA-T score (78) may be explained by literacy difficulties as reported by the teacher and seen in his MICRA-T score of 79. Poor concentration skills or different levels of home support also may have played a part. Two of these children, Child 2 and Child 3 had been identified as having mathematical difficulties four years earlier. These children (Children 1, 2 and 3) had varying amounts of in-class and small group support over the four intervening years and yet they continued to struggle.

It is difficult to disentangle the reasons behind any one child's success or failure in mathematics because of the myriad of intermingling individual and environmental influences on children's learning. Recent research on mathematics interventions (Williams, 2008; Dowker 2009) indicates that the most effective mathematics' interventions occur daily in 1-1 sessions or possibly within a group of three or four children, with a specially trained teacher, for a whole school term. Williams (2008) suggests that best practice includes careful selection of children, detailed assessment of their strengths and weaknesses, parental consultation, dedicated resource rooms, materials, multi-sensory tools and use of technology. Many of these practices are part of *Mathematics Recovery* (Wright et al, 2000) intervention which is available in DEIS schools. However, *Mathematics Recovery* begins in First Class and this can often be two full years after the first differences in mathematical ability have been noticed. *Mathematics Recovery* was available in the school in which this study took place in 2009 because the school did not have DEIS status.

The principle of early intervention is widely accepted, the practice of early intervention is not yet widespread in Irish schools (Travers, 2007). There has been progress but we still have a long way to go in order to ensure that every child receives the right support ***early*** enough to make a difference. Early intervention needs to be embedded in all of our schools, not just in our DEIS schools. Early mathematics interventions need to focus not just on number concepts but on language, literacy skills and mathematical reasoning. We need resources, professional development and reviews of interventions. It will be expensive (Every Child a Chance Trust, 2009) but in the long term, the return will be worth the investment.

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Supporting the Maths Difficulties of Children with Dyspraxia/DCD in Irish Primary Schools

Catherine Sweeney

A flower that blooms in the face of adversity is the most beautiful flower of them all.
Motto of the Dyspraxia Association of Australia Inc. (ADA). (1998-2011)

Introduction

This article summarises the typical characteristics of children with Dyspraxia/DCD which often overlap with the characteristics of other Specific Learning Disabilities (SLD) and outlines why most of these children may have difficulty with specific areas of Maths.

In-depth exploration of maths' strategies is beyond the bounds of this study. However, good inclusive practice is suggested in the context of a whole school approach. This, combined with parental and student involvement, assessment and some teaching and learning intervention strategies should help to overcome the students' barriers to Maths learning. These are based on an examination of wide-ranging International and Irish relevant research and the many years experience of teaching students with SEN including those with Dyspraxia/DCD. The suggestions are intended mainly as illustrations of approaches that could also support all children including those with SEN as "good practice will help all learners, but it is an essential for dyspraxic and dyslexic learners" (Chinn in Yeo, 2003: vii).

Parent and teacher knowledge of the characteristic difficulties of dyspraxia/DCD are crucial to support the successful inclusion of children with this disorder in school (Macintyre and McVitty, 2004; Portwood, 2005). Further, teachers' confidence, knowledge and personal learning styles greatly influence students' success in Maths (Henderson, 1998). But many children with dyspraxia/DCD will present with difficulties in most areas of maths and some may even be considered to have co-morbid dyscalculia (Dixon and Addy, 2004; Yeo, 2003).

> *Unfortunately there appears to be no detailed published research on the Maths abilities of children who have been formally diagnosed as dyspraxic. Standard ability measures used by educational psychologists show that dyspraxic children are often weak at Maths. Teachers report that a great many of the dyspraxic children in their classrooms have difficulties with the numeracy aspects of*

Maths…. and that most dyspraxic children have serious word-problem-solving, number-puzzle solving and pattern-solving weakness which persist throughout their primary school careers (Yeo, 2003:5).

The above excerpt reflects the dearth of published International and Irish research about the specific Maths difficulties of students with Dyspraxia/DCD. The fairly recent research of Sweeney (2007) showed that 81.5% of parent members of the Dyspraxia Association of Ireland (DAI) considered that their children with Dyspraxia/DCD had Maths difficulties ranging from mild to severe. In the same study nearly two thirds of the RT and LS Teachers surveyed considered that they had students with undiagnosed Dyspraxia/DCD on their caseloads and that over half of their students had Maths difficulties. However, this study did not examine which specific areas of Maths were difficult for their children/students. Regrettably, 50%-60% of teachers are only somewhat confident or very confident teaching Maths to lower achieving students (DES, 2010).

Understanding Dyspraxia/DCD

Dyspraxia/DCD is the term used in this study as it is the preferred term of the Dyspraxia Association of Ireland (DAI). There is not a consensus on whether Developmental Co-ordination Disorder (DCD) is the same as Dyspraxia (Dyspraxia Foundation UK, 2006), or if Dyspraxia is a motor planning disorder which is a sub-type of DCD (Dixon and Addy, 2004 : ADA. 1998-2011). But, both terms are commonly used for the disorder (Grant, 2005).

DCD is the official term used in international research literature. It is classified in the DSM-IV Manual (American Psychiatric Association, 1994: 2000) with four criteria for diagnosis. These include a marked impairment in the development of motor coordination which significantly interferes with academic achievement and daily living skills (Reid, 2011). The "Leeds Consensus Statement, 2006" which was attended by international and UK experts, agreed that DCD is a Specific Learning Difficulty and adopted the definition as listed in the DSM-IV-TR (2000) with some clarifications and amendments. It agreed that

"DCD is a separate neurodevelopmental disorder which can, and often does, co-occur with one or more other neurodevelopmental disorders. Commonly, these include attention deficit hyperactivity disorder (ADHD), autistic spectrum disorder (ASD) and developmental dyslexia" (dcd-uk.org, 2006).

However, Dyspraxia is still the name commonly used in the UK, Ireland and Australia. Also, Dyspraxia is the term used by the Department of Health and Children and the Department of Education and Skills in Ireland that list it as a physical and sensory disability with an entitlement to 3 hours additional Resource Teaching hours.

There are no official statistics of prevalence of dyspraxia/DCD available in Ireland. But, the DAI, 2005 suggests 6% prevalence rates for children in Ireland**.** But, these percentages of prevalence may greatly increase because co-morbidity or overlap with other SpLDs "is the rule rather than the exception" Kaplan (2005). These percentages have significant educational implications with the figures suggesting that there is one child with Dyspraxia/DCD in the average class (Portwood, 2000). In the UK boy/girl ratios of 4 to 1 are suggested (Kirby and Drew, 2003). However, Grant (2005) questions the accepted unequal gender ratios because many girls are not identified until they are adults.

It is generally accepted in the research literature that Dyspraxia/DCD is a complex neurologically based developmental disability which is present from birth that may cause characteristic significant delays or difficulties in the planning of what to do and how to do it in motor coordination. To explain its complexity, Grant, 2005 compares Dyspraxia/DCD to an ice-berg in two ways. Firstly, the visible parts are gross and fine motor incoordination and language difficulties, which may 'melt' away with time and intervention. Secondly, the covert aspects are attention, memory and perception difficulties which do not change and can greatly impact on home and school life.

Dyspraxia/ DCD is often called a hidden disability because it is difficult to identify as most children with this disability have average or above average IQ ability levels and may find ways of hiding their difficulties until the work load increases in senior classes in Primary Schools (Kirby and Drew, 2003). This agrees with the research of Sweeney, (2007:36) in which 18.6% of parents of children with Dyspraxia/DCD said that their children were assessed as having above average intelligence while 58.2% were within the average intelligence range. They appear the same as any other child and it is only when a skill is performed that the disability is noticeable (ADA, 1998-2011).

Cognition refers to the process of thinking and learning. Children with classic Dyspraxia/DCD cognitive characteristics may have brain differences with "a tendency towards right hemisphere weakness or immaturity and with relative left hemisphere strength" (Yeo, 2003). The learning of children with dyspraxia/DCD may be affected by difficulties in automatic information processing, generalisation of skills from one context to another, conceptual ability, gross and fine motor skills, visual difficulties, working memory, organisation, neurological connections, language, literacy, numeracy, perception, visuo-spatial awareness, social skills and behaviour (Addy, 2003; Dixon and Addy, 2004; Grant, 2005; Hull Learning Services, 2005; Reid, 2005; 2011). This has huge implications for supporting these children's learning particularly in Maths and will be further discussed.

As previously stated, Dyspraxia/DCD often overlaps with other disabilities especially Dyslexia, Specific Speech and Language Disorder (SSLD), Attention

Deficit Hyperactivity Disorder (ADHD), Autistic spectrum disorder (ASD) and Dyscalculia. Most children with dyspraxia/DCD will present with a cluster of these characteristics which may be on a continuum ranging from very mild to very severe. They may begin Primary School lagging a number of years behind their peers because of these characteristic difficulties. Dixon and Addy (2004) stress that they are not a homogeneous group and all have individual profiles of varying degrees of needs and strengths. Reid (2005; 2011) suggests that it is more useful to focus on the individual profile of the child that relates to barriers to learning rather than the condition.

Identification and Assessment of Children with Dyspraxia/DCD in Irish Primary Schools

At the time of writing this article the DES has just published *Literacy and Numeracy Strategy for Learning and Life,* (DES, 2011). This welcome National Strategy aims to improve Literacy and Numeracy among children and young people including those with SEN. The DES (2007) recommended a staged approach to identify and support all children with SEN including those with Dyspraxia/DCD**.** It appears that this policy will be further strengthened with earlier identification of children's learning difficulties by the second term in Junior Infants.

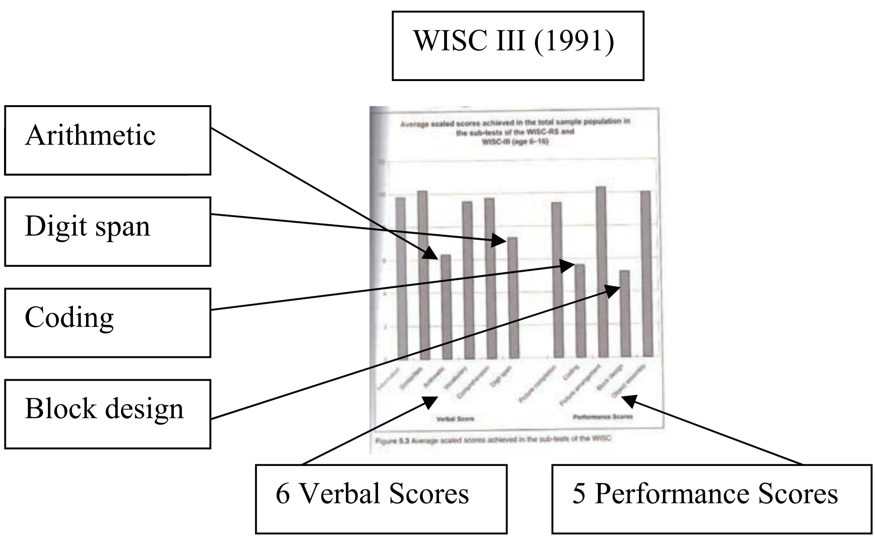
At Stage 1, Class Teachers may identify children's difficulties with the help of checklists and developmental profiles such as those of Addy (2003); Jones (2005); Macintyre (2000); Portwood (2000). A short support plan is devised and delivered preferably with the support of the children's parents. If the children's difficulties are not resolved after a number of reviews, they may move to Stage 2 of the assessment process. (DES, Circulars SP Ed, 24-03; 02-05).

Children who are identified with mild characteristics of Dyspraxia/DCD will also be included in Stage 2 of the assessment process. They will be referred to RT/LS Teacher/s for supplementary teaching. The school will seek a formal assessment for children who have more severe characteristics of dyspraxia/DCD.

Children who are formally diagnosed with dyspraxia/DCD will be listed at Stage 3. The DES lists it as a low incidence, physical and sensory disability that entitles the child to 3 hours additional RT hours. A multi-disciplinary team is seen as the best way to assess the overall difficulties of the child (Jones, 2005). An in-depth profile of the child is assembled through parent, teacher and child interviews coupled with results of informal and formal school assessments. Formal Assessment is usually requested from a Neurologist, Occupational Therapist (OT) Physiotherapist, Speech and Language Therapist (SLT) or Educational Psychologist (EP), Traditionally, the Movement ABC Test Battery (Henderson and Sugden, 1992 : 2007) is administered by one of the medical professionals. Children who score below the 15th Percentile on this normed movement test may have Dyspraxia/DCD, while those below the 5th Percentile are considered to have severe Dyspraxia/DCD.

The EP will use standard psychometric ability measures such as the WISC III (1991) or more recently WISC IV (2003) to assess their cognitive ability. A ‘spiky’ profile on these tests suggests a SpLD. As already stated, many children with Dyspraxia/DCD may have left brain strengths which are linked with good verbal ability and right brain weakness which may manifest itself by a non-verbal learning disability (NLD). This is shown by “poor performance on tasks requiring visual-spatial organisation together with poor psycho-motor, tactile, perceptual and conceptual skills and abilities” (Portwood, 2005:154). The opposite may be true for children with classic Dyslexia who may have left brain weaknesses and right brain strengths which are associated with poor verbal scores and good non-verbal or performance skills. However, the high overlap between Dyspraxia/DCD and Dyslexia stresses the need for an individual assessment of the child. Also, Montgomery (2004) claims that the high IQs of many gifted children with NLD have gone undiscovered because their low performance scores depressed their overall score.

Portwood (2000) graphically shows the ‘spiky’ profile from the averaged scaled scores achieved in the subtests of the WISC III (1991) of a sample of children with dyspraxia/DCD aged 6-16. It has particular relevance for Maths difficulties. As can be seen there were lower than expected scores for Arithmetic, Digit span, Coding and Block design subtests. The Arithmetic subtest is given orally without visual aids to test maths problems. Digit span tests the ability to repeat dictated series of digits (e.g., 4 1 7 9) forwards and other series backwards. Coding measures visual motor skill and Block design tests abstract visual-perceptual ability, spatial and nonverbal problem-solving. From this graph it can be deduced that these brain differences may be some of the reasons why many children with Dyspraxia/DCD have perceptuo-motor difficulties that impede



processing of specific areas of Maths. Addy (2003:42) stresses that it is important for teachers to realise that these children do not have significant learning difficulties but have "difficulties specific to motor planning and perception".

Maths Assessment for Students with SEN including Dyspraxia /DCD

Henderson (1998) says that continuous assessment in Maths is of vital importance for students with SpLD. Accurate assessment of a student's current competencies must be a starting point for any intervention at the individual level (Westwood, 2003). For children with Dyscalculia and overlapping Dyslexia or Dyspraxia/DCD it is crucial to accurately analyse both the learning strengths, difficulties and errors in order to devise a learning plan to best support their progression (Emerson and Babtie, 2010). Knowing exactly in what way to intervene is a key to successful intervention (Riccomini and Witzel, 2010 in Long, 2011). However, Inspectors were critical of assessment practices in Maths in a number of schools and said that some teachers did not adequately use assessment data to inform their maths lessons and programmes of work (DES, 2010). Hopefully this will change with the introduction of the new *Strategy* (DES, 2011) which stresses improved use of assessment data to inform the teaching and learning of all students including those with SEN.

The staged approach to early identification and informal assessment of children in Irish Primary Schools has already been discussed. Also, it is hoped that the new *Aistear* programme (NCCA, 2010) for all children aged 0-6 which emphasises multisensory play, activity and informal assessment linked to learning, will also support children with SEN. In DEIS schools the excellent programme *Ready Steady Go Maths* (Pitt, 2011) is delivered in infant classes, but all schools can now access this recently republished manual.

Maths Recovery is an Australian programme adapted from the work of Wright, et al (2006). This programme is in wide use internationally. It has been adapted for Irish schools by Noreen O'Loughlin, Mary Immaculate College and is presently delivered from 1st class in DEIS schools. With increased teacher training it is hoped to extend its use countrywide. It is closely linked with extending children's number knowledge, understanding and strategies and "offers an extremely detailed profiles-based assessment of pupils in respect of these areas and provides a framework for individual, group or class-based instruction which is suitable not only for pupils who are experiencing difficulties but also for average and more able children" (www.mata.ie. 2010).

Research in the Literature emphasises the importance of both the traditional Assessment of Learning (AoL) and also Assessment for Learning (AfL) for all children including those with Dyspraxia/DCD. Clausen May (2005:7) stresses the value of AfL which she says "enables teachers to relate what pupils are learning now to what they have learnt in the past, and to pave the way for what they will learn in the future". Children's Maths' difficulties may be assessed with the help of a broad range of assessment tools (NCCA, 2007).

For children with motor and perceptual difficulties, teacher observation in Maths can holistically assess and record the student's competence and confidence, progress, specific errors, attitude to Maths, speed and learning style, use of Maths' language and organisational skills.

Teacher designed tests and checklists are also useful in assessing the child's understanding and knowledge. Error analysis is particularly useful with older students on an individual basis. There is an excellent example archived on the PPDS website (www.ppds.ie) based on the 4th class maths' curriculum. Teachers could design suitable ones for other class levels It is considered very important to look at both the errors and the non attempted algorithms of children with SpLD. Also a valuable aspect to error analysis is that the student is encouraged to explain how they did each sum which can pinpoint which concepts are understood or otherwise and the student's use and understanding of Maths' language. Student interviews are suggested by Westwood (2003). Videoing or audio recording of these activities could form part of an 'electronic portfolio'.

Increasing self assessment is recommended as in the excellent *Makesure Maths* series from Infants to 6th class by a very experienced Irish teacher and author (Gavin, 2007).

Parents' crucial role in advice and knowledge of their children's strengths and needs can greatly inform assessment and developmental profiles. This will be further discussed in another section.

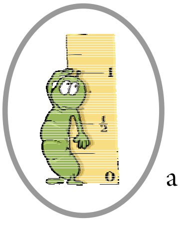
Most Irish Primary Schools administer Drumcondra or Sigma standardised Maths tests in classes from 1st to 6th. However, from September 2011 the results from these tests given at the end of 2nd, 4th and 6th classes will be communicated to the school's Parents and the B.O.M. Emphasis will also be put on examining the results/error patterns diagnostically to better inform on the child's knowledge or needs in each strand/unit of the Maths' curriculum (DES, 2011).

There are a number of useful screening Maths tests. The Maths section of Wide Range Achievement Test 4(WRAT) is used by many psychologists and specialist SEN Teachers. The numeracy checklist in Addy (2003) is particularly good as an initial assessment for children with Dyspraxia/DCD. Also, those in Clayton (2008) provide useful assessment pointers. However, Emerson and Babtie (2010) offer the most useful and detailed investigation of students' basic numeracy skills in *The Dyscalculia Assessment* for children with overlapping Dyspraxia/DCD. After an initial background questionnaire, number sense and counting, calculations, place value, multiplication and division, word problems and formal written numeracy are assessed in 6 sections. The focus is on finding out what the student can do and how they reach their answers. In-depth advice is given for teachers in analysing these assessments and strategies to support their planning and teaching.

There is a lack of diagnostic tests in Maths for children with SEN linked to the Irish Primary Schools Maths Curriculum. However in the UK the standardised Mathematics Assessment for Learning and Teaching (MaLT) (Hodder, 2010) is useful for students including those with Dyspraxia/DCD. It has 10 levels suitable for both groups and individual children aged 5-14. It is available in both pencil-and-paper and interactive computer-adaptive (CAT) formats. **MaLT** assessments were purpose-written to pinpoint particular errors and misunderstandings which are diagnostic of key learning needs. The CAT format, suitable from aged 8 is particularly useful for children with poor fine motor skills and slow information processing. Many students with Dyspraxia/DCD like the CAT format of assessment as it is non threatening and they can work at their own pace which relieves anxiety. It gives instant and personalised analysis and results feedback to support both AoL and AfL which can printed as a profile. (www.hoddertests.co.uk).

One important aspect of assessment for students with Dyspraxia/DCD is to determine their Maths' learning style. There is a lot of discussion in the literature about *Inchworms* and *Grasshoppers* that are two distinct learning styles (Chinn and Ashcroft, 1993 : Henderson, 1998 ; Tandy Clausen May, 2005 ; Clayton, 2008 ; Chinn, 2009). While these are popular terms the terms *Sequential* and *Holistic* are in current use (Clayton, 2008). On assessment children with dyspraxia/DCD will typically present with *Inchworms* type learning styles with a preference for analytical and clearly defined methodical ways of working. Portwood (2005) says that children with Dyspraxia/DCD do not need special teaching but need effective teaching strategies that could apply to all learners grouped by their learning styles. Many children with dyspraxia/DCD may have strengths in verbal, visual and kinaesthetic learning styles and like to work in a detailed methodical way. Clayton (2008:27) gives the following clear examples of the two Maths' learning styles.

The *grasshopper*
prefers
controlled exploration.
30x8=240
240-8=232
29x8 =232



The *inchworm*
prefers to follow
a formula or recipe
29x8 =
29
x 8
232

After accurate identification and assessment the planning for an intervention programme for the student with SEN including those with Dyspraxia/DCD can begin.

Effective Intervention Planning

Long (2011) suggests a useful framework for intervention linked to assessment.

- What does the student know?
  - Identify strengths
- What does he need to know?
  - Identify Learning Needs
  - Identify Priority Learning Needs
- Prepare an Intervention Programme in collaboration with Class Teacher, Parents (School Support Plan/IPLP/IEP)
- Implement, evaluate and review the intervention programme.

Maths is a Difficult Subject

Maths has a widespread reputation as a difficult subject for many children including those who do not have learning difficulties. "There are a number of features of maths which distinguish it from most other subjects" (Kay and Yeo, 2003:2). They say that in the main, Maths is usually presented in a very abstract way that some students do not understand. Further, calculation and problem solving in Maths involve thinking out and planning series or sequences which are difficult for many children. They also emphasise that good memory skills play a key role in successful Maths' learning. They contend that Maths is a building block subject which is agreed by Chinn and Ashcroft (2001), who say that it is a sequential subject building on early skills and knowledge to take the pupil on to new skills and knowledge. They agree that a child may get stuck at more demanding stages such as multiplication, division and fractions but that some children get lost at the beginning stages of number which is the foundation of Maths. Similarly, Clayton (2008) says the teaching and learning of Maths is like building a wall that takes eleven years to build.

Intervention Strategies to Support the Maths' Learning of Students with Dyspraxia/DCD

This section suggests research informed interventions to support the Maths' learning of students with dyspraxia/DCD.

> *Interventions use plans, strategies and support to facilitate the learning and address the special needs of students. They are those adaptations or modifications that are designed to enable a student to achieve a desired learning goal (NCSE, 2006).*

In-depth exploration of maths' strategies is beyond the bounds of this study. However, good inclusive practice is suggested for a whole school approach, parental and student involvement and some suggestions about general teaching and learning principles that may help overcome the students' barriers to Maths' learning.

Whole School Approach

A holistic, whole school collaborative approach is needed to address the characteristic difficulties of children with dyspraxia/DCD including those in their Maths' learning (Dixon and Addy, 2004). The collaboratively devised whole school Maths 'plan should include details of how the needs of children with SEN including those with dyspraxia/DCD will be addressed. Some of the targets set by the new *Literacy and Numeracy Strategy* (DES, 2011) include:

- Promoting better attitudes to Mathematics among children and young people
- Improving outcomes at early childhood level and a readiness to develop early mathematical language and ideas
- Ensuring that each primary school sets goals and monitors progress in achieving demanding but realistic targets for the improvement of numeracy skills of its students in a school improvement plan
- Increasing the percentage of primary children performing at the highest levels
- Reducing the percentage of children performing at the minimum level.

The Principal Teacher should involve the entire school community including parents and also enable professional development to support improved Maths learning. The School Maths Improvement Plan should also detail the Maths Curriculum content, teaching approaches, assessment, and collaboration with parents, interventions, equipment, ICT integration, and how a maths rich environment would be implemented. It is very frustrating and confusing for many children with SEN and Dyspraxia/DCD with an *Inchworm* learning style when class and support teachers use different methods and language. Working together, Special Education Support Teams (SEST) consisting of RT and LS teachers will provide advice on assessments and IPLPs/IEPs that outline additional Maths' support for children with SEN. (DES, SP ED 02/05).

Collaboration with Parents of Children with Dyspraxia/DCD

Research suggests key points for schools' good practice in parental involvement. These include acknowledging parents' crucial advisory role, informing of how the school proposes to support their child's holistic needs, involving them in decision making, IEP planning and regular meetings (DES, SD ED, 02/05; NCCA, 2000; NCSE, 2006; MacIntyre and Mc Vitty, 2004; Kirby, 2007).

Parents have a pivotal role in developing a positive attitude to Maths' in their children and revision of school work. Shopping and cooking activities link Maths with real-life experiences. Topping and Bamford (1998) have devised parent-assisted learning in Maths that could benefit children with dyspraxia/DCD. Their book on Paired Maths advises parents to use "structured mathematical games which aim to consolidate and deepen maths understanding and generalise problem solving skills out of the classroom into "real-life" community" (www.dundee.ac.uk.).

Playing traditional card and board games such as "Snakes and Ladders" and "Bingo" can develop the child's enjoyment and numeracy practice as well as social skills which are often a difficulty for children with Dyspraxia/DCD. Further, the NCCA (2006) has published an explanatory DVD for parents to support the implementation of the Revised Curriculum (DES, 1999).

Finally, Tilstone (2005) recommends ICT strategies to increase parent/ school communication such as email, Internet, distance learning and virtual classes. Kirby (2007) recommends the use of *Numbershark4* software (Whitespace, 2009). In my experience this is the best software to encourage the Maths' learning of all children with SpLD. It has over 40 games to cover the basic number operations, fractions, decimals and percentages and tips for home use can be downloaded from its website. There are many excellent free Maths websites and downloadable applications suitable for both school and home use. *Mathletics* (www.mathletics.ie/) is an subscription on-line Maths programme which is being increasingly used at school and at home. It has been customised by publisher CJ Fallon for the Irish Maths Curriculum and was the 2011 Maths' award winner at BETT in London.

Respecting the views of children with Dyspraxia/DCD

The voice of the child with SEN, including dyspraxia/DCD, should be respected in decisions involving his/her educational provision (Jones, 2005). The child with dyspraxia/DCD can give information on his/her difficulties and preferred learning styles that may suggest good inclusive teaching strategies (Addy, 2003).

Positive Support for Maths Teaching and Learning

As previously discussed, teachers' confidence, positive attitude, knowledge and personal learning styles greatly influences students' success in Maths (Henderson, 1998). Enjoyment of and competence in Maths are closely linked. Without success children can develop Maths anxiety which can be a total barrier to learning. Overcoming anxiety is the first priority so that the student can succeed in Maths (Dixon and Addy, 2004; Chinn, 2007). Suggested ways of helping Maths' anxiety include:

- to play motivating games to make Maths fun
- break activities into small key steps

- differentiate the class Maths' work and text books
- use simplified Maths workbooks such as those by Florence Gavin
- use motivating and real life activities
- encourage having a go, 'guesstimating' and finding ways of figuring out solutions
- use pair and group work,
- give wait time and opportunities for over learning
- practice number skills in different contexts such as linking with motivating ICT
- emphasise the student's present strengths and knowledge of key facts. Many students are reassured by the approach of Chinn (2009 b), who suggests breaking aspects of Maths into small key units. He says that there are only 121 facts to be learnt in both addition and subtraction and these can be presented in an addition facts square, as each fact is learnt. Similarly, he says that the Tables Square has 121 facts to learn (Chinn, 2009 a).

My Maths' classes always started and finished with games that were linked to the topic being learnt in class. Daily games included card and dice games, dominoes, triominos, tangrams, digit cards, loop cards, target boards, place value abaci, modified Bingo games, peg patterns in flexible 100 square and multiplication boards in *Number Board*. See the archived Maths section on the PPDS website for details of these and also of activities to support the learning of tables which may be very difficult for children with SpLD (www.ppds.ie).

Also of crucial importance is teacher knowledge of how the many characteristic difficulties may challenge the Maths' learning of students with dyspraxia/DCD. There are differing views about whether or not they need special teaching but Portwood (2005) states that they only need effective teaching strategies which could apply to all learners grouped by their learning styles. Many children with dyspraxia/DCD may have strengths in verbal, visual and kinaesthetic learning styles and like to work in a detailed methodical way. It is universally recommended in the literature that multisensory teaching and learning are needed to effectively support all learning styles.

Concrete-Representational-Abstract (CRA) Instructional Interventions

Research suggests that the Math's learning of students with SEN can be enhanced using a three stage instructional sequence called Concrete-Representational-Abstract (CRA) as an intervention. Maths is a building block subject and each of the three stages builds on the previous instruction to help student's learning, retention and conceptual knowledge.

In the concrete stage, the teacher models each mathematical concept with concrete

materials such as a Slavonic abacus, coins, cubes, base-ten blocks, pattern blocks, pie or bar fraction pieces bars, and geometric figures. Also, Kirby (2007) recommends the use of *Numicon* for students with Dyspraxia/DCD. Chinn (2009 a) recommends the use of coins to support real life activities using addition, subtraction and place value. But children with Dyspraxia/DCD may find working with 1cm cubes or coins challenging because of their poor fine motor skills. Addy (2003) advises sticking a bead to coins to support their use. Clausen May (2006) strongly advises the use of Slavonic abaci which support a 'seeing' rather than a 'counting' approach to number. But Kay and Yeo (2003:24) emphasise that "pupils learn most from cognitive tools when they are guided to use them in meaningful ways". It is important not to move to the next stage too quickly. Many children with SpLD need a lot of support as they tend to inefficiently count in ones and also have difficulty in counting back.

In the semi-concrete level or representational level the teacher transforms the concrete model into a representational level, which may involve drawing pictures; visual cues, arrays, using circles, dots, and tallies, 1cm graph paper or using stamps to imprint pictures. Personally, I have found that many children with SEN including those with Dyspraxia/DCD need a lot of practice to consolidate the link between these stages.

It is emphasised in the literature that some students may get stuck if they are introduced too quickly to the third or abstract stage of Maths' concepts which use only numbers or symbols.

Teaching Maths Procedures and Sequences

Students with SpLD including Dyspraxia/DCD need to be taught Maths' procedures and sequences in a structured way. Effective teaching helps students to understand and master reasoning strategies that will be a key part of their learning Maths' facts such as tables. Chinn (2009: 44 d) says that "self-voice learning can be stunningly effective" in the learning of tables. He suggests that students record themselves saying key table facts of 1x, 2x, 5x and 10x and practice listening and saying them until they are mastered.

However, spatial organisation may be the most significant difficulty experienced by students that will affect many areas of maths including place value. Helpful strategies include: squared paper and assigning a square to each digit, providing a coloured line of direction for calculations and using specific colours for thousands, hundreds, tens and units matching those of Diennes' blocks (Dixon and Addy, 2004).

Differentiating teaching and learning is seen as an effective strategy to remove the barriers to curriculum access of children with dyspraxia/DCD (Kirby and Drew, 2003: Reid, 2005).

In addition, some children with dyspraxia/DCD are gifted students. Differentiation could address the needs of gifted children (Kerry and Kerry 1997 cited by Westwood, P. 2003:203).

The use of ICT is seen as being particularly useful in differentiation (NCCA, 2002:20).

Maths Language

"A large part of understanding in number work is mediated through language….that is not easy to understand" (Kay and Yeo, 2003). In agreement, Henderson (1998: 23) says that breaking down multi-syllabic Maths words and making lists of Maths phrases and words are really helpful. She also points out that apart from Maths words that "the biggest problem of all seems to be with the non-mathematical words that are put into maths questions to make 'real live' situations". This will affects their problem solving skills which many children with SpLD find very difficult. This may be helped by Maths Mind mapping which will also assist comprehension, memory, and word recognition (Buzan, 2003).

Teachers need to be aware that many children with Dyspraxia/DCD may have receptive and expressive language difficulties that challenge "their understanding of the language of spatial organisation, sequencing and time concepts" (Ripley, 2001:35). She suggests that the precise meaning as well as the social usage of key words would be taught firstly by teaching the concept in a structured one to one or small group setting. Secondly, planning small group activities that practice the new words and thirdly by targeting the use of the words in the context of the classroom and the curriculum. Also she suggests teaching and constantly practising vocabulary and language needed for daily school activities and instructions. Further, she recommends the use of visual representations that "do not fade like the spoken word" such as "visual timetables, cue cards and flow diagrams". In addition, Addy (2003) suggests using gestures, spontaneous expression, sequencing games, fun raps, mimes, guessing games and chants.

Other strategies include teaching Maths language and linking with colour coded visual supports such as variety of words for symbols. Students may greatly benefit from using Maths dictionaries especially when they make and personalise their own. Eather (2011) has designed an excellent on-line *Maths Dictionary for Kids* that gives visual support to explain each word. 'Journal writing' is also helpful from a young age and which is now on the Junior Certificate Programme. Westwood (2003) recommends teaching meta-cognitive skills and as previously described Chinn (2009 d) says that self-voice learning greatly supports rote learning.

Classroom Environment

Strategies to adapt the classroom environment include the child's table being at the correct height so that his/her feet would be flat on the floor and hips at 90 degrees when seated, table could be positioned against a wall to assist with shoulder support. Clear pathways around the child's desk and include suitable lighting to help visual sensitivity and a quiet corner where work could continue undisturbed (Dixon and Addy, 2004; Jones, 2005).

Handwriting and Fine Motor Skills

Most children with dyspraxia/DCD "find handwriting extra-ordinarily difficult to master" Henderson (2005:59). She suggests that a partnership of assessment and intervention is often a crucial strategy to help children to understand their difficulties and suggest a solution. Her suggestions are similar to some of those of Addy (2004). These include learning to write correctly with correct posture, writing slant, spacing and pencil grip. Like many other experts, Culligan (2009) advises teaching a fluent cursive style from the early stages of writing development. He also gives a very useful list of supportive fine motor activities.

Children with dyspraxia/DCD also benefit from a slanted writing surface, dycem to prevent paper slipping, ridged ruler, raised lined paper, hand hugger pens and pencils, graphite pencils, ball point and gel pens (Jones, 2005; Kirby and Drew, 2003). It should be stressed that many students with Dyspraxia/DCD will have difficulty copying work from the board, book or workcards. Also they need support when writing numbers in calculations as previously described (Dixon and Addy, 2004).

ICT to Support Maths Learning

> *For children with Dyspraxia, ICT can play an important role in their education. Internationally, ICT is increasingly being used to enhance their learning. ICT has enormous potential to reduce learning difficulties and compensate for disabilities. (NCTE, 2006).*

ICT accommodates their differing learning styles, gives instant feedback and extra practice to master basic skills, is non judgemental and gives control of their learning In addition, ICT can help children with dyspraxia/DCD in social skills, work presentation, motivation and self-esteem (NCTE, 2006).

Assessment and intervention are closely linked. Many children find the non-judgemental aspect of computer-aided assessments helpful and motivating.

Assistive Technology can support the motor difficulties of children with dyspraxia/DCD. Keates (2000) lists inexpensive low-tech ICT products to support the motor difficulties of children with SpLD including dyspraxia/DCD. These include cassette recorders, dictaphones to orally record schoolwork, portable word-processors, laptops or notepads to support writing.

Interactive Motivational ICT Maths' software programmes are recommended for children with dyspraxia to "develop specific aspects of number theory, aid mental recall of number facts, sharpen pupil's calculation skills and extend what they have been taught in class" (NCTE, 2006). . ICT allows graphs or geometrical objects to be generated and transformed. It can link the child with the real world using real data that may be downloaded (Swan, 2005).

Increasingly many useful Maths' related applications are being designed and can be downloaded to computers, iPhones/iPod's. In my opinion, iPad's are particularly motivating and useful for students with Dyspraxia/DCD because of their sturdiness and practicality.

Whiteboards (IWB) are becoming increasing popular internationally and in Ireland. Irish schools "are exploring how these devices can open up new horizons in the business of teaching and learning" (O'Leary, 2006:43). Children with dyspraxia/DCD who have mobility problems can control the IWB from their seats.

Problem solving, Comprehension, organizational, memory and thinking difficulties are common in children with dyspraxia/DCD. Mind mapping software such as graphic organizers can support these difficulties (Inspiration Software, Inc, 2003).

ICT facilitates the social interaction and communication of children with dyspraxia/DCD (NCTE, 2006). These skills can be helped through collaborative ICT project work, peer tutoring and sharing of ideas through email or video conferencing (Tilstone, 2005).

Conclusion

This article summarised the typical characteristics of children with Dyspraxia/DCD which often overlap with the characteristics of other Specific Learning Disabilities (SpLD) and outlines why most of these children may have difficulty with specific areas of Maths**.** Good inclusive practice is suggested for a whole school approach, parental and student involvement and some teaching and learning intervention strategies that may help to overcome the students' barriers to Maths' learning. To conclude, supporting children with dyspraxia/DCD in Primary Schools requires teachers to have a "state of mind that really requires an attitude of motivation and acceptance" (Dixon and Addy, 2004:55).

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Catherine Sweeney is currently National Chairperson of the Irish Learning Support Association (ILSA). She taught in inner city Dublin for many years before returning ten years ago to Ennis, Co. Clare to work as a Resource Teacher for Children with SEN and also with Newcomer Children. She has been an INTO/NCTE tutor since 1999 and has delivered many computer courses to parents, teachers and SNAs. She has delivered many presentations in Clare Education Centre. She was seconded as a Cuiditheoir for Learning Support, Maths and English with the then Primary Curriculum Support Services and remains on its database as a local facilitator She is also a local facilitator with the Special Education Support Service. She has long had an avid interest in supporting children with Dyspraxia/DCD. Her M.Ed in SEN dissertation was "Good Inclusive Practice for Children with Dyspraxia/DCD in Irish Primary Schools" which was later published by the Dyspraxia Association of Ireland.

A Social Developmental Approach to Teaching Young Children with ASD

Mary McKenna

(Names changed to preserve anonymity)

The broad range of training on various methodologies for teaching children with ASD, as made available through the Special Education Support Service (SESS), is crucial and to be thoroughly commended. This is reflected in the affirmation of continuing professional development by all teachers and principals surveyed by Ring (2010). There is however, the potential for teachers to experience overload and confusion, as they try to make sense of what can be perceived as somewhat polarised rationales. Returning to the classroom after any given course, determined to implement every strategy as therein suggested, can lead to fractious practice and unsatisfactory outcomes for all involved. The essential challenge lies in discerning the core elements of each methodology and in exploring how they can be adapted or shaped to meet the needs of individual pupils at any given time (Mc Kenna, 2009). This once again reflects the findings of Ring, who suggests the advantages of isolating effective elements of common and ASD-specific teaching approaches in order to form an alternative approach, rather than restricting educational practice to one specific intervention model.

When asked by a journalist in 2008 'If you don't do ABA, then what do you do?' I searched for words to describe my work and failed to make it sound anything even approximating cohesive. It seemed that I was better equipped to list the things I didn't do than to profess to having any idea of what it was that I actually did. All I knew was that it worked.

That day I resolved to examine my practice in order to formulate a cohesive

Sitting on the 'Humpty Dumpty Wall'

Story and Rhyme Time

description (and indeed a title), based on an understanding of ASD as provided by both the children I have been lucky enough to work with, the broad training in ASD accessed through the SESS (and the DES before them) and the many fine clinicians from Beechpark Services (Health Service Executive), who have supported me over the last twelve years. Attention has been drawn by Ring (2010) to the contribution initial teacher training makes to the repertoire of pedagogical knowledge in meeting the needs of pupils with ASD. Sometimes we underestimate the skills and understanding we have gained through our years in training college while we focus on the ASD-specific training. I have worked alongside several exceptional teachers in the other Scoil Mhuire class who were exceptional from their first day, before accessing any specialist training.

This article outlines what evolved from this examination to form a simple blueprint whose single requirement of the practitioner is to base each and every decision on the needs of both the individual child and the class group.

A Social Developmental Approach: A triad of questions to address a triad of impairment/difference?

An Autistic Spectrum Disorder is a complex developmental disability that essentially affects the way a person *communicates and relates to people* (Department of Education, Northern Ireland, 2002). It involves a triad of impairments (Wing, 1996): social and emotional understanding, social communication and social imagination i.e. flexibility in thought and behaviour. Children with ASD are affected in their ability to understand social behaviour, which affects their ability to interact with other children and adults. They are affected in their ability to understand and use verbal and non-verbal communication. And they are affected in their ability to think and behave flexibly (Jones, 2002). Guldberg (2010) warns of the danger of looking to models of intervention before first having a good understanding of the autism spectrum. This highlights the necessity for training in order to ensure that practitioners and parents possess specialist knowledge and understanding of the specific needs of children on the autism spectrum, as emphasised by Guldberg, Parsons, MacLeod, Jones, Prunty and Balfe (2011).

The diagnosis of ASD goes way beyond simply a deficit of skills. It would be misguided to think that teachers can simply teach pupils with ASD the skills that, from our perspective, they appear to lack. Programming skills onto individuals does not constitute development. This concurs with the views of Bauminger (2002), who advises the teaching of social understanding, as opposed to teaching splinter skills and Jordan who exclaims in the Gulliford lecture (2008) "Will social skills lessons ever end?"

Atwood (2000) emphasises the importance of developing effective intervention based on a theoretical understanding of the mechanisms underpinning ASD. Given that the areas of the brain affected by ASD are those responsible for social processing, it follows that social development should be the focus of any intervention aiming to address these deficits in order to support full access to real education and maximise potential development. Guldberg et al. (2011) stress the

Circle Time

Blue Table Group

importance of focusing on developmental areas such as *functional spontaneous communication and language, social understanding and joint attention, peer interaction and appropriate toy play.*

Given the broad variations in how ASD can manifest itself in individual persons it is crucial to approach each young child as an individual first and foremost. 'When you have met one person with autism, you have met one person with autism' (Shore cited in Hudson Baker, Murray, Murray-Slutsky & Paris, 2010). This reflects the views of Jones, English, Guldberg, Jordan, Richardson and Waltz (2008) who recommend basing interventions on the individual child's strengths and interests. Subsequently I know that the next child to walk in the door of my classroom will be a new adventure and it will be my responsibility to individually assess him/her with respect to his/her strengths, interests and preferences as recommended by Jones (2002) and to support them to the challenges they face as a result of his/her diagnosis of ASD as recommended by Jordan (1999).

So the first question that needs to be asked of the new pupil is:

Question 1 '*Who are you?*'
What do you see? What do you feel? How does your body hold itself and how does it move? How do your senses process their intake? What/who do you relate to? What/who do you respond to? What lights you up/engages you? How do you perceive yourself, the world around you and the people in it? **What has been your life experience (physical/intellectual/emotional) up to this point?** What provides security for you and what threatens it? What are your character traits, apart altogether from your given diagnosis? What is your family dynamic? What are your strengths, interests, passions? What are the things that you can do with ease and what are the things that challenge you? (McKenna, 2009). A parent whose child was experiencing significant challenges arising from his world-view (i.e. I will be annihilated if I don't dominate), once told me:

Gym Room

Work with Teacher

'You were the first to really see Johnny.
Then you showed him to us.
And I can even say you showed him to himself'

Sufficient time needs to be allocated to exploration of this question in order to support the design of a meaningful individualised programme for development. Too often the temptation to launch headfirst into the security of programmes can result in exhaustion and frustration from misappropriated investment of time, but more importantly, energy, expended in the wrong direction which ultimately fails to meet the child's needs. After all, we are in the business of education, which stems from the latin word educare meaning 'to bring up' which in turn is related to educere which means to 'bring forth what is within' (http://en.wikipedia.org/wiki/Education). It is inherent in the responsibility of the educator of children with ASD to invite the child to show up through his /her play and in so doing support the individual in developing a sense of self, so often underdeveloped in persons with ASD; an understanding of that self in relationship with others and an understanding of that self in relationship with the world. This reflects the goals of the Social Personal and Health Education (SPHE) curriculum (National Council for Curriculum and Assessment. 1999). When this becomes central to our practice, we can aspire to the true title of 'educerists'.

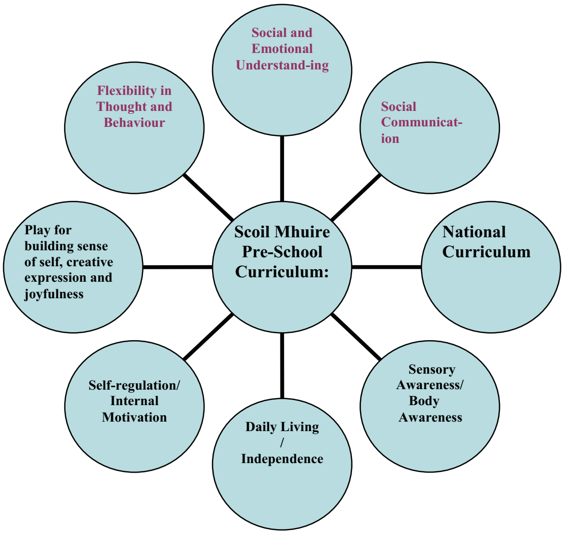
Question 2: ***What do you need?***
This is the million dollar question which has fuelled frequent and energized debates in the context of service provision which have largely concentrated on whether the child would benefit more from a classroom predominantly based on a particular methodology such as TEACCH or ABA. From a more simplistic perspective however the child whose development has been arrested due to ASD needs to have this point of arrest identified and to have his development jump-started once more from there. Systems of intervention that may or may not support this development are of secondary importance (Mc Kenna, 2009). What is of central importance is the child him/herself and the capacity of both the personnel and environment to meet his needs.

If the given diagnosis of ASD is correct, we can safely assume that the child's development has been affected by an arresting of development in Social and Emotional Understanding; Social Communication and flexibility in thought and behaviour. So the child needs to develop these areas and he needs a lot of help to become empowered as a social participant, a social communicator and supportive staff and environment that will invite him to develop creativity and flexibility in his thoughts and actions.

> *The problem may be identified as speech, language or communication disorder or delay, but the underlying issue is often a need to develop relationships with people. Consequently the major question is not 'How do children learn language?' but 'How do they develop relationships that will support the social use of language?*
>
> Mac Donald, 2004, p.6

The importance of basing learning goals on the child's own experience in order to develop him/her as an autonomous being, who will be motivated to develop and sustain relationships is highlighted in the views of Jordan (2003), who maintains that failure to experience spontaneous and collaborative patterns of behaviour leads to under developed self-awareness, motivation, memory, socialisation and self control. If the child learns early on that language is merely something he is required to use by his educators and parents i.e. something unconnected to himself, it can be difficult albeit crucial for me as a teacher to facilitate the reconnection of language to his being and ignite the joy of expression. As Albert Einstein said it is '*the supreme art of the teacher to awaken joy in creative expression and knowledge*'. '*Learning is experience. Everything else is just information*'. (cited in Call & Featherstone, 2003 p.112; 116)

Figure 1



See Figure 1 for outline of curriculum for Scoil Mhuire Pre-School for children with ASD showing the areas that I have found to have particular relevance for the children in my class.

Question 3: ***How will I meet your needs?***

So now we've worked out what we need to do, we need to find out how. Each child will be different but many will share similarities depending to a large extent on their life experience up to now and the level of challenge that they experience arising from their diagnosis of ASD and any other diagnosis such as level of general learning disability. Some are crying out for increased structure and predictability, while others need a gentle departure from rigidity of routines and to be directed towards freedom and exploration. There is no pre-set starting point apart from within him/herself (Mc Kenna, 2009). The essential information that will answer our first question (i.e. who are you?) has yet to be gathered. A general rule for commencement in Scoil Mhuire is freedom to play, explore and process the environment. This allows staff to observe and assess and work out the answers i.e. who are you and at what point of the developmental scale have you stalled? After a period of time as dictated by the ease at which the child is playing within the school setting, parallel play can be introduced. The following section outlines a personal overview of the stages of social development as experienced in my own practice with suggestions regarding how to support the children wherever they may be.

Developing a Framework for Social Development: 6 Easy Steps

1. Child's own agenda: Free Play and exploration (building sense of experiencing self). Staff can name reality for the child in simple language e.g. 'You're jumping on the trampoline', thereby ensuring that the language is aligned to what is registering in his/her body i.e. language has meaning as connected to the individual as an experiencing self. This reflects the values of the Marte Meo programme as developed by Maria Aarts in 1987 (http://www.martemeo.com/en/home).Restrict language to commentating (NO questions which can pressurise child and pull them out of their experience!) Let him be. Resist the urge to jump into showing parents how effective we can be with their children. Our goal for the child's first day is that he goes out the classroom door at the end of the day with one thing and one thing only…..an overwhelming desire to get back in through the same door tomorrow!

2. Parallel Play (allowing others into their space). Continue commentating if appropriate e.g. 'You're jumping. I'm jumping'; 'You're pouring sand'; 'You're playing with bricks'. Some children respond to us singing the words. Some of our most exciting language breakthroughs come when a non-verbal child starts to sing imitating the melody and sounds of our activity songs. As before, it is important to observe the zone of personal space required around him before s/he starts to feel discomfort.

3. Engagement (connecting with others in their space / building relationships): Staff build on the child's communicative initiatives to sustain engagement. When you structure their learning on their own registration of themselves and the world, with their personal experience as the foundation blocks, then they do not lose their learning. It is part of them; internalised. I use the metaphor of a mobile phone mast. I need to become a communications-receiver like a giant aerial picking up and receiving communications. It calls for strong powers of observation. Observe and tune in. When you tune into the child's world you will get clues as to how to engage. It's impossible to pre-empt. Mutual creativity, viewed by Fogel (1993) to be the essence of communication, is called for at this stage. He claims that co-regulated communication occurs when both participants feel free to contribute to the process and warns against focussing on rules for fear of missing *'the core of the process and the excitement that keeps us involved (p.41)'*. This reflects the views of Wieder and Greenspan (2003) who stress the importance of interactive play for children with ASD claiming that it addresses the core deficits of relating and communicating, thereby facilitating development.

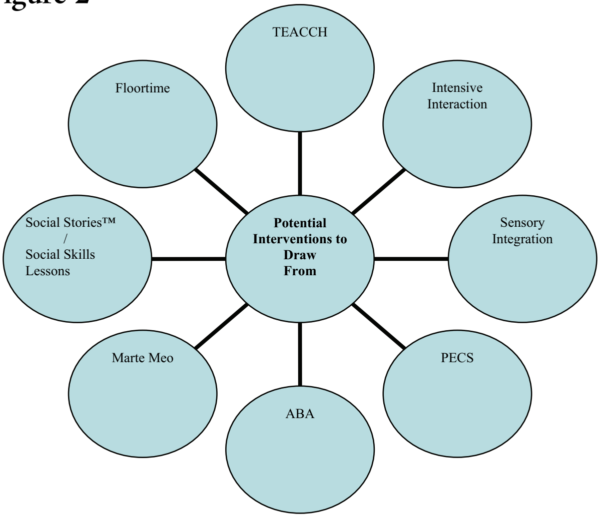
4. Give & take: Staff develop communication circles, as described by Wieder and Greenspan (2003), around the child's communicative initiative to sustain engagement thus laying the ground work for turn taking. This is the first time we're requesting the child to purposely participate in a two-way communication. So we're using our relationship to help draw him into our world as opposed to joining him in his which we have been doing up to now. So when a staff member has an activity up and running e.g. swinging child in swing or blowing bubbles, they stop activity and wait for communicative sign from child to continue which could range from eye movement, gesture, vocalisation to words depending on the level of communication development of individual child. We're waking the child up to the concept that interacting can be fun.

5. Turn taking (with adults and then peers). 'Your go on the car track; my go on the car track' progressing towards 'Your go/ John's go'.

6. Adult led activities: taking direction from adult (following the agenda of another). Examples include: 'Clean up/ Circle Time/ Time for Yard/ John, give me the red teddy/ John please give Sam a go' and general instructions throughout the school day.

See Figure 2 to see list of already existing methodologies which can be drawn upon to support a learning rich environment. But remember their role i.e. to meet the individual needs of the child /children in your class to develop the areas within the curriculum as outlined in Table 1.

Figure 2



The curriculum may be delivered through various modes of teaching and contexts, as dictated by the needs of both the individuals and the group, with emphasis on maximising use of naturalistic settings and spontaneous opportunities for learning. These include play; movement; music; individual teaching; independent table-top work; group teaching in structured settings e.g. 'Circle Time', 'Story and Rhyme Time' , 'Gross-Motor Group' 'Body Awareness Group' and unstructured group activities as initiated by the children themselves and supported by staff.

Flexibility and Structure: Delicate Balance Required!

Structure without flexibility = rigidity

Flexibility without structure = chaos.

The importance of structure for children with ASD is widely supported in literature. From the perspective of the practitioner however, it is important to be cognisant of the fact that its role is to meet the child's need i.e. support his understanding, and if the child already understands, it would be wrong to insist on adherence to restrictive practices. An example of this might be when all the class have organised themselves and are sitting in a group for Circle Time and attending to the teacher and then a well meaning supportive staff member notices that Child A has not placed his Circle Time card on the visual Schedule and exclaims 'Johnny! Go get your card and stick it!' which disrupts the whole group and reinforces the child's dependency rather than his independence that the said schedule card had originally sought to promote!

Structure within the environment can support children with ASD as they may lack *internal structure* and need structure created for them in the external environment (Lorna Wing, 1996). Structure helps them to make sense out of the world which can often appear as if governed by no sense whatsoever. It helps to avoid fear and anxiety and brings ease into the child's body. This is the starting point. If you have not got ease in your body there will be no learning because every sense and every capacity will be taken up with trying to cope with the distress.

In my class I aim to provide as much structure as necessary and to take it a step further I aim to facilitate the child in the internalisation of this framework so that he gains an ability to self organise, self regulate and be able to understand that a time of chaos does not equal the end of the world as they know it. As they move on from dependence on external structure it is vital that we, as their facilitators, respond and encourage them to try new things or perhaps old things at new times and to move beyond their comfort zones. In parallel to the broad support for least restrictive setting as the ideal for education of children with ASD as recommended by Taskforce (DES, 2001), I would argue the ideological case for *least restrictive practice*. As ever, it requires the power to observe and read when the child is in a state of emotional equilibrium. When the child is at ease and you can sense that you can afford to push the boat out a little, you might decide that it's the right day to introduce a little departure from schedule or normal practice. For example the experience of major trauma on a day when the usual door to yard was broken, woke me up to the fact that we had fallen into the habit of using the same door, day in day out. It being my tenth year teaching children with ASD, I was appalled to observe how ritualistic we had allowed ourselves to become as staff, without a single diagnosis between us! Indeed general experience would indicate that teaching children with ASD can result in rigidity, unless we remain acutely aware of the danger and guard against it. We had to give up on getting to yard that particular day and eventually made it back to classroom, where we did our best to recover. However on a following day when I perceived the class to be settled, I said 'I know let's do something different. Let's go out a different door'. We moved swiftly towards the new door singing 'Let's go to the yard' song and were in the yard before they knew it. Later, we introduced a choice board of different doors, so they could feel some power over what was happening to them. Needless to say we have hardly ever used the same door two days in a row with subsequent classes. We try to model openness to change, new experiences, flexibility and fairness and talk through our decisions for those children who have sufficient receptive understanding of language. Remember it can be as easy to set yourself up for success as failure. It can often depend on which choices you make. I chose the door nearest to the classroom as the *different new door* that first day, which meant that we were outside more quickly than ever before and could hear and see, albeit from a distance, the children playing in the yard. This meant that their understanding was being supported, both visually and aurally and hence they were getting the message

'Let in the Light'

that their destination was indeed their intended one. That day my choice was a good one but sometimes I am appalled at the consequences of my own poor choices.

Fostering Development in the Children / Developing Ourselves

Brownlow (2010) urges professionals to celebrate individual neurological differences and negotiate a means by which persons with autism can embrace difference, while maintaining a positive identity and position within society. This demands renegotiating our construction of autism from one of deficit to one of difference.

It's always easier to focus on others, and how, according to our perception, they need to change. It is a far greater challenge to focus on ourselves and explore how we perhaps might benefit from development. It is my sense that it is as much about our way of being as about what we do. Remember Einstein's advice and awaken joy in our own creativity and practice. Invite joy and acceptance of difference/diversity into our classrooms instead of fear and anxiety. Foster the art of perception. Observe and learn from the children. Learn when to keep out of things and when to step in. Learn to duck assaults. Learn to pre-empt the meltdowns. People sometimes ask how my current work compares to my previous work in mainstream. I tell them the highs are higher and the heartbreak is deeper. Celebrate the highs and there will be many and on the low days remember the words of Leonard Cohen:

> *There is a crack in everything*
> *It's how the light gets in.*

Let in the light. We need it as much as the children.

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Look at the past, organise for the present and plan for the future…

John Phayer

An examination of primary school teachers experiences of using Special Educational Technology in the classroom

Abstract

The aim of this article illustrates a study undertaken to ascertain the level of use and non-use of specialised Special Educational Technology, primarily looking at Assistive Technology software and hardware, utilised by primary school teachers and to describe their experiences of using it within an Irish school setting. In particular, the study wished to examine teachers levels of access and usage of this type of technology in their teaching, to identify possible reasons which could influence them in using more of it and to suggest ways to encourage greater participation through the medium of C.P.D. Twenty-five teachers actively participated in this I.C.T in S.E.N summer course, each of whom came from different teaching backgrounds, mainly Learning Support, Resource and Mainstream Teachers. The primary data collection methods used for this study were questionnaires and informal interviews to reinforce the data. The main findings, which evolved in the study demonstrated that a significantly high percentage of teachers expressed the view of lacking specific knowledge about the various types of Special Educational technology as well as having a lack of appropriate support in guiding them to use it in an effective way in their teaching, resulting in their making minimal use of it. On one level, lack of resources (e.g. funding) available to them, the physical age of computer equipment, having a fear of the technology, time problems and the possibility of being a late adopter of technology are other factors which contributed to teachers using less of this technology in their teaching. On a much deeper level, a lack of a proper framework demonstrating to teachers how to use specific types of Assistive Technology in teaching, the possibility of integrating A.T. into teaching programmes and the lack of sufficient C.P.D. courses in this field are other difficulties which emerged in the study. Consequently, Education Centres, which already play an imperative role in tackling teachers C.P.D. needs, could possibly address some of these issues.

Introduction:

Information Communication Technology (I.C.T.) continues to saturate student's educational experiences through e-mail, online chat tools and video conferencing tools, allowing them to communicate with other students on the Internet around the world (Wright, Wilson, Gordon and Stallworth, 2002: 1).

It is well documented that special needs children are one of the most important groups in society (I.N.T.O, 1999: I) and I.C.T. has enormous potential in helping students with all types of Learning Difficulties. Morrison (2007: 1) makes reference to Blackhurst and Edyburn (2000), who stress the way that Assistive Computer Technology has revolutionised the educational needs of students with various learning problems and the way it creates equal access to learning opportunities (Morrison (2007: 1). The advantage behind this is that educational software can be used to tailor the speed and difficulty of tasks in order to facilitate errorless or non-threatening learning (St. John of God School, 1999: 1). It is also well acknowledged that failure to provide necessary accommodations of I.C.T resources for this group of students will place them at a further disadvantage (I.N.T.O, 1999: 1). Martin (2006: 1) claims that providing:

> access to technology can result in meaningful learning experiences to develop problem solving and higher order thinking skills and to function in the world beyond the classroom.

Primary research question

In approaching a survey examining the types of Special Educational technology utilised by primary school teachers, a major research question was formulated that asked "What are primary school teachers experiences of using specialised Assistive Technology software and hardware in their teaching within the classroom?"

Secondary research question

When this primary research question is analysed further a number of secondary questions arise as follows:

- What general types of I.C.T. do Learning Support and Resource teachers use in their teaching and how often are they used?
- What types of Assistive Technology software do teachers use in their classroom and how useful are they?
- What types of Assistive Technology hardware do teachers use in their classroom and how useful are they?
- How competent do they feel in using these technologies in the classroom?
- What factors inhibit them in using this type of special educational technology with their students in the classroom?
- What additional supports and services could be made available to assist teachers in the area of ICT in SEN?

Factors affecting the adoption of technology by teachers

Although many different types of technologies have been introduced into schools in the last decade, they are not a panacea to every problem. Despite that computer technology offers specific assistance to both teachers and students that was unavailable to them in the past (Buckenmeyer, 2008: 1), technology continues to act as a more powerful and efficient tool for teachers who teach students with disabilities, whereby it offers new and more efficient means of learning, while concurrently individualising instruction to a broad range of student learning needs. Teachers and other educators now use I.C.T as a tool to facilitate learning beyond the means of 'teach and drill', in order to accommodate various learning situations of all students with Learning Difficulties (Behrmann, 2004: 1). Despite all the positive factors associated with using ICT and Special Educational technology in the classroom, there are many factors which affect teachers use of ICT, including (a) lack of time to learn about new technologies; (b) lack of technological resources to support them; (c) a limited number of technology training opportunities (N.C.A.T.E.: 1997, cited in Davis, 2003: 62) and Edyburn (2000) cited in Morrison, 2007: 2); (d) technical support (Wright, Wilson, Gordon and Stallworth, 2002: 355); (e) teachers' attitudes (Zabala, 2006, cited in Morrison, 2007: 2) and (f) integration (Kleiman, 2000, cited in Buckenmeyer, 2008: 7). In this article, three of these inhibiting factors will be debated as follows:

Integration:

Kleiman (2000, cited in Buckenmyer (2008: 7) suggests that access to computer technology could be regarded as the first step to integration and this integration occurs when the teaching profession are prepared to use it (Becker, 1999, cited in Buckenmeyer, 2008: 8).The possibility of not just getting the technology into the classroom but enabling teachers and school systems to prepare well to use the different types of technologies is also another issue (Buckenmeyer, 2008: 7). One study which examined this issue, carried out by Firek (2003, cited in Buckenmeyer, 2008: 8), examined the way teachers use technology in the classroom. The results demonstrated that newly qualified teachers still lack the necessary skills to successfully integrate ICT into the classroom. Martin (2006: 6) states that (a) the concept of software integration into the classroom, (b) the method in which it meets content standards and (c) the way it impacts on student learning, are areas of extreme importance when it comes to using any technology in a classroom and is an area requiring further research.

Resistance to change:

Crawley (2000: 3) states that the majority of teachers are skilled, motivated professionals whose purpose is to educate students but at the same time a minority of these individuals resist change. The teaching profession has learned a particular set of tools to deliver its material to students, but as more technologies are being developed and used within the educational system, many teachers now require learning in how to use these new tools, the approaches and skills required which accompany these new technologies. Buckenmeyer (2008: 8) argues the point that teachers attitudes towards using the technology in the first place is a strong indicator of its 'acceptance, adoption and use' (McGrail, 2005, cited in Buckenmeyer. 2008: 8). Research carried out by Ertmer (2005, cited in Buckenmeyer, 2008: 8) proposes that in order to change teachers beliefs about using technology, the research needs to be tailored and carried out on teachers who have firsthand experience of (a) using the different technologies, (b) exploring the aspects of integration that worked / did not work and (c) learning about change through Continuing Professional Development.

Reluctant users – Late Adopters:

Crawley (2000: 3) argues the fact that a lot of the technology which has been created and programmes of study pertaining to Technology Professional Development have been created by individuals who are enthusiastic about technology with little empathy for reluctant users. Some of these reluctant users / late adopters have also been provided with little support, few opportunities and marginal equipment. These'late adopters'can be classified as being 'a teacher who has not yet embraced new technologies or integrated them into their classroom' (Crawley, 2000: 4). Martin (2006: 2) states that to be a technologically competent educator, teachers must have (a) the skills to select developmentally appropriate software; (b) understand the related benefits of the software and (c) align the software skills with the curriculum.

Research tools used in the study:

The main data collection technique used to gather the data from both Primary Learning Support and Resource teachers was a questionnaire. Twenty six school teachers actively participated in the I.C.T. in S.E.N. course, but only twenty five completed the questionnaire because one teacher was classified as being 'newly qualified' and did not have a permanent job. Informal Interviews with the teachers were also utilised to seek firsthand knowledge and clarification of the difficulties they encounter using this technology in the classroom.

Findings:

The purpose of this article examined primary learning support, resource and mainstream teachers' use of special educational technology in a classroom setting. The article also attempted to outline some of the most common difficulties and reasons why they do not use more of this technology in their teaching from the 25 participants in the research.

The study began by asking teachers to indicate their teaching category. From the findings, all of the participants (i.e. 100% of teachers) indicated they were Primary school teachers and as a follow up to this question, they were then asked to indicate if they were (a) Learning Support (b) Resource (c) Mainstream or (d) both Learning Support and Resource **(Fig. 1):**

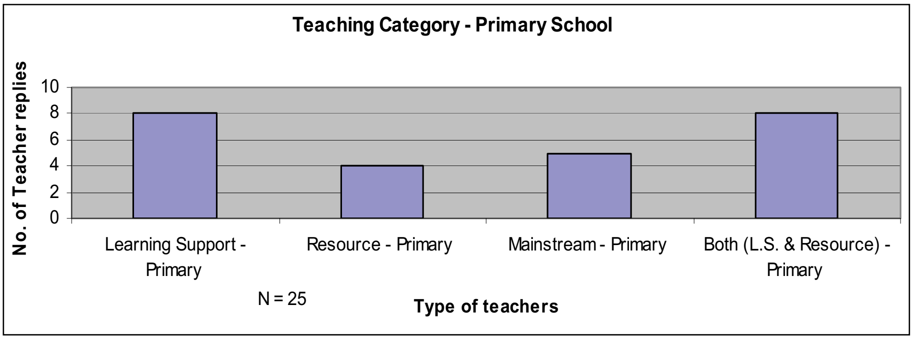

Fig. 1: Type of Teacher category

From the findings, 32% of participants indicated 'Learning Support', 16% indicated 'Resource', 20% indicated 'Mainstream' and 32% of teachers indicated they were both Learning Support and Resource. The next question sought to identify how many students with Learning Difficulties attended their class? **(Fig. 2)**

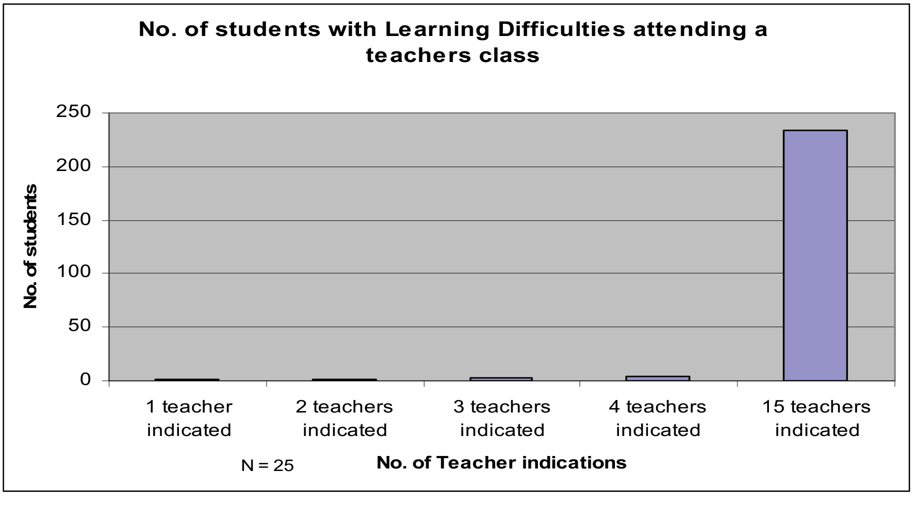

Fig. 2: Number of students with Learning Difficulties attending a teacher's class

From the findings, it was discovered that 60% of respondents dealt with the largest cohort of students (234 students) who may have been diagnosed as having a specific type of difficulty e.g. Dyslexia, Dyspraxia, Dyscalculia, ADD / ADHD, Autism, Asperger's Syndrome or another type of difficulty as viewed by the respondents. The next part of the questionnaire required teachers to indicate if they used laptops or desktop computers in the Learning Support / Resource classroom? **(Fig. 3)**

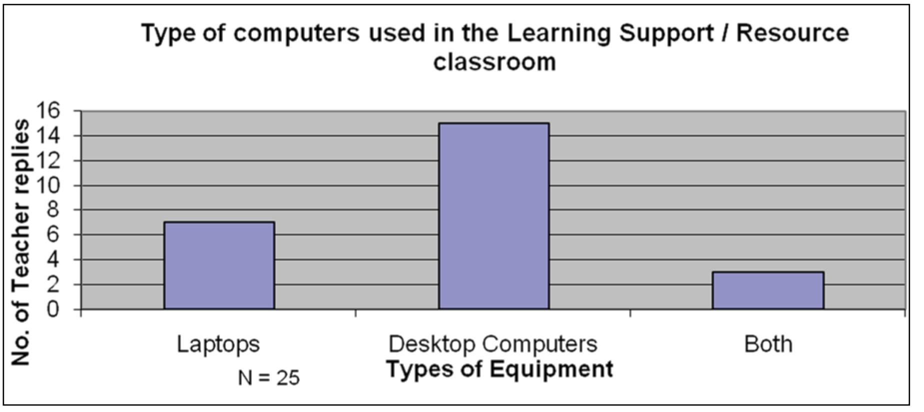

Fig. 3: Type of computers used in the Learning Support / Resource Classroom

From the findings, 28% use laptops, 60% use desktop computers while 12% use both and as a follow up, the next question briefly studied the age of these computers / laptops **(Fig. 4).**

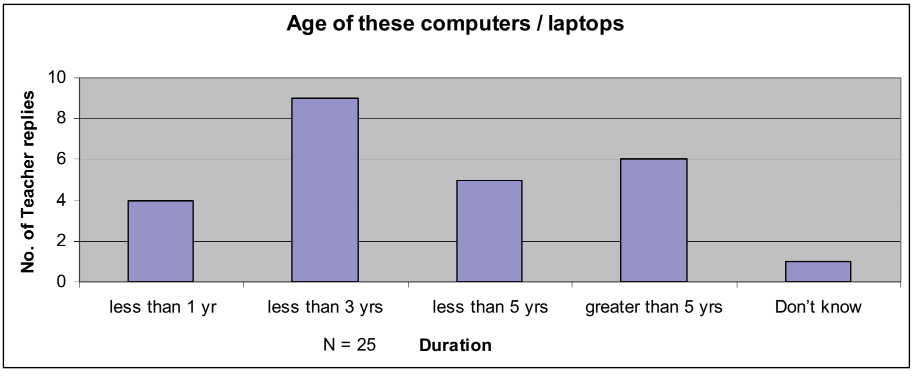

Fig. 4: Age of these computers / laptops

From the findings, 72% of teachers indicated had equipment <5 yrs, whilst a small minority, 24% indicated >5 yrs, and 4% indicated they did not know. Another issue to keep in mind is that computers and laptops over 4 years old can be prone to breakdown especially if the operating system is much older than the new software package being used. This assertion is validated by **Fig. 5** which demonstrates that many teachers are still using 'old' computers with Windows 95 / 98 / 2000 or Windows XP operating system.

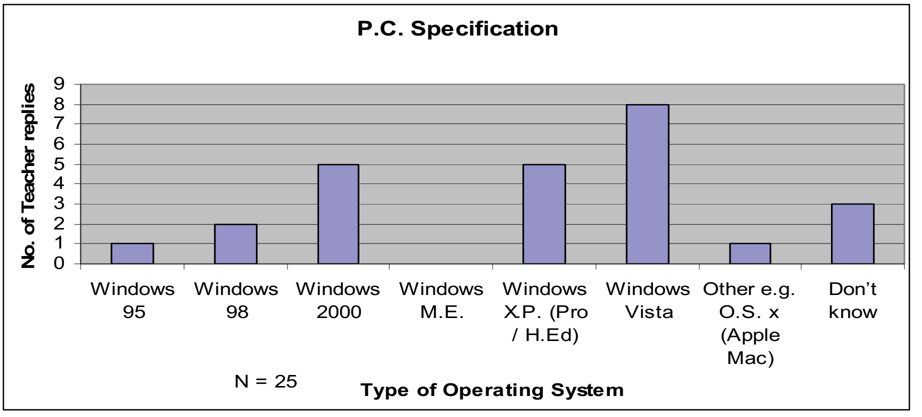

Fig. 5: P.C. specification

A typical 'stop go' nature of funding for computer equipment in a school exists. Craddock (2004) validates this by indicating, a lack of funding for training, support and maintenance of Assistive Technology equipment also exists for students who proceed from primary to secondary school and onto third level. The only funding that is made available is only for 'technical aids' under scheme M11/95 (Craddock, 2004). The next part of the questionnaire examined how often teachers used general types of ICT equipment in their teaching when providing support to their students **(Fig. 6).**

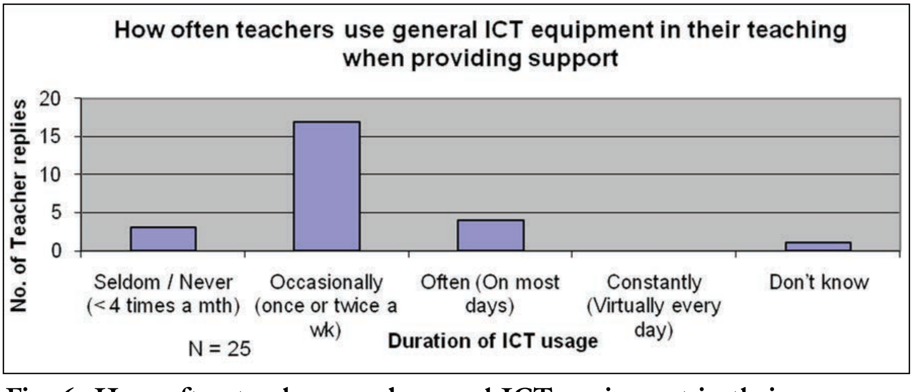

Fig. 6: How often teachers used general ICT equipment in their teaching when offering support

The purpose of asking this question was to identify how often would teachers consider using any type of Information Technology equipment as an aid in their teaching to enhance learning for a student who was classified as having a Learning Difficulty. A large cohort of teachers (68%) indicated only 'occasionally – once or twice a week, whilst a minority (12%) indicated Seldom, 16% indicated Often, 4% indicated don't know' and 0% indicated they never used ICT on a constant basis. Interestingly, M.B. and K. O' T (Interview, 02/07/2010) stated 'due to poor quality broadband, no interactive whiteboard and lack of good resources to use in their teaching, they felt they were facing a constant barrier'. The next question explored the types of general ICT hardware that are available and used in the Learning Support / Resource classroom by these teachers **(Fig. 7).**

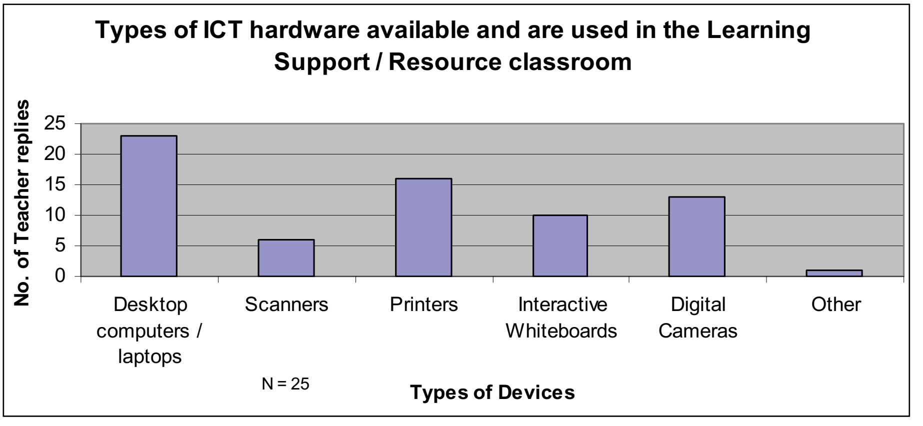

Fig. 7: Types of ICT hardware available and used in the Learning Support / Resource classroom

From the findings, 92% indicated Desktop computers / Laptops; 24% indicated Scanners; 64% indicated Printers; 40% indicated Interactive Whiteboards; 52% indicated Digital Cameras while 4% used other types of ICT hardware in the classroom. The next question sought teacher's commentary about what they felt was the greatest difficulty in using ICT in the classroom with their students? A range of answers evolved like (a) lack of proper resources; (b) lack of time; (c) teachers self confidence and (d) lack of knowledge in identifying what software should match the child's needs. For example, M.B. (Questionnaire, 01/07/2010) indicated that "access to different types of C.D.'s knowing what one is best to use" is also a problem. DMcD (Interview, 03/07/2010) indicated a number of factors like "time constraints, lack of facilities for group of students, lots of 'games' – but how effective are they really, can I teach a concept faster with pen and paper?".

The kernel of the study sought to explore the types of Assistive Technology software that these teachers have used in the classroom and to comment on their usefulness. The researcher chose a number of different but common types of software under various categories used for students with different Learning Difficulties. The information provided to the researcher also gave a good indication of whether or not they were competent in using this software in the classroom and is presented in **Table 1** as follows:

Software Category	Examples	Extremely Useful	Very Useful	Moderately Useful	Vaguely Useful	Not at all Useful	Never Used
Voice Recognition Software	Dragon Naturally Speaking	0	0	0	0	0	100%
	Qpointer	0	0	0	0	0	100%
	Handsfree	0	0	0	0	0	100%
Visual Mapping Software	MindManager	0	0	0	0	0	100%
	Inspiration	0	0	0	0	0	100%
	Kidspiration	0	0	0	0	0	100%
	BubblUs	0	0	0	0	0	100%
Text to Speech Software	TextHelp	0	0	0	0	0	100%
	Claroread	0	0	0	0	0	100%
	JAWS	0	0	0	0	0	100%
	PowerTalk	0	0	0	0	0	100%
	Wordshark	24%	20%	4%	0	0	52%
	Numbershark	12%	12%	16%	0	0	60%
Word Prediction Software	Prophet	0	0	0	0	0	100%
	Prophet 2	0	0	0	0	0	100%
Mag. Software	ZoomText	0	0	0	0	0	100%
	Supernova	0	0	0	0	0	100%
Spelling s/w	Starspell 2.4	8%	4%	0	0	0	88%
Other: (Please specify)	Clicker	4%	0	0	0	0	96%
	Nessy Learning	0	4%	0	0	0	96%

Table 1: Specific types of Assistive Technology software used by teachers in their classroom.

From the data presented in **Table 1,** it is abundantly clear that the sample surveyed demonstrate appalling lack of usage of Assistive Technology software and that the teachers surveyed only made wide usage of Wordshark (48%), Numbershark (40%) which were deemed 'Extremely Useful, Very Useful and Moderately Useful', whilst minimal usage has been made of Starspell 2.4 (12%), Clicker (4%) and Nessy Learning (4%). Possible reasons might include teachers being unfamiliar with different types of technologies, fear of using technology or lack of proper upskilling in this area. For instance, M.B. (Interview, 01/07/2010) stated that many of her teacher colleagues could be technophobic, need better confidence and self esteem in using this technology. In one sense, teachers are not aware of using 'free' Special Educational Technology software e.g. the speech plug-in in Microsoft Word 2003 (Phayer, 2009(a): 83), in Windows Vista (Phayer, 2009(b): 13) or even identifying different types of Text to Speech software e.g. Claroread Plus V5 (Phayer, 2010(a): 17), TextHelp Read and Write Gold (Phayer, 2007: 45), TextHelp R & W Gold Speech-input tool (Phayer, 2009(c): 000775) or possibly Kurzweil 3000 (Phayer, 2010(b): 001724). A definite connection exists between teacher's knowledge of these technologies and in-service course delivery in this field. A study carried out by Phayer (2010(c): 83) examined the important role which Education Centres play in delivering ICT in SEN courses and was found that, 35.71% of teachers indicated they attended 1 course, 14.28% indicated two courses while amazingly 50% of teachers indicated they attended "no ICT in SEN course" in the past (Phayer, 2010(c): 83). It was also found that many school teachers were unfamiliar with the most popular applications used in this field and would like to make more practical use of the software.

The next major part of the study sought to explore the types of Assistive Technology hardware that these teachers have used in the classroom and to comment on their usefulness. The researcher chose a number of different but common types of hardware under various categories used for students with different Learning Difficulties and are outlined in **Fig. 8** as follows:

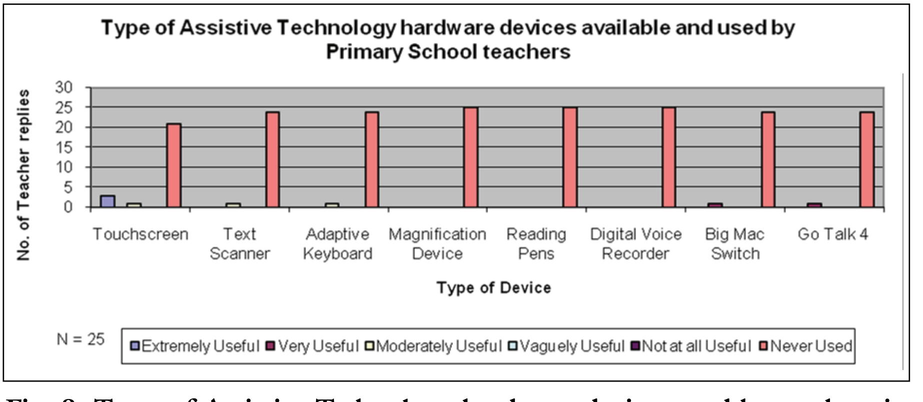

Fig. 8: Types of Assistive Technology hardware devices used by teachers in their classroom

From the above findings, there is also an appalling lack of Assistive Technology hardware used by these teachers in the classroom. The results further demonstrate the only types used with minimal use are: Touchscreens (16%); Text scanners (4%) and Adaptive Keyboards (4%) indicating either 'Moderately Useful' or 'Very Useful'. Possible reasons might include, teachers not being able to identify suitable technology for the student or not having a good working guide about the different technologies. These were areas which emerged as being important traits of a technology course from a teacher's perspective and would certainly contribute to increased uptake of this type of technology (Phayer, 2010(c): 84). For example, DMcD (Interview, 03/07/2010) stated 'not having access to the full technology in the classrooms is a big problem'. Craddock (2004) illustrates the fact that major problems in the A.T. area exist amongst government departments which fund service providers and are plaguing the A.T. system e.g. untrained personnel being allowed to recommend costly equipment without providing proper assessment of their client or environment. The next section of the questionnaire sought teacher's competency in using the various A.T. software and hardware in the classroom which is presented in **Fig. 9:**

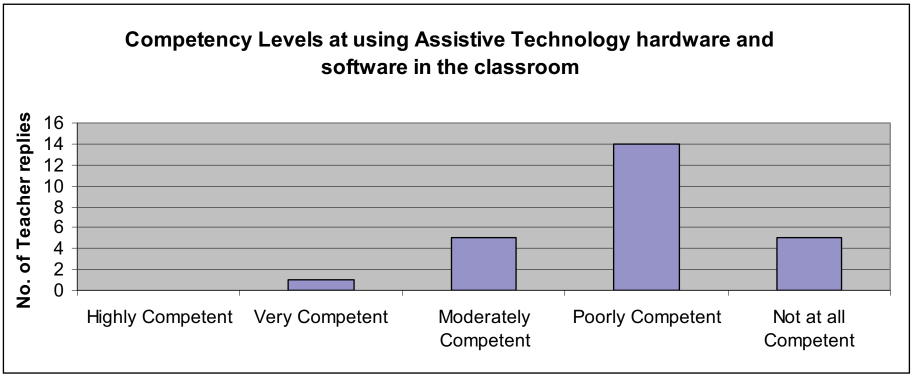

Fig. 9: Competency levels of Primary school teachers using Assistive Technology hardware and software in the classroom

From the above results, the largest cohort of responses (56%) indicated being 'poorly competent' using this technology followed by 20% indicating 'Moderately Competent' and a further 20% indicating 'Not at all competent'. A mere 4% of teachers indicated they were 'Very Competent' using this technology. These findings are parallel with data presented in **Table 1** and **Fig. 8,** which depicts poor uptake and usage of many Assistive Technology software and hardware technologies. This relative lack of competency in using this technology suggests an urgent need for further Continuing Professional Development courses in this field (Phayer, 2010(c): 75). The next part of the questionnaire examined teachers responses if they ever encounter problems using this technology, who do they seek support from? **(Fig. 10)**

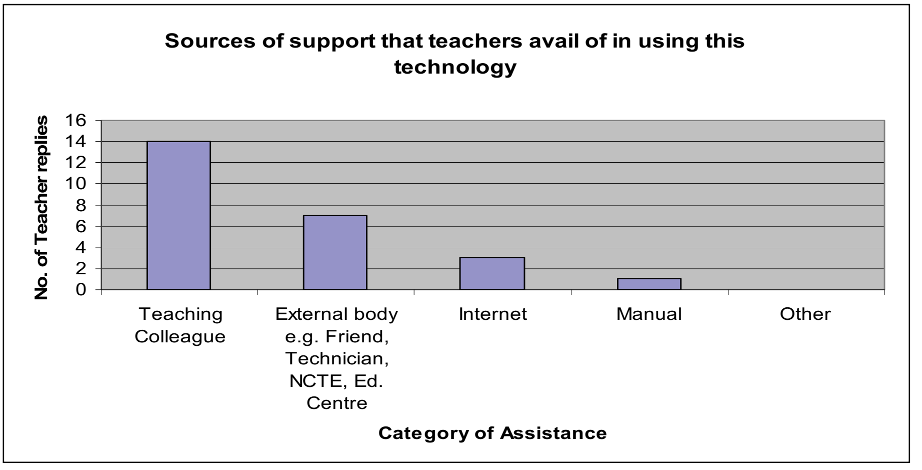

Fig. 10: Types of support which teachers obtain when using this technology

From the findings, 56% sought support from a 'Teaching Colleague', 28% indicated an External body e.g. Friend, Technician etc, 12% indicated 'from the internet', while 4% indicated support from a manual. One teacher, D.M. (Interview, 06/07/2010) stated that "she might often have to spend endless hours trawling for information on the internet just to solve a simple problem". Certainly, the need for urgent and instant support is quite apparent. The possibility of an Education Centre providing a 'drop in' service offering teachers assistance with this technology or the possibility of providing an information based service which compare and contrast the different types of other Assistive Technologies and how they are used in a school setting could be a support mechanism for teachers in this area (Phayer, 2010(c): 86).

The final part of the questionnaire briefly examined teachers C.P.D. experience in this field and sought answers from them to identify how often they attended training seminars in the use of various Assistive Technologies? A mixture of results emerged like: B. McG (Questionnaire, 01/07/2010) stated 'seldom – not available in the Ed. Centre', F. McK, (Questionnaire, 01/07/2010) stated 'whenever opportunity arises – which is not often enough', E. McS.K (Questionnaire, 01/07/2010) stated 'attended one last year – Would attend further courses if and when available'. One excellent response came from E.T. (Questionnaire, 01/07/2010) who stated she 'would be interested in attending them if they suited our specific situation and were relevant to the needs of our school. The Dept. of Education approved a week course on whiteboards. The school would love to know about Voice Recognition software and a general run through various software available over a week or a six week period'. These findings are consistent with a study carried out by Phayer (2010(c): 86) who examined the various factors affecting teacher uptake of ICT in SEN courses and was established that Education Centres have and continue to play a highly important role in such delivery. Factors like the location, number and types of courses offered by these centres affected teacher uptake. Even the medium in which courses were promoted was critical to their continued interest. Providing more appropriate ICT in SEN training seminars that are target specific for teachers in the use of this technology on a regular basis, was also suggested as another possible area of support (Phayer, 2010(c): 86)

Conclusion:

This article concentrated on examining primary school Learning Support, Resource and Mainstream teachers level of access and usage of Assistive Technology software and hardware, to establish the reasons for poor uptake and use in teaching and to suggest ways to encourage greater C.P.D. participation in this field. This study clearly identified that teachers do not use Special Educational Technologies in their teaching as much as they would like to. Difficulties like improper integration of technology, lack of time and improper resources, being resistant to change / a late adopter of technology, not knowing how to match the students needs with the technology and even the lack of sufficient C.P.D. courses to using this technology in teaching, were factors which contribute to its overall use. Education Centres could perhaps address some of these issues. Funding was also a major issue. Integrating Assistive Technology modules into teacher training programs e.g. the INTEGER project (Feyerer, Miesenberger and Wohlhart, 2002) could possibly offer a method of addressing this problem. In one sense, a suitable framework suggesting and identifying ways of using specific Special Educational technologies in an efficient manner in the classroom would possibly contribute to more technological use. Further research could examine this theme in more depth.

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Evidence based interventions in primary mathematics

Joseph Travers

Introduction

The recently published national strategy for literacy and numeracy has highlighted attention on raising standards in these core areas (Department of Education and Skills, 2011). The focus of this article is on analysing a range of evidence based interventions in mathematics for students who experience difficulties with the area including those with learning disabilities at primary level. The first section focuses on major literature reviews and the second on key individual and group interventions in mathematics.

Reviews of Interventions in Mathematics

Miller *et al.,* (1998, p1) in a review of the literature of validated practices for teaching mathematics to students with learning disabilities, argue "that there is little debate with regard to the need for quality instruction in math for students with learning disabilities." Their review confined itself to studies, which only focused on students with learning disabilities, or studies that gave separate data for such students. Thus it did not include students at risk or with mild general learning disabilities. The rationale for their exclusion is not presented and given the lack of evidence matching categories of disability with specific interventions is surprising (Wang *et al.,* 1991).

In the oft cited area of difficulty, that of memorisation of multiplication facts, four studies are reviewed involving between three and six students each. All reported success using the behavioural techniques of constant time delay and one using prompt fading as well. Miller *et al.* (1998) refer to students maintaining mastery and generalisation in two of the studies. Peer tutoring and setting goals to encourage motivation and improvement were also effective in relation to computation. Miller *et al.* (1998) summarised the use of computer assisted instruction as holding promise for achievement in both computation and problem solving.

In addition, strategy and self-instruction interventions were shown to be very effective for both computation and problem solving instruction as were the use of manipulative devices. Direct instruction defined as including fast-paced lessons, demonstration, modelling, guided practice, independent practice, feedback, repetition and modelling of student progress was also found to be effective. Such techniques involve more direct teacher input in the teaching and learning process.

Areas of mathematics not covered in the Miller *et al.* review due to lack of research include algebra, money skills, fractions, percentages, decimals, time, measurement and geometry. Furthermore, none of the studies cited involved assessing how students' needs could be met by mainstream class instruction and what modifications could reasonably be made to ensure this. All seemed to be based on the assumption that separate instruction was required.

In a separate review Butler *et al.* (2001, p20) analysed the literature in teaching mathematics to students with "mild-to-moderate mental retardation." While behavioural approaches, such as constant time delay and aspects of direct instruction proved beneficial, there was also evidence of students devising cognitive strategies and engaging in problem solving (Baroody, 1996). The move to more research in these areas is vital as:

> Perhaps now more than ever, limiting mathematics instruction to rote computation practice will deprive students with disabilities from competence in important mathematics concepts and, thus, prevent them from succeeding in real-world activities (Butler *et al.,* 2001, p20).

A key theme of research in this area is that the range of strategies which proved effective crossed pedagogical philosophies incorporating constant time delay, peer tutoring, time trials, direct instruction, strategy instruction and using concrete materials (Butler *et al.,* 2001). Learners benefited from "interventions stressing frequent feedback, explicit instruction, and ample drill-and-practice" (p29). At the same time "strategy instruction promoted student independence in addition to increasing mathematics performance" (p29). However, limitations are that the number of students in these studies was small and militates against validating some of the practices. In addition, the lack of studies in inclusive settings and the feasibility of integrating such practices in mainstream classes are absent from these reviews, which presents a gap in this literature. It is also noteworthy in terms of professional development that the level of teacher input in all studies was substantial.

In terms of raising standards in mathematics for pupils with general learning disabilities Porter (2003) stresses the following: tailoring the learning context to the pupils' needs and interests, connecting the abstract with the practical, linking skills with understanding, reducing the emotional impact, scrutinising and adapting the language of instruction, paying attention to old as well as new learning, providing contexts for consolidation and generalisation and using visual cues to reduce the load on working memory. The work of Porter (1998, 1999) demonstrated that pupils with moderate learning disabilities showed evidence of proficiency in counting and an understanding of what it means to count. In addition she found that "some pupils are not only able to show proficient skills but able to apply them to problem solving" (Porter, 2005, p60). These counting skills can then be used to develop key life skills, for example purchasing skills.

In a review of 43 studies in teaching money and purchasing skills to students with disabilities, Browder and Grasso (1999) report the following validated strategies depending on level of disability: use of the calculator, the "one more than technique" where students who haven't mastered counting beyond 10 are taught to count on to the next euro/pound/dollar when presented with prices such as €4.78 and say €5 euro and teaching discrimination between types of money for response class formation which involves students associating the purchase of a sample of items with a particular amount of money and generalising these to the natural environment.

However, some of the techniques while specialised offer a way into mainstream curricula for many students with disabilities. There is a key role for support teachers to develop such differentiated approaches in schools in collaboration with their mainstream colleagues.

In analysing reviews of literature, particularly those that end with assertions of what is best practice, careful attention must be paid to the criteria used to select studies to be reviewed. In this regard, three recent major reviews are worth analysing. These are a research report, *What Works for Children with Mathematical Difficulties* (Dowker, 2004), commissioned by the Department for Education and Skills in England; *A Synthesis of Empirical Research on Teaching Mathematics to Low-Achieving Students* (Baker *et al.,* 2002) in the US and a report by Gersten *et al.,* (2009) entitled *Assisting students struggling with mathematics: Response to Intervention (RtI) for elementary and middle schools* conducted for the U.S. Department of Education.

Dowker (2004) included everything from experimental designs to small action research projects. It is interesting to note that no exclusionary criteria are given. In contrast, Baker *et al.* (2002) included only experimental and certain quasi-experimental intervention studies. Only 15 studies met the inclusion criteria. What is surprising is that only one of these appears in the Dowker (2004) review, which does include studies using experimental and quasi-experimental designs. Given this, what emerges from each of the reviews as advice for practitioners, while containing similarities, has many differences.

Baker *et al.* (2002, p67) having set up their "gold standard" (Whitehurst, 2003) criteria maintain that: "Although this is not a large body of research, four findings are consistent enough to be considered components of best practice." First, providing students and teachers with specific information on how each student is performing seems to improve mathematics achievement, "raising scores, on average, by .68 SD units" (p67). Second, using peers as tutors or guides enhances achievement. This is confined to computational abilities and "holds promise as a means to enhance problem-solving abilities" (p68). Third, based on two studies, providing "specific, objective, and honest" feedback to parents of low achievers and detailing "successes (or relative successes) as opposed to failures or difficulties" have the potential to enhance achievement (p68). All of these seem very low cost measures on the surface, but the level of knowledge and skill involved in diagnosing strengths and needs to be used for feedback and further teaching should not be underestimated (Pitt, 2001).

The fourth finding is the most controversial in the literature and goes to the heart of the debate on theories of learning in mathematics:

> In terms of curricula, a small body of research suggests that principles of direct or explicit instruction can be useful in teaching mathematical concepts and procedures. This includes both the use of strategies derived from cognitive psychology to develop generic problem-solving strategies and more classic direct instruction approaches where students are taught one way to solve a problem and are provided with extensive practice. With the latter approach, concepts involving fractions, ratios, or decimals are presented using a wide range of examples (Baker *et al.,* 2002, p68).

The different examples referred to above point to the complexity of the issues in this debate. Direct or explicit instruction can vary along a continuum of teacher direction and mean very different things, based on how much direction is provided. Many factors can influence this, including how well a child is progressing at their own level or not. Also, at what point does guided discovery learning cease to be discovery and at what point does guidance become direction?

In addition, there is a huge difference between directly teaching only one algorithm for a particular operation and directly teaching metacognitive strategies for problem solving to be used for a variety of mathematical problems. Yet often they are grouped together in a blanket criticism of the approach (Harniss *et al.,* 2002). Baker *et al.* (2002) draw on the work of Engelmann and Carnine (1982) in defining direct instruction as:

> Teaching rules, concepts, principles, and problem-solving strategies in an explicit fashion. This includes providing a wide range of examples of the principle or concept and providing extensive review and discriminative practice (Baker *et al.,* 2000, p64).

If there is evidence that this works for some children who are low achieving in mathematics what bases are there for rejecting it? Most of the criticism seems to be ideological rather than empirical in character. Curricular approaches deriving from constructivist and socio-cultural perspectives are often ambiguous about the role of the teacher and see direct instruction approaches as inducing passivity in the learner (Smerdon *et al.,* 1999). It could be argued that such methods should be in the repertoire of all teachers, as part of a balanced approach to mathematical teaching.

Woodward (2004) points out that in one of the studies used by Baker *et al.* (2002) to support direct instruction, (that of Woodward, Baxter and Robinson, 1999) their finding that the gains of direct instruction were reduced dramatically by poor retention was omitted from the research synthesis. However, it could be argued that this is to be expected and there is evidence to suggest that without carefully planned revision that is sufficient, distributed, cumulative and varied that this is likely to happen (Dixon *et al.,* 1992).

There are of course examples of behavioural approaches, which have focused on rote memorisation and drill without understanding with children who would be very capable of more active learning approaches. Likewise, Conway (2002) suggests that pedagogical experiences of many in disadvantaged communities in Ireland are "characteristised by an emphasis in low-order thinking and a persistent assumption of the solo or individual learner" (p61). He argues for the benefits of a socio-cultural perspective, which would entail a shift from a psychology of individual differences to building learning communities with more attention paid to the social context and participation structures. However, this approach should not preclude the use of direct instruction where the aim is to increase participation rates for example through strategy learning.

Alternative approaches are also dogged by a lack of specificity in relation to how children with difficulties and low achievement actually learn particular skills and concepts. Inspired by reform efforts generally in mathematics education (NCTM, 1989, 2000), terms such as "anchored instruction" (Bottge, 1999, 2001) came to describe approaches that embed relevant facts, procedures and concepts in authentic problem-solving contexts.

Criticisms of this approach, which are not unreasonable, are that what seem authentic problems for adults may not be for children and that "math is still math, and the context for understanding and solving these problems takes place in school classrooms. For some students, motivation remains a key factor" (Woodward, 2004, p24). In addition, Woodward (2004) highlights concerns over the vagueness in such studies on how skills and concepts are developed in contrast to the rich accounts of the problem solving contexts. Given what we know about the difficulties many children have with traditional problems in mathematics, there is an underestimation of the challenges that the kind of complex problems used in anchored instruction present (Woodward, 2004).

In conclusion, it seems reasonable based on the research evidence to see a place for some direct explicit instruction particularly as it relates to strategy learning for pupils who are failing by other approaches. This is endorsed in the major review by Gersten *et al.,* (2009). Studies for this review were chosen on the basis of strict criteria in relation to the level of evidence. These were defined at three different levels:

1. *Meets Evidence Standards*—for randomized controlled trials and regression discontinuity studies that provide the strongest evidence of causal validity.

2. *Meets Evidence Standards with Reservations*— for all quasi-experimental studies with no design flaws and randomized controlled trials that have problems with randomization, attrition, or disruption.

3. *Does Not Meet Evidence Screens*—for studies that do not provide strong evidence of causal validity.

Once selected studies were then analysed and grouped around eight recommendations based on the level of evidence found. Strong evidence corresponded to number one above, moderate evidence to two above and low evidence to "expert opinion derived from strong findings or theories in related areas and/or expert opinion buttressed by direct evidence that does not rise to the moderate or strong levels" (p2). Table 1 outlines the recommendations that satisfied the evidence criteria.

Table 1. Recommendations for interventions and corresponding levels of evidence from Gersten et al. 2009

Recommendations	Level of evidence
1. Screen all students to identify those at risk for potential mathematics difficulties and provide interventions to students identified as at risk.	**Moderate**
2. Instructional materials for students receiving interventions should focus intensely on in-depth treatment of whole numbers in kindergarten through grade 5 and on rational numbers in grades 4 through 8. These materials should be selected by committee.	**Low**
3. Instruction during the intervention should be explicit and systematic. This includes providing models of proficient problem solving, verbalization of thought processes, guided practice, corrective feedback, and frequent cumulative review.	**Strong**
4. Interventions should include instruction on solving word problems that is based on common underlying structures.	**Strong**

Recommendations	Level of evidence
5. Intervention materials should include opportunities for students to work with visual representations of mathematical ideas and interventionists should be proficient in the use of visual representations of mathematical ideas.	**Moderate**
6. Interventions at all grade levels should devote about 10 minutes in each session to building fluent retrieval of basic arithmetic facts.	**Moderate**
7. Monitor the progress of students receiving supplemental instruction and other students who are at risk.	**Low**
8. Include motivational strategies in tier 2 and tier 3 interventions	**Low**

Dowker's (2004) conclusions take a different slant and avoid the debate on methodology. She makes the case for intervention, arguing, "research strongly supports the view that children's arithmetical difficulties are highly susceptible to intervention" (p42). In terms of the type of intervention, she emphasises the benefits of individualised instruction:

> Moreover, individualized work with children who are falling behind in arithmetic has a significant impact on their performance. The amount of time given to such individualized work does not, in many cases need to be very large to be effective (Dowker, 2004, p43).

A rationale for prioritising individualised work over small group interventions (3 children), which allow for peer discussion and collaborative problem solving, as well as individualised work is not offered. Dowker's (2004) conclusion offers no advice on approaches to content selection, materials, teaching and learning strategies and the implications for professional development.

As regards what should be covered in the intervention, she side steps the issue by stressing the role of assessment in identifying a child's strengths and needs and that the intervention "should ideally be targeted toward an individual child's particular difficulties. If they are so targeted, then most children may not need very intensive interventions" (p45). While highlighting other beneficial strategies, she alludes to the key role of the teacher: "peer tuition and computerized teaching play a useful role in mathematics interventions, but cannot substitute for interaction with a teacher" (Dowker, 2004, p45).

In summary, it is clear from Dowker's overview that targeted interventions based on a diagnostic assessment of the strengths and needs of the pupil in relation to mathematics can be very beneficial and should be a feature of any support system put in place to address low achievement in mathematics. Ginsburg *et al.* (1998) and Westwood (2007) argue the case for flexible or informal diagnostic interviewing as an essential component of this process. This focus on targeted interventions raises the question as to which types of interventions hold out the most promise of success. In the following section I will analyse two such programmes, being the most recent and relatively large-scale interventions in the area.

INDIVIDUALISED INTERVENTIONS

Mathematics Recovery (MR) (Wright *et al.,* 2000) and *Numeracy Recovery* (Dowker, 2001) are targeted interventions that represent two significant attempts to address the needs of six to seven year old children at risk of having difficulties in mathematics. Dowker (2004) outlines differences and similarities between the two interventions. In relation to similarities they are both individualised, rooted in a cognitive science theory of arithmetic development, target the early primary years, focus primarily on number and arithmetic and involve close collaboration between researchers and teachers.

The differences between the programmes are that *Mathematics Recovery* is much more intensive, emphasises methods of counting and number representation across broad developmental stages. In contrast, *Numeracy Recovery* emphasises estimation and derived fact strategy use and "treats mathematical development, to a greater extent, as involving potentially independent, separately-developing skills and processes" (Dowker, 2004, p35).

Mathematics Recovery

Mathematics Recovery is an intensive individualised intervention targeting low-attaining six and seven year-olds. It was developed in the early 1990s in Australia. Theoretically it is based on the development of counting theory of Steffe *et al.* (1988) who posited the following stages of development: perceptual, figural, motor, verbal and abstract. Wright *et al.* (2000) applied this conceptualisation in designing the Learning Framework in Number, which incorporates a developmental staged approach to the mastery of specified knowledge, and skills in the *Mathematics Recovery* programme.

Children are assessed individually and placed within a stage and then taught individually for 30 minutes a day over a period of 12 to 14 weeks in key topics relating to the child's stage. Wright *et al.* (2000) report the outcomes of two implementations of the *Mathematics Recovery* programme in Australia in 1994 and in the US in 1995-96.

The Australian study incorporated substantial professional development for teachers in the theory and practice of the intervention. This was ongoing for the length of the project. Twelve teachers in 11 schools with 89 children participated in the study. The intervention used the criterion-referenced measures of the programme in evaluating progress. Over 75% of the children reached age-appropriate or higher levels on these measures and the teachers found the intervention very useful in terms of their own understanding of early mathematical development and used activities from the programme in their subsequent classroom teaching. Data is also presented for the five lowest attaining children at the pre-assessment phase. Some made modest gains and one child substantial gains.

The American study in 1995-96 involved 15 teachers and 91 participants in 13 elementary schools. Similar results were reported for these participants (Wright *et al.,* 2000). The evaluation design of these studies did not involve any group comparison or the use of norm referenced measures so comparison with other programmes cannot be made. Interventions, which involve such a level of professional development, combined with such one-to-one intensity over a long period of time (the Australian study had an average of 41 teaching sessions), raise questions about what exactly makes the difference. Would teachers using a far less scripted approach but immersed in the psychology of early number development achieve similar gains if working in one-to-one sessions? The translation of skills and knowledge into new jargon and mnemonics (for example, Backward Number Word Sequence (BNWS)) necessitating a glossary for the programme, lends an added layer of mystique and dressing up of the findings of cognitive science research into privileged knowledge only attainable through use of the programme. Smith *et al.*(2010) in an evaluation of Math Recovery across 25 schools in the US found that participants showed increases in mathematics achievement across all assessments during the tutoring period (with $p<.05$ in each case), although this growth rate tended not to be maintained after completion of the intervention.

Another question that arises with such programmes is the level of difference between them and the normal curriculum in use in the school and whether incorporating principles of the intervention in the mainstream class programme would make a difference? Interestingly, Wright *et al.* (2000) report on the application of the programme to class teaching in a project titled *Count Me In Too (CMIT)*. This, we are told "can be regarded as an application of the theory and methods of MR to classroom teaching and to average and high-attaining children as well as to low-attaining children" (p184). Bobis (1996) (Cited by Wright *et al.,* 2000) evaluated this project in the 13 participating schools documenting the perceptions of teachers, principals and trainers. It also included case studies of three of the teachers and five of the children and reported on a sample of 37 of the participating children in terms of progress on pre- and post-assessments after 15 weeks tuition. The evaluation report to the New South Wales Department of Education and Training is unpublished but Wright *et al.* (2000) report its findings as follows.

Teachers were very enthusiastic about the project. Approximately three-quarters of the children sampled were using more sophisticated strategies for addition and subtraction with approximately 90% progressing at least one stage on two or more aspects of numerical development (Wright *et al.*, 2000). However, children at more advanced stages initially, made more progress than children at earlier stages. We are not told how much progress the lowest attaining children made. Again, no comparison or control groups were used in the evaluation and it would be interesting to use standardised measures to assess the level of progress made.

Numeracy Recovery

Another individualised intervention targeting six and seven-year olds is *Numeracy Recovery* (Dowker, 2001, 2003, 2004). This programme has been piloted on 175 children in Oxford, England. Initially, the children were identified by their teachers as having difficulties with arithmetic. They amounted to about 15% of the classes. The children were assessed on nine components of early numeracy. In contrast to the daily intervention of *Mathematics Recovery*, the children received a weekly individual intervention of half an hour per week. The class teachers were released by supply teachers to give the intervention, which lasted for thirty weeks.

The assessment and intervention focussed on components of early arithmetic development identified in the research literature as being important. The nine components were: (i) counting procedures, (ii) counting principles, (iii) written symbolism for numbers, (iv) understanding the role of place value in number operations and arithmetic, (v) word problem solving, (vi) translation between arithmetical problems presented in concrete, verbal and numerical formats, (vii) derived fact strategies in addition and subtraction, (viii) arithmetical estimation and (ix) number fact retrieval (Dowker, 2004).

Also in contrast to *Mathematics Recovery*, the evaluation design used standardised measures. The children and a control group were given the British Abilities Scales Basic Number Skills subtest, the WOND Numerical Operations test, and the WISC Arithmetic subset. Between them, these tests cover computation abilities and arithmetical reasoning. The children were tested twice in the year (Dowker, 2004).

Dowker (2004) reports results for 146 of the children in the project and for 75 in the control group. None of the children in the control group showed significant improvement in standard scores on any of the tests. However, we are given no information on these children and whether or not they were also receiving any other form of intervention. The findings for the children in the intervention group are impressive. The difference in mean standard scores for the BAS Basic Number Skills subset, the WOND Numerical Operations subset, and for the WISC Arithmetic subset were significant at the 0.01 level using Wilcoxon tests. Differences in the median standard scores on all these measures were also significant at this level. Just over a hundred of this sample have been retested and have maintained their improvement. Unlike the Wright *et al.* study we are not given separate data for the lowest achieving of the children.

In contrast to *Mathematics Recovery*, the intervention draws on a combination of some published mathematics materials, activities designed by the author and techniques devised by teachers in the project (Dowker, 2001). There is no attempt to repackage activities under invented terminology as is evident in *Mathematics Recovery*. It could be argued that this is an acknowledgement that there are many existing games and exercises that can usefully target components of early mathematical development identified as important. The key is to know which games and knowledge of this area can only benefit this selection. However, what makes the difference in this intervention is not clear. There is no information on the extent or type of professional development, if any, given. The degree to which the prolonged individualised nature counts is unclear or if it would work as a small group (three children) intervention and how much could translate to mainstream class teaching and in-class methods of support.

These interventions prompt many questions in terms of their application. How much of these programmes could inform class teaching? Could in-class interventions based on these principles be just as effective? Given the fact that we have neglected the role of counting in early mathematics activities in Junior Infants there is a very strong rationale of incorporating the principles of these programmes into the mainstream curriculum (Mullan and Travers, 2007a). An effective programme must cater for all children. The knowledge of pre-school education in Ireland currently points to little or inappropriate mathematics teaching in state sponsored settings (Lewis and Archer, 2003; DES, 2003).

In summary, these interventions regardless of whether they need to be totally individualised or not, are very systematic in assessing pupils' strengths and needs and the interventions are closely aligned to the findings from cognitive science research on the key role that counting plays in early number development (Griffin *et al.,* 1994). This systematic assessment and focus warrant being part of early interventions schemes in schools.

However, there still exists the necessity for whole class interventions, particularly in schools with very low achievement levels, often in areas of socio-economic disadvantage. In the next section, I will analyse two whole class interventions, drawing out the key findings.

WHOLE CLASS INTERVENTIONS

Ready Set Go – Maths

Pitt (2001) reports on an action research project instigated by the Northern Ireland Steering Group for Numeracy. The group seconded Pitt for two academic years from the Education and Training Inspectorate to conduct the project. The purpose of the research "was to investigate factors which affect some children's level of achievement in numeracy during years 1 and 2 of primary school and to identify a range of teaching and learning approaches to bring about improvement" (Pitt, 2001, p2). The project was based in ten schools, two from each Education and Library Board. One class in each school was chosen to participate. The focus was on early years number in the mathematics curriculum in year one and follow on to year two. The majority of children were aged four in year one.

In terms of the intervention, Pitt designed a line of development of activities in sorting, counting and recognition, understanding number, and relationships and operations that formed a book called *Ready, Set, Go-Maths.* Progress records were also devised. The connectedness of the areas was stressed but in terms of emphasis, sorting seemed to have being prioritised (Pitt, 2001). There is no theoretical framework given or conceptual basis for this. It could be argued that it relates to set theory and the influence of Piaget on early number development.

It is not clear what baseline measures were used, if any. At the end of each year the children were assessed using criterion-referenced measures relating to the above-identified areas of number. Not much detail is given of the results but we are told that

> Most of the children made secure, steady progress during the two years. A few made particularly good progress, and their teachers were considering transferring them to the middle group in the class. Three children had moderate learning difficulties. Having made only limited progress in year 1, they finally began to grasp ideas in year 2, at their own pace (Pitt, 2001, p12).

The reaction of teachers was very positive to the project and they highlighted better planning, better knowledge of children's strengths and needs, attention to language and use of resources for co-operative activities as areas of development for them (Pitt, 2001). Two aspects highlighted by Pitt (2001) in making a "significant difference" for the children in the target group were the requirement that the children experience success through differentiation and the benefits of the teachers developing a sharper focus on the children's level of mathematical thinking and understanding.

As this was an action research project it is only reasonable to review it against this background. The fact the project was conducted within existing resources and used in-class models of support is impressive and an important contribution to our understanding of what is possible in an inclusive setting.

Rightstart/Number Worlds

Building on the work of Resnick (1983), who proposed that young children represented the addition process like a mental number line and on the work of Siegler (1976) on children's quantitative understandings and finally on Gelman and Gallistel's (1978) principles of counting, Griffin *et al.* (1994) devised a model of the organising schemata that, they propose, is central to children's understanding of early addition and subtraction. These schemata, they term "central conceptual structures" for conceptualising the world in terms of quantitative dimensions (p35).

A number knowledge test designed to assess mastery of this knowledge revealed large differences in performance between children "from low-income communities" (p39) and middle-income children. A curriculum was designed, called *Rightstart,* later *Number Worlds* to specifically teach the knowledge components underpinning the central conceptual structure theory. The intervention aimed to test the theory that such knowledge was central, and to bridge the conceptual gaps between the children's current understanding and that implied in the mental counting line structure. Thirty interactive small group games were devised each targeting components of the structure.

In an evaluation of the programme, using control groups, the gap between these groups was eliminated in four studies in the United States and Canada in six separate schools. The effects were also apparent one year after the programme had ended. The evidence seems to back up the authors' contention that "it enabled children to acquire the numerical understandings specified in the central conceptual structure" (p48).

Gersten *et al.* (2005) in analysing early identification and intervention for pupils with difficulties in mathematics argue the following about the *Number Worlds* programme:

> However, based on implementation research (Gersten, Chard, Griffiths, Katz, and Bryant, 2003), we would only recommend the whole-class activities, such as practice in "counting on," practice in listening to coins being dropped in a box and counting, practice in counting backwards, practice in linking adding and subtracting to the manipulation of objects. These could easily be done with small groups of children and appeared to be helpful in building a sense of number in students who need work in this area. In contrast, the games that composed much of the curriculum proved extraordinarily difficult to implement in a typical classroom (p301).

In contrast, Mullan and Travers (2007b) in a study involving the implementation of the programme in 11 classrooms in schools in disadvantaged areas in Dublin, Ireland found that once the class teacher had assistance from a learning support teacher, classroom assistant or parent, that teachers were very enthusiastic about the small group games and once children were familiar with the procedures for the games, implementation was very feasible and worthwhile.

SUMMARY

In summary, the intervention projects reviewed are using findings from cognitive science research particularly in relation to the development of number concept in devising interventions (Griffin *et al.,* 1994). As such, these validated practices are more closely aligned to addressing gaps in pupil knowledge and skills than traditional curricula based more on Piagetian lines. They also focus heavily on early intervention strategies.

The above interventions represent very important whole class initiatives with great potential to stimulate more in-class models of support involving learning support/resource teachers, special needs assistants and parents. Utilising these resources with empirically validated and theoretically robust materials and pedagogy could present new opportunities to prevent and reduce future difficulties in mathematics.

Given the diverse range of pedagogies which can or could potentially contribute to meeting the needs of pupils with difficulties in mathematics, the question arises as to how specialised these approaches are. In a review of pedagogies for inclusion, Lewis and Norwich (2005) suggest the notion of a continua of common teaching approaches that can be subject to various degrees of intensification depending on pupil need. A key benefit of this conceptualisation is that it helps to move the debate on from interpreting different teaching approaches as dichotomies with advocates in each camp.

However, they also state that "in advocating a position that assumes continua of common pedagogic strategies based on unique individual differences, we are not ignoring the possibility that teaching geared to pupils with learning difficulties might be inappropriate for average or high attaining pupils" (p6).

The above reviews offer a range of evidence based approaches which have the potential to raise the achievement levels of pupils experiencing difficulties in mathematics.

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Dual Exceptionality: Identifying Exceptional Ability with Dyslexia

Jean Johnston

Introduction

The term 'dual exceptional' refers to individuals who may be exceptionally able in one or more ways, but who also have learning or other difficulties that may mask or inhibit achievement. Difficulties in identifying students with dual exceptionality have been acknowledged since interest in the field began to emerge over thirty years ago (Hemming,1985; Yewchuk, 1986; Brody and Mills, 1997; Baum and Owen, 2003; Krochak and Ryan, 2007). One of the most prevalent forms of dual exceptionality is exceptional ability in conjunction with dyslexia (Montgomery, 2000). Brody and Mills (1997) contend that it is most difficult to recognise and understand students whose exceptional ability and difficulties lie in the same area. Similarly, a report for the Council of Curriculum, Examinations and Assessment (CCEA, 2006) notes that, while a student with difficulties in academic areas often gains recognition for great ability or achievement in other domains, it is more difficult both to identify and understand those whose ability and learning difficulty occur in the same, or related academic areas.

Dyslexia

The *Report of the Special Education Review Committee* (1993) uses the term 'specific learning disability' (SLD) in preference to 'dyslexia'. This report defines the condition as 'impairments in specific areas such as reading, writing, spelling and arithmetic'. The definition of the *Report of the Irish Task Force on Dyslexia* is to be preferred, as it more accurately reflects the most recent understanding of the causes and effects of the condition. Dyslexia, it states,

> ... is manifested in a continuum of specific learning difficulties related to the acquisition of basic skills in reading, spelling and/or writing, such difficulties being unexpected in relation to an individual's other abilities and educational experiences. Dyslexia can be described at the neurological, cognitive and behavioural levels. It is typically characterised by inefficient information processing, working memory, rapid naming and automaticity of basic skills. Difficulties in organisation, sequencing and motor skills may also be present (DES, 2002:xii).

The difficulties caused by dyslexia are now understood to be due to a phonological processing problem, which prevents the individual with the condition from understanding and using verbal codes. In brain imaging studies, a difference has been observed in the speech processing areas of the left hemisphere of the brain during simple phonological tasks. In individuals with dyslexia there was less activation in these areas of the brain, when compared to those of controls, and these areas were not activated in concert (Paulesu *et al.,* 1996; Shaywitz *et al.*,1998). A causal model was developed by Uta Frith (1998) in which the relationship between biological, cognitive and behavioural levels is indicated by causal arrows (Figure 1).

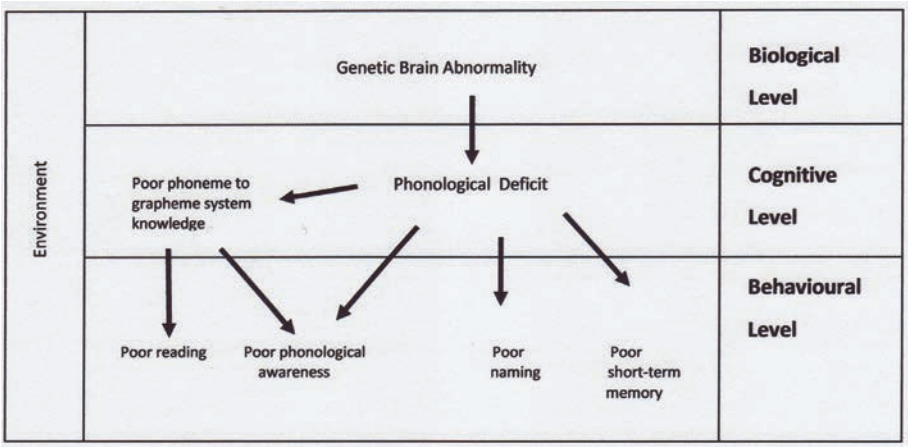

Figure 1 (Frith,1998: p.191).

This model indicates the scope and variety of difficulties that may arise from dyslexia. While dyslexia is most commonly associated with difficulties in reading, it has been shown that difficulties in spelling are almost invariably concomitant (Vellutino,1979; Frith,1980). Montgomery (2003) argues that spelling is a core problem in dyslexia, that appears to be more fundamental than reading. Difficulties caused by short-term memory deficits and 'poor naming', although less easy to identify, may also create significant barriers to learning. Short-term memory difficulties may give rise to difficulties in both self-organisation and in the organisation of material in written tasks. Poor spelling may lead a student to write slowly and carefully, confining the vocabulary used to words he/she can spell, resulting in work that does not accurately represent the ability of the student.

In Ireland, the identification of dyslexia is based on a discrepancy between cognitive ability and attainment in basic literacy skills measured by standardised norm-referenced testing. General cognitive ability must be within or above the average range (above 90 standard score) and performance in basic skills must be at or below the second percentile (two standard deviations below the mean), in order for the difficulty to be recognised as SLD (dyslexia) for the purposes of accessing extra supports (DES, 2002: p.20).

Exceptional Ability

The term 'exceptionally able' is the preferred term used in Ireland to describe students who are elsewhere labelled as gifted and/or talented. It describes one part of the continuum of ability, ranging from 'disability' to 'profound ability', that is found in all populations. The National Council for Curriculum and Assessment (NCCA) uses this term to identify those "students who require opportunities for enrichment and extension that go beyond those provided for the general cohort of students" (NCCA, 2007:7). Seven domains in which an individual may exhibit exceptional ability are named in the NCCA *Guidelines for Teachers*; 'general intellectual ability' is one of these domains. While noting that there is no single code in use, a set of measurement levels to define exceptional cognitive ability is outlined:

- Able – IQ range 120 to 129
- Exceptionally able – IQ range 130 to139
- Profoundly exceptionally able IQ range 170+ (ibid: p.8)

According to this scale, an exceptionally able student is identified as being two standard deviations above the mean. Quite commonly, a student with dual exceptionality may be two standard deviations below the mean in achievement in basic skills, while being two standard deviations or more above the mean in ability. This represents a very wide discrepancy between (potential) ability and attainment.

Dual Exceptionality

There is some evidence from research to indicate that dyslexia in conjunction with high ability may cause an exceptional ability to develop (Geschwind, 1984). Johnson and Evans (1992) found evidence, through a comparison of the sub-tests of the Weschler Intelligence Scales for Children–Revised (WISC-R) that in some very able individuals there may be a greater development of spatial abilities at the expense of language functions. Both sub-test scatter and discrepancy between Verbal and Performance scores on the WISC-R were examined, by Patchett and Stansfield (1991), Montgomery (1997) and Herskovits and Gyarmathy (1995), in an effort to establish a pattern that would clearly identify students with exceptional ability and a learning difficulty. Gyarmathy (1995) though, in reviewing these and other similar studies, concluded that, because of the possibility of over-inclusion, caution is necessary in using sub-test scatter or discrepancies as evidence of dual exceptionality.

Identification at Primary Level

Difficulties caused by dyslexia may be apparent in children in the first few weeks of school as they begin to fail to link the sounds of the alphabet to the letters. However, children who have good visual memories manage to conceal this difficulty by their ability to remember whole words. Montgomery (2003) suggests that the very able child may succeed in concealing reading difficulties until about eight years of age. At this stage, the demands of the curriculum suddenly expand and the strategies the child has employed may no longer be sufficient. Mandatory testing carried out at the end of first class or the beginning of second class should reveal difficulties, however some very able students manage to achieve average scores on these tests. As the areas of study broaden in the middle years of primary schooling, in addition to a good work ethic, greater concentration and excellent memory skills are required to conceal difficulties. Eivers *et al.* (2010) in their report on the National Assessments found that, while 16 to 17% of second-class students were considered by their teachers to be behind the class level in reading ability, in the case of sixth-class 35% of students were thought to be behind class level. This supports Montgomery's contention, noted above, that as demands increase, difficulties become more apparent.

At primary level, when a student is seen to have difficulties in basic skills, initial support is put in place in the classroom, unless the difficulties are very severe. Since dyslexia is a high-incidence difficulty, if problems in learning persist, support of extra teaching will be given under the general allocation model (Special Education Circular 02/05:4.2). While screening and diagnostic testing are normally carried out within the school, assessment by an educational psychologist will not necessarily be carried out. Schools are limited in the number of these assessments that they may avail of annually, so psychological testing may be reserved for students who have low-incidence needs, for those students whose difficulties are very severe or for students about to transfer to second level. As there is currently no provision of resources for students with exceptional ability, there is no compelling reason to prioritise the formal identification of these students. Informal assessment and observation by well-informed teachers may identify high ability in students, with or without attendant difficulties. In the case of pupils with severe difficulties due to dyslexia however, it is possible that they may be so overwhelmed with difficulties in the acquisition of basic literacy skills, that they lack the self-confidence to freely engage with the learning process in a way that might reveal their ability.

Transition

The amount and quality of information about in-coming students transferred from the primary to the post-primary school varies greatly. The recent document *Better Literacy and Numeracy for Children and Young People* asserts that:

> The transfer of information from primary school about what children have learnt in general and about their learning in literacy and numeracy, is patchy at best and sometimes anecdotal only (DES, 2010: 6:6).

Despite this assertion, there are many primary and post-primary schools whose personnel liaise very effectively, ensuring a successful transition for their students from one sector to the other through the dissemination of relevant information. While various guidelines underline the importance of good communication and consultation between the two sectors about students in transition (NCSE, 2006; NCCA, 2007; DES, 2007), and an onus is placed on primary school principals to ensure that procedures for consultation are put in place (DES, 1999), the steps outlined are not very specific. In the absence of clear directives on specific procedures, there are bound to be great variations in practice. The proposal in *Better Literacy and Numeracy for Children and Young People* (2010) to provide for the transfer of the results of the standardised tests carried out towards the end of primary education, and to provide a written report on achievement in a number of areas including literacy, would provide a sound basis for a continuum of learning for all students through the transition period.

Second Level

It is unusual for students entering post-primary school in Ireland to transfer with a formal assessment of exceptional ability. In the case of students with dual exceptionality who are tested because of a learning difficulty, cognitive testing will sometimes reveal potentially high ability. However cognitive testing, using Weschler Intelligence Scales, of students with dyslexia or other learning difficulties, may not identify exceptional ability, particularly where only Full Scale scores are used. The very able student who has learning difficulties may present as average because of low scoring on some of the sub-tests, or because of a large discrepancy between Verbal and Performance scores. Where testing of intelligence/cognition is part of incoming tests, exceptional ability may be identified, but in this testing also, scoring of very able students with dyslexia may be uneven or misleadingly 'average'. Students with dual exceptionality may remain undetected throughout the school years either, as Krochak and Ryan (2007) argue, because these students compensate well for their disability or because they do not demonstrate the high achievement that is usually associated with exceptional ability. Brody and Mills (1997) suggest that it would be better to avoid set cut-off points for identification or for admitting to programmes, as this discriminates against students with dual exceptionality.

A representative sample of incoming assessment results of students with dyslexia, who were later identified through observation, testing and/or achievement as being exceptionally able or having the potential to be exceptionally able academically, is shown in a table below so that variations and similarities in scoring may be seen (Figure 2). These examples are drawn from testing carried out in the course of this writer's work as a special education teacher in a post-primary school. They are followed by three brief case studies that illustrate to some extent the heterogeneous nature of dual exceptionality. The AH2 was the test in use for incoming assessments at the time when these students entered second level. This is a test of general reasoning that has now been replaced in many schools by the Cognitive Abilities Test 3 (CAT 3).

Student Name	Reading Age	Maths Skills (N. France) Standard Score	AH2 Total	AH2 Verbal	AH2 Quantitative	AH2 Non-Verbal
Jamie	12.6	108	C	C	C	C
Ewan	12.2	100	C	C	D	C
Elizabeth	10.5	95	C	C	C	B
Henry	8.5	83	D	E	E	C
Kate	9.5	99	C	C	C	C

Figure 2.

** This student missed the incoming assessments and was tested in the summer term of first Year.*

- In three of the cases, Elizabeth, Jamie and Ewan, testing was carried out by an educational psychologist at primary level
- Reading, measured by D. Young Cloze Reading Test 3, shows a wide range of scores
- All but one student scored in the average range in Mathematical Skills
- All students scored average or above on the Non-Verbal Test

The Junior Certificate results in the core subjects of these five students are shown below (Fig. 3). Religion was not a core subject at the time some of these students took Junior Certificate examinations, so it is not included. Level taken, higher, ordinary or foundation, is shown in brackets beside the student's grade in each subject. CSPE has one level only. An asterisk marks a spelling and grammar waiver. Jamie and Henry had readers.

Subject/ Student	Eng.	Maths	Irish	French	Ger.	Hist.	Geog.	Sci.	CSPE
Jamie	B* (h)	A (h)	-	D* (o)	-	B (h)	A (h)	B (h)	B
Ewan	B (o)	B (o)	-	-	-	D (h)	D (h)	B (o)	A
Elizabeth	B (o)	B (o)	D (o)	C (o)	-	B (h)	B (h)	D (h)	B
Henry	B* (f)	B (o)	-	-	D *(o)	B (o)	A (o)	B (o)	C
Kate	C* (h)	B (h)	B* (h)	B* (o)	-	D (h)	C (h)	C (h)	A

Figure 3: Junior Certificate Results

Case Study 1: Elizabeth

Elizabeth was assessed by an educational psychologist when she was in 5th Class:

WISC III:	Weschler Objective Reading Dimensions (WORD):
• Full Scale, 127 Standard Score (SS) • Verbal, 126 SS • Performance, 121 SS	• Basic Reading 75th percentile • Spelling 7th percentile • Reading Comprehension 15th percentile

No WORD composite score was given. A specific learning difficulty (dyslexia) was identified from these scores, with spelling being particularly affected, but scores were not low enough to qualify Elizabeth for an SEN allocation. At transition to post-primary school, Elizabeth's incoming test results (Figure 2 above) showed an 'average' student with a weakness in reading. Her reading age however was above the cut-off point for Learning Support, which was offered to students with a reading age of below 10.5. A student on the borderline in this way would normally be monitored to check for any difficulties; however Elizabeth was a diligent student with no apparent difficulties during her years in Junior Cycle. She showed exceptional ability in Art and Crafts. Junior Certificate examinations presented no difficulties for her (Fig. 3), but only three core subjects were taken at higher level. Her only 'A' was in Art which she took at higher level.

When Elizabeth was in 5th Year, her French teacher approached the SEN Department as she was concerned that Elizabeth's spelling was causing difficulty in written expression, holding back a student who was otherwise very able. An SEN teacher spoke with Elizabeth's English and Irish teachers, who also had concerns that her written work did not represent her ability in those subjects. Elizabeth was offered one class a week of support. Discussion with Elizabeth, her other subject teachers and with her parent suggested that a spelling and grammar waiver for Leaving Certificate would give Elizabeth greater possibility of achieving to her potential in the exams. Reasonable Accommodations (RACE) were applied for and a spelling and grammar waiver was granted on the basis of Elizabeth's spelling in the Wide Range Achievement 4 (WRAT 4), which was below the 10th percentile. In Leaving Certificate examinations, Elizabeth took Irish at Foundation Level and Maths and English at Ordinary Level. She did not achieve as highly as she had hoped, although on the basis of an excellent portfolio she got the third-level course of her choice.

Elizabeth's Leaving Certificate results did not reflect her ability. A significant difficulty for Elizabeth in examinations was that, in an effort to avoid making spelling mistakes, she had become accustomed to writing very brief responses to questions. This is a common tactic used by students with dyslexia, as also is the overuse of direct quotation from texts. Repetition is also common in longer writing tasks. These characteristics were features, not only of Elizabeth's writing, but of Kate and Henry's also.

Early identification and the introduction of support are extremely important in the case of highly able students like Elizabeth. Kate, whose in-coming testing results are also shown above (Fig.2), had a very similar profile on incoming to Elizabeth, but had greater difficulties in reading. While no assessment information transferred from her primary school, Kate was offered Learning Support on the basis of her incoming reading test score. During first year she took part in a reading intervention provided by pairing first year students with trained transition-year tutors. Post-testing showed that Kate's reading had improved by 1.9 years. Like Elizabeth, Kate coped very well with the curriculum in Junior Cycle, achieving satisfactory results in Junior Certificate examinations, in which all but one subject was taken at Higher Level (Fig.3). In exactly the same way as Elizabeth, Kate's difficulties in language subjects due to very weak spelling were brought to the attention of the SEN Department in her fifth year. All her teachers confirmed that Kate was a student with exceptional ability, whose written work did not represent her very high ability.

When students are unable to express themselves fully and freely in writing they often become inhibited, not only in their writing but also in other ways. Elizabeth was a quiet, hard-working student who lacked self-confidence in her own academic ability. The difficulties of both students appeared to have been mild enough to have been overcome, but in fact they were severe enough to prevent both students developing to their full potential at second-level. Early identification of the effects of dyslexia on the learning of both these students, as well as recognition of the exceptional ability that was masking their significant difficulties, may have made a significant difference to their academic achievement at second level.

Case Study 2: Ewan

In third class in primary school, due to difficulties in literacy skills, Ewan was referred to an educational psychologist for assessment:

WISC-III:
• Full Scale, 66th percentile
• Verbal, 75th percentile
• Performance, 47th percentile

WORD:
• Reading, 68 Standard Score
• Spelling, 68 SS
• Comprehension 80 SS

This testing showed a significant difference between Verbal and Performance scores. Freedom from Distractibility was also an area of weakness. Reading comprehension was an area of relative strength. Dyslexia was diagnosed, with a specific difficulty in both spelling and reading. Ewan was supported under the general allocation. A review report two years later, when Ewan was in 5th Class gave no scores for cognitive testing, stating that cognitive levels were the same as at previous testing. WORD showed:

- Basic Reading, 10th percentile
- Spelling, 4th percentile
- Reading Comprehension 16th percentile
- Word Composite, 5th percentile

At transition to post-primary school, incoming tests indicated that Ewan was an 'average' student (Fig. 2). He was above the cut-off point for both additional support for SEN and for Learning Support. He had been granted an exemption from Irish at primary level. A highly verbal student, Ewan was often disruptive in class. He was exceptionally able in Art, although he frequently failed to complete projects that were assigned. As he progressed through school, there were frequent difficulties with behaviour. He was intractable when he felt that he was being, in his own words, 'disrespected'. He doodled when he was thinking or when he was bored, which caused frequent difficulties with his teachers. His creative writing was of a very high quality, but the mechanics of his writing were poor. On a one-to-one basis, Ewan's verbal ability, general knowledge and interest in current affairs revealed a highly intelligent, thoughtful student. However in third year, he frequently talked about dropping out of school and in fact Ewan left after Junior Certificate. His Junior Certificate results, with the exception of Art and CSPE, did not reflect his ability (Fig.3). Ewan's exceptional academic ability was in the same area as his difficulty, which was a primary cause of his frustration with his learning. Early identification of dual exceptionality may have changed outcomes for this student.

Case Study 3: Jamie

Jamie experienced great difficulties in the acquisition of literacy skills from the time he began primary education. His first assessment by an educational psychologist was when he was in fifth class. WISC-III testing resulted in the following:

- Full Scale: 98 SS
- WORD Composite: 2nd percentile.

The educational psychologist noted that, during testing, Jamie frequently used his intelligence to accurately guess a word by recognising a single initial letter. Severe dyslexia was identified. Jamie was given in-school support and his parents arranged for additional support outside school.

At transition to post-primary school, Jamie was granted 2.5 hours of additional SEN teaching. He also had an exemption from Irish. Jamie's incoming test results revealed an 'average' student, who was well above the cut-off point for Learning Support classes (Fig.2). Despite these results, Jamie had severe difficulties in reading and writing. His slow and inaccurate reading made access to texts difficult. He used Kurzweil text-to-speech software in the SEN Department but, as he found it difficult to concentrate on text in that way for long periods of time, his SEN teacher read many texts to him. Initially Jamie was very nervous and lacking in self-confidence, but as he became accustomed to second level school and to working with his SEN teacher he began to benefit more from the extra classes. He also benefitted from the fact that he was very competent in mathematics and so all SEN classes were devoted to working on literacy skills and texts. All extra teaching classes were individual as he was withdrawn from mainstream class during Irish classes. As Jamie's confidence increased, it became clear that he was a very able student. Junior Certificate examinations were taken at higher level with the exception of French (Fig.3).

Assessment was carried out by the educational psychologist prior to application for Reasonable Accommodations for Leaving Certificate. WAIS results:

- Verbal, 99.7th percentile
- Performance, 61st percentile

The WAIT-II showed Pseudo Word Decoding at the 1st percentile. The National Educational Psychology Service (NEPS) psychologist noted that a Full Scale score would not adequately reflect this student's true cognitive ability. She described him as a 'young man of superior ability'. With a reader and a spelling and grammar waiver, Jamie achieved excellent Leaving Certificate results which included an A1 in Higher Level English. His results were equal to his expectations and he is currently studying his first-choice course at third level.

Henry was another student with similar difficulties to Jamie. Henry did not have an assessment before transfer to second level. Assessment carried out by an educational psychologist during his first year found him to be in the "upper end Low Average/ Average range", with WORD Composite at 0.2% ile. An allocation of 1.5 hours was made at the beginning of his second year. At this stage, Henry was overwhelmed by his difficulties and had little self-confidence. With support, over the next few years he gradually became more aware of his own self-efficacy in learning. He began to participate more in group work and discussion, although written work continued to be very brief and undeveloped.

A review assessment before application was made for RACE for Leaving Certificate, showed "current cognitive functioning in the Above High Average Range". Henry got 170 points in his Leaving Certificate and after a year spent doing a post Leaving Certificate course, he is now studying for a degree in third level. A comparison between the attainment at second level of Henry and Jamie underlines the importance of individual or small group support from an early stage.

Summary and Conclusions

Early identification, preferably at primary level, is important if students are to fulfil their potential at second level. Incoming assessments as shown above (Fig. 2) did not indicate the extent of either the difficulties or the potential ability of the students described here. The recent addition of a spelling test to incoming assessments in the writer's school has helped to identify dyslexic difficulties in students who performed well on the reading test. The introduction of CAT 3 also gives a clearer cognitive picture than AH2, which was not as stringent a test. However identification of dual exceptionality at second level would be greatly facilitated if standardised assessments carried out in primary school were available to the post-primary school, as trends in attainment would be seen and could be compared with further testing carried out at second level.

Students in Junior Cycle are unlikely to be identified as having exceptional abilities and/or learning difficulties, if they are performing satisfactorily in tests and examinations. Dual exceptional students will usually show some discrepancies between potential and performance, so each student's progress should be compared to his/her potential and dips in progress should be monitored. For this reason, tracking of end-of-term exam results should be the norm in Junior Cycle in particular, and progress should be checked in the light of performance in standardised assessments such as incoming tests, or cognitive tests such as WISC III or IV where they are available. Although cognitive testing does not give a full picture, it provides a basis for understanding. However, it is important to bear in mind that no fixed assumptions should be made about a student's potential based on cognitive testing alone. The two students described above who had review assessments in fifth year, showed a significant increase in cognitive functioning on reassessment. In the experience of this writer, this has been an invariable outcome for all students having psychological reviews in fifth year, whatever their level of ability.

Students whose difficulties appear relatively mild may prove to have significant difficulties in spelling in Senior Cycle, particularly in languages other than English, as was the case with Kate and Elizabeth. The most harmful aspect of a spelling difficulty at any stage of second level is the constricting effect it has on the writing of otherwise very able students. When the habit of writing only what one can spell has become ingrained, it takes a long time and a great deal of effort to develop complexity and fluency in one's writing. Students with dual exceptionality who have 'mild' dyslexia and are unsupported by extra teaching are as likely to underachieve in Certificate examinations as dual exceptional students who appear to have more severe difficulties.

Lack of self-confidence is a very large factor in the underachievement and the disengagement from learning of many students with dual exceptionality. As outcomes fail to match expectations, often because of poor performance in written work due to errors in spelling and grammar, poor organisation of writing or lack of plan and structure, these students lose confidence and feelings of self-efficacy. This begins most often in the higher stages of primary school and the first years of second level, when students begin to compare themselves to others and 'deficiency becomes identity and learning is transformed from the early child's free exploration of the world to a chore beset by insecurities and self-imposed restrictions' (Papert, 1980:5). When students lose heart and have no enjoyment in learning, they lose the 'task commitment' that Renzulli (1977) identifies as one of the three necessary elements of giftedness. Once disengagement becomes an entrenched attitude, it is difficult to reverse. This risk is always present for students with dual exceptionality, but perhaps it is most particularly so for students with dyslexia, as so many outcomes in school arise from written work. It is for this reason that it is so important to identify and support both the difficulties and the exceptional ability of these students.

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Comparing five interventions for struggling readers in Ireland: Findings from four years of action research

Mary Nugent

ABSTRACT

This paper summarises findings from four years of action research projects. The Waterford Reading Projects aimed to introduce a variety of evidence-based literacy interventions for struggling readers to local primary and secondary schools and to evaluate outcomes, using action research methods. Participants were 200 students in the age range 5 to 17 years and had average reading scores at approximately the 13th percentile at pre-intervention. There were ultimately five Projects. Each project involved learning support teachers delivering an evidence-based intervention over a specified time frame (3 months) and collecting pre and post-intervention data. In reporting on the findings, this paper summarises the evidence base for five particular interventions: Acceleread/ Accelewrite, Peer reading, Toe by Toe, SNIP and ARROW. Furthermore, the outcomes for 200 students using these five different intervention programmes are compared and discussed.

INTRODUCTION

This paper summarises findings from a four year study (from 2006-2010) organised by the local National Educational Psychological Service (NEPS) in Waterford, Ireland. The Waterford Reading Projects aimed to introduce a variety of evidence-based literacy interventions for struggling readers to local primary and secondary schools and to evaluate outcomes, using action research methods. There were ultimately five separate projects, each involving learning support teachers delivering an evidence-based intervention over a specified time frame (3 months) and collecting pre and post-intervention data.

LITERATURE REVIEW

What do we Know about Teaching Children to Read?

The synthesis of research findings reported here, draws on a number of meta analysis and research synthesis studies, completed within the last 12 years. Specifically, Swanson and Hoskyn (1998), Vaughn, Gersten and Chard (2000), the Report of The National Reading Panel (NRP, 2000), Scammaca, Vaughn, Roberts, Wanzek and Torgesen (2007), Slavin, Cheung, Groff and Lake (2008) Brooks (2007) and Singleton (2009). Information from meta analyses and best evidence syntheses is supplemented by recent individual studies, demonstrating the effectiveness of particular approaches in the UK. Therefore, information from the work of Solity and his colleagues (reported in Solity 2000 and Solity, Deavers, Kerfoot, Crane and Cannon 2000) and the work of McKay (2006) also were considered. See Nugent (2010, in press) for a full discussion about this literature.

In summary, the following approaches have been found to be effective:

- Structured, systematic teaching (NRP 2000, Swanson and Hoskyn 1998, Singleton 2009)
- Small group settings (not more than 3) or individualised teaching are best (Vaughn et al 2000, Swanson & Hoskyn 1998, Scammaca et al 2007)
- Teachers need to be well trained and have on-going professional development (NRP 2000, Slavin et al 2008)
- Co-operative learning, including peer reading approaches can be highly effective (particularly with adolescents) (Brooks 2007, Slavin et al 2008, Vaughn et al 2000)
- Teaching should be daily or almost daily, with practice distributed rather than massed (Solity 2000, Scammaca et al 2007)
- Students need to be taught new skills to the point of fluency (NRP 2000, Solity et al 2000)
- Task difficulty should be managed to give students high levels of success (Vaughn et al 2000)
- Intensive interventions of relatively short duration can be highly effective and interventions of longer duration do not necessarily produce better outcomes (Brooks 2007, Vaughn et al 2000, Singleton 2009)
- On-going assessment of student achievement and early identification of difficulties (Solity et al 2000, Scammaca et al 2007)
- Computer assisted learning has considerable potential, but needs to be carefully matched to student need (Brooks 2007, NRP 2000)
- Encouraging children to make positive declarations about their future achievement can be helpful (MacKay 2006)

Evidence-Based Interventions and Measuring Progress – What is Possible?

There is an increasing emphasis on evidence based interventions: interventions where there is research evidence to support the efficacy of the approach (see Brooks 2007, Scammaca et al 2007, Slavin et al 2008, Singleton 2009). Brooks sets out various methods of measuring progress in reading and sets a standard by which literacy interventions for failing readers can be measured. One way of measuring progress is by using ratio gains: a calculation of the rate of progress over the time of the intervention. Particularly helpful, is the guidance for interpreting ratio gains. Brooks (2007) suggests that ratio gains of more than 2 are the standard to which to aspire, as *'many schemes now produce impacts of this order or more'* (p30). In effect, Brooks argues, *'Good impact- sufficient to at least double the standard rate of progress- can be achieved and it is reasonable to expect it'.* (p32).

Programmes that Help Struggling Readers

In the Waterford Reading Projects, the psychology team presented up-to-date research evidence about named intervention programmes or approaches, so that teachers had an evidence based menu from which they could select a programme.

In order to make this manageable and accessible, a limited number of programmes were presented. They were largely programmes that were readily available in Ireland. However, teachers were also made aware of other interventions, which required additional training or funding or large scale organisation (such as Reading Recovery, ARROW, and Phono-Graphix). One of the developments that happened over the course of the projects was that when schools were made aware of the potential of the ARROW programme, a number of schools invested in that programme, which was, at that time, entirely new in Ireland. Ultimately five interventions were chosen by the vast majority (87%) of teacher participants:

- Acceleread/ Accelewrite (Ciifford and Miles 1994)
- Peer Reading (see Topping 2000 for a discussion)
- Toe by Toe (Cowling & Cowling 1993)
- SNIP (a precision teaching package, see Binder and Watkins (1990) and Smart & Smart, undated)
- ARROW (ARROW 2008).

Other interventions were either not selected (often due to a lack of available training) or selected by very small numbers (and therefore did not provide adequate data for comparison purposes).

As these interventions may not be familiar to the reader, a brief summary of each, with information about the evidence base, is included here. Much of the data reported below is drawn from Brooks, (2007) *What Works for Pupils with Literacy Difficulties* (2007). This substantial text compares 48 schemes used in the UK. However, this information is supplemented by additional research (some of it unpublished) carried out in Ireland and the UK.

Acceleread / Accelewrite

Accelread/ Accelewrite is a computer based programme, developed by Clifford and Miles (1994). It uses 'talking' word processors, and involves students reading text, memorising sentences, typing in the text and listening to the computer 'read back' what they have written. Students can self-correct errors. It is a highly structured programme and the recommended protocol is for individual tuition for 20 minutes, 5 days per week for 4 weeks.

Research reported by Brooks (2007) based on the Jersey Project, involved 61 students in 15 primary schools and 4 secondary schools. After 4 weeks of intervention, students made ratio gains of 8.3 in reading, with further increases reported over time. Brooks also reported on the Bristol study, which involved 60 children in 13 primary schools. After 8 weeks of intervention students made ratio gains of 2.3 in reading accuracy and 2.9 in comprehension.

Irish research, involving 13 pupils aged 11 to 13 years, who received between 11 and 17 sessions of Acceleread / Accelewrite found that they made average gains of 12 months progress in reading and 7 months progress in comprehension (Tierney, 2005). Furthermore, a small-scale study by Devenney (2007) showed the potential for class teachers to deliver Acceleread / Accelewrite, while continuing to teach the mainstream class group. Seven participants in this study, who completed a four week block of intervention, working on a computer within the classroom, under the supervision of the class teacher, made 9 months progress (progress of 5 standard score points) in reading, while a control group (those attending learning support) made no measurable progress.

Peer Reading

Peer reading, almost certainly familiar to readers, is largely based on the work of Keith Topping and colleagues. Broadly speaking, those who need help with reading are matched with a non-professional who assists by reading to the learner, reading alongside the learner and then listening to the learner read in a graduated system of support. Procedures for correcting errors and giving frequent praise are specified. In this project, the peer reading generally involved children reading with peers in school. Peer reading is reportedly cost effective in terms of teacher time, but needs on-going organisation, including the training of tutors, monitoring of progress, maintenance of the programme (for example monitoring attendance and trouble-shooting incompatible pairings). Logistical issues of time, space and suitable reading materials also need consideration.

Peer reading is one of the most comprehensively researched interventions available. Brooks (2007) reports on studies involving 2,372 children in 155 projects in 71 schools. Ratio gains of 3.3 in reading and 4.3 in comprehension were reported (effect sizes were .87 and .77 respectively). As Topping (2000) noted, the general picture in published studies is that peer readers progress about 4.2 times 'normal' rates in reading accuracy, during the initial period of commitment. Further research in Ireland found that this approach was also effective with students with a mild general learning disability. In this study of cross-aged peer tutoring, data was collected for 30 'helpers' and 18 'learners', attending a special school. Those involved in peer tutoring made twice as much progress as control groups, with 'helpers' making 15 months progress in reading, while a control group made 7 months progress and 'learners' made 7 months progress, while a control group made 3 months progress (see Nugent, 2001). In a further study, Nugent and Devenny (2008) reported on a peer reading scheme in a secondary school in Ireland. Consistent with other findings, it was found that helpers make the most significant progress, making twice as much progress in reading over the course of the intervention, than did a comparison group.

Toe by Toe

Toe by Toe is a highly structured programme that teachers phonic skills. The reading of non-words is a feature of this programme, and there is considerable emphasis on recording progress. It is suitable for children from the age of 6 years and has been used effectively in the prison service. lt is an individualised approach and the recommended protocol is for 20 minutes of instruction, daily.

Published research includes a study of 24 secondary aged pupils. There were matched pairs in the control group (normal learning support) and the experimental group (Toe by Toe, taught individually, for 20 minutes per day, five days per week, for an average of 3 months). The results were reported in Literacy Today in 2004:

> *'The results were definitive. The experimental group made average gains of three and a half years. The control group made average gains of five months.'* (McKay and Cowling (2004).

Furthermore, MacKay (2006) used the Toe by Toe intervention with 91 children who struggled with reading in 32 Scottish primary schools (part of the West Dunbartonshire Reading Initiative). After 6-7 months of intervention, the average participant made gains of 14 months in reading (representing a ratio gain of 2.3). Finally, Brooks (2007) reported on an unpublished study by Keith Taylor, which found that 21 participants in a primary school made gains of almost 4 years in reading, over an 18 month period of intervention (ratio gains are reported to be 2.7).

SNIP

SNIP is perhaps the least well-known of the intervention methods described here. It is grounded in the theory of precision teaching and instructional psychology and was developed by Carol and Phil Smart. lt is suitable for children in the upper part of primary school or early secondary school and aims to develop their sight vocabulary, particularly of essential curriculum words. Students are taught lists of sight words, which they practice daily, for five minutes, until they attain fluency. SNIP was attractive to the psychologists organising this research because it was freely available to download! The evidence-base for it as an intervention was relatively poor. On their website, the authors claimed, *'Using this pack we have achieved measurable gains of three years in an academic year with some of our pupils'* (Smart and Smart). Although this claim does not constitute reliable evidence, nonetheless the efficacy of precision teaching methods is well-documented (See Binder and Watkins 1990).

ARROW

ARROW stands for Aural- Read- Respond- Oral- Write. lt is a programme developed by Colin Lane (2008). lt works on the principle that hearing one's own voice is a psychological key to much language comprehension. The system involves children recording and playing back their own voices reading, using laptop computers and headphones and a structured system of examples and exercises. The program displays a piece of text at the appropriate level (anything from a single letter to a short paragraph). The child hears it spoken, then repeats it aloud, and records it, then plays it back. At the end of the process, the child writes down the piece of text. The programme has a range of protocols, typically 30 minutes per day, for a total of 10 hours tuition. One adult is able to supervise a number of children (typically 5), as long as each child has access to a computer.

Brooks (2007) evaluated a large range of literacy interventions and, in relation to ARROW he noted, *'The ratio gains show that this amount of progress ... was remarkable, if not spectacular'* (p133). In the study cited by Brooks, 91 children made average gains of 7 months in reading and 6 months in spelling after just 1.5 week's of intervention.

Lane also reported on further data (2008) involving 445 children in 20 schools. Typically, after 2-3 hours of ARROW training, children made average gains of 9.5 months in reading age. Those who undertook longer programmes (8 to 10 hours of ARROW tuition) made gains of 14 months in reading age.

METHODOLOGY

The Four Studies

This report amalgamates data from five Waterford Reading Projects.

- Project 1- 2006-2007, targeted primary aged children
- Project 2- 2007-2008, targeted secondary aged children
- Project 3-2008-2009, targeted both primary and secondary children
- Traveller Project- 2008-2009, an associated initiative, requested by the local Visiting Teacher for Travellers in Waterford, who felt that the Traveller population would benefit from being targeted systematically.
- Traveller Project 11- 2009-2010 (as above)

Each project involved the following elements:

- A presentation by the NEPS psychologists to learning support about evidence-based approaches and interventions in reading

- Implementation of a range of evidence-based interventions over a period of 3 months
- Completion by teachers of logs to monitor attendance, duration of teaching and learning
- Completion by teachers of qualitative questionnaires
- Collection or pre and post intervention data using a standardised reading test
- A total on 3 meetings for teachers over the course of the 4 months, to set-up, monitor and evaluate the projects

Data were collected about the gains children made in reading using standardised tests. In Project 1, the Nfer Group Reading Test (Nfer-Nelson 1992) was used, using both the sentence completion and (where applicable) context comprehension forms. All subsequent Projects used the Wide Range Achievement Test (WRAT 4, 2006), including word reading and sentence comprehension.

Information about Participants

The total number of participants (students) involved in each intervention is set out below:

Table 1. Number of Participants (students) in each Intervention

Intervention	Students
Accelread	43
Peer reading	54
Toe by toe	33
SNIP	21
ARROW	49
Total	**200**

Some schools and some teachers participated in more than one project and a small number of students may also have been involved in more than one project, but since their data was anonymous, it is impossible to be accurate about this. Over the three years, 46 teachers participated in the action research, and data was collected for 221 students. Of these, valid pre and post-intervention data was collected for 200 participants who followed the five most popular interventions.

The age range of participants was from 5 years, 9 months to 17 years, 1 month. The mean age of participants at the start of intervention was 12 years. There were 126 boys and 63 girls participating, with 11 participants for whom gender was unspecified.

RESULTS

Gains in Reading Ability – All Participants

Pre-and Post Intervention Scores

The data presented here, represents pre and post intervention data. At pre-intervention, students generally were performing below the 13th percentile, with mean word reading standard scores of 81 and mean comprehension standard scores of 83. At post-intervention, the mean standard score for word reading was 85 and for comprehension was 86 (see Table 1). Therefore, the average participant was reading between the 16th and 18th percentile, within the low average range. In Ireland, these students are likely to be discharged from learning support and to have their needs met through mainstream education.

Table 1. Pre-and post intervention standard score test results, all participants

Test	N	Pre-intervention	Post Intervention
Word reading	200	80.6	85.3
Comprehension	188	82.6	86.2

Another way of understanding these results is to transform these standard score results into age equivalents. The GRT 11 provides such age equivalents scores, but the WRAT 4 provides grade equivalent scores. lt is then possible, using a procedure outlined by Shearer Mariotti and Homan (2005), to convert grade equivalent scores into age equivalents. These calculations have, in turn, been used to calculate ratio gains. On the basis of this information, it was found that over the course of a 3 month intervention, the average participant made gains of 12 months in both word reading and in reading comprehension. The average pre-intervention word reading score was 8 years, 3 months, while the post intervention score was 9 years, 3 months. The average pre-intervention comprehension score was 8 years, 9 months, while the average post intervention score was 9 years, 9 months. This represents a ratio gain of 4.

Gains in Reading Ability – Comparing Interventions

In this section we move from considering the overall progress of participants, to comparing the progress made by participants using five different interventions.

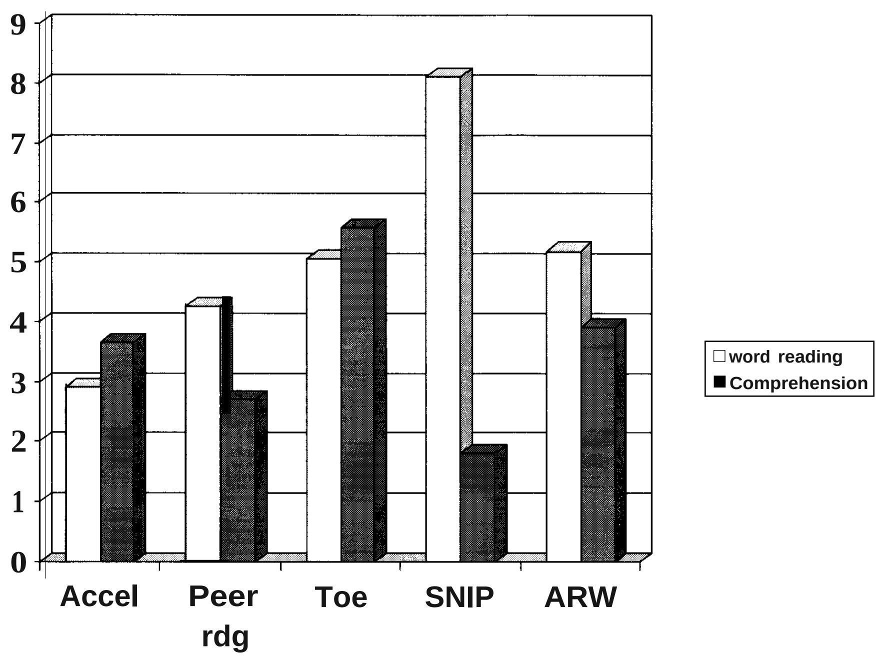
Data presented in Table 2, shows the average standard score gains made by participants in word reading and comprehension, in each of five intervention groups.

Table 2. Mean standard score gains in word reading and reading comprehension, by type of intervention, with number of participants.

Intervention	Acceleread N=43	Peer Reading N=54	Toe by Toe N=33	SNIP N=21	ARROW N=49
Mean gains in word reading	2.91	4.26	5.06	8.09	5.19
Mean gains in comprehension	3.64	2.70	5.58	1.80	3.91

As can be seen from Table 2, those following the SNIP programme made the most progress in word reading, while those following Toe by Toe made the most progress in reading comprehension. Another way of considering this data is to look at standard score gains for each intervention graphically.

Figure 1. Comparison of interventions, based on standard score gains in word reading and comprehension.



What the above data is telling us is complex: lt is not the case that any one intervention can be declared the most effective. lt appears that SNIP can be a highly effective intervention in the area of word reading, but is less effective in the area of comprehension. This is perhaps not surprising, as this intervention is solely based on word reading tasks. Toe by Toe was impressive, in that it appeared to address both word reading and reading comprehension equally effectively.

Teaching Time and Learning Time

An important consideration in calculating the efficacy of any intervention programme is to look at the amount of time given by students to learning and the amount of teacher time required to deliver the programme. Data was collected about how long each student attended tuition (calculated in hours and minutes) and about how many students were in the teaching group. This data then allowed the researcher to evaluate how much teacher time each student received, (by dividing teacher time by the number in the teaching group), see Table 3. However, it was not possible to estimate teacher time involved in peer reading, as the time involved in was not just contact time, but time spent organising.

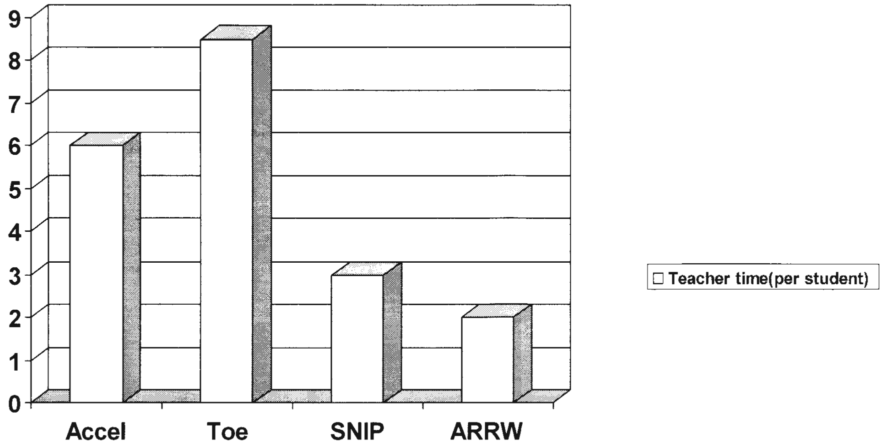
Table 3. Interventions, teaching and learning time per student

Name of Programme	Total of teacher time, per student*	Total of learning time, per student
Acceleread/ Accelewrite N= 43	6 hours	8 hours
Peer Reading **N**= 54	N/A	13 hours
Toe by Toe **N**= 33	8.5 hours	10.5 hours
SNIP **N**= 21	3 hours	6 hours
ARROW N= 49	2 hours	7 hours

* Data is rounded up or down to nearest half hour division

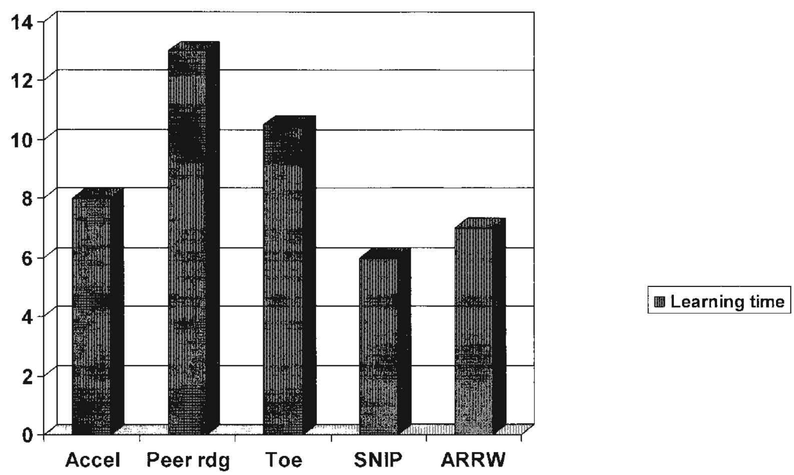
As Table 3 shows, students in Acceleread / Accelewrite, SNIP and ARROW spent broadly comparable amounts of time learning (between 6 and 8 hours), although those participating in peer reading spent significantly longer (13 hours). More impressive is the value that ARROW and SNIP give in terms of teacher time. The average amount of teacher time used, per student, was 2 hours for ARROW and 3 hours for SNIP. One of the particular advantages of the ARROW programme is that is can be effectively delivered to groups – typically 5 students at a time. The SNIP programme was delivered in both a larger group setting (7 students) and individually, for very short periods of time (10 minutes) making this a very time efficient intervention for both students and teachers. These results are presented graphically in figures 3 and 4, below.

Figure 3. Graph comparing the amount of teacher time spent per student, for each intervention



*Note, teacher time for Paired Reading could not be calculated

Figure 4. Graph comparing the amount of learning time spent, per student, for each intervention



DISCUSSION

Summary of Findings

Five different intervention approaches were trailed with data collected from 200 students. While outcomes were variable, it was not the case that any one intervention could be favoured over others, as some interventions were highly effective in one area (such as word reading) but not in another area (such as reading comprehension). Additionally, when the factors of teacher time and learner time are considered, the picture is again more complex: some interventions were relatively time-efficient because they could be delivered to groups or in very short bursts of time, while others required more one to one teaching. Peer reading required greater learning time, while SNIP and ARROW were both time-efficient in terms of both teacher time and learner time. On the other hand, Toe by Toe, which required higher levels of teacher time, produced impressive results in both word reading and in reading comprehension. This was less true of both SNIP and Peer Reading, which produced relatively weaker results in the area of reading comprehension, but then these interventions are relatively cost effective.

Systematic Interventions

Feldman (2004) suggests a number of steps which are fundamental to successful interventions, including selecting 'a *research-based, validated curriculum as the programme "anchor"*' (p1). Teachers participating in this study choose such a programme anchor and delivered it systematically. (This was monitored through the teaching logs that each teacher completed for each participant, which documented the frequency and duration of teaching sessions and included qualitative notes about student responses). The main element in the success of this project was the commitment and dedication of teachers. Each teacher implemented a structured intervention in a systematic way and monitored outcomes. In a way, what was done was the application of research knowledge to the 'real world' problem of reading failure.

Short-term Intervention

As note in the review of literature, there is evidence that intensive interventions of relatively short duration can be highly effective. For example, Singleton (2009) points out that some data suggests that the rate of progress may drop off after the first 12 hours of tuition. Topping (2000) suggests that progress in Paired Reading of 4.2 times the normal rate of progress is achieved during the <u>initial period</u> of commitment. The interventions reported above generally did not go beyond 12 hours (those participating in Paired Reading were the only one to spend more than 12 hours on tuition). While the gains reported above are impressive, it does not follow that the same rate of progress could be attained over a longer period of intervention. While average participants made a year's progress in reading over a 3 month period of intervention, it does not follow that participants could make two years progress over 6 months, or indeed, four years progress over one year of tuition. Further, longitudinal studies may be helpful in tracking the rate of progress of students involved in various forms of intervention.

These findings also have implications for teachers when designing their learning support timetables. Short-term, intensive intervention is certainly found to be more effective than longer term, less frequent, intervention. In Ireland, some students selected for learning support, may continue in support for the full academic year, without a formal review of literacy skills. lt is suggested here that termly programmes of intervention, with reviews of progress that include formal testing, may be the most appropriate model of support.

One to One or Small Group?

One of the dilemmas for learning support teachers is whether to offer small group tuition (thereby reaching more students) of to offer one to one tuition. The research suggests that one to one tuition is the 'gold standard', but that highly trained teachers using a structured approach can be effective with groups of up to three (Vaughn et al 2000, Swanson & Hoskyn 1998, Scammaca et al 2007). What this study found was that some approaches, such as ARROW, can be used effectively with groups of up to five students, although it remains the case that one of the most consistently effective interventions for both reading and reading comprehension (Toe by Toe) was delivered in a one to one setting. SNIP was interesting because it was effectively delivered both to a group (7 students) and on a one to one basis, and both approaches were effective, although, not surprisingly, the student receiving one to one tuition did best. On the other hand, a programme such as Paired Reading can deliver intervention to relatively large numbers of students. The finding in this study, that Paired Reading was less effective in teaching reading comprehension, is not borne out in other studies, and may be a feature of the students selected (N=54). The one to one versus group tuition dilemma is not straight-forward and is dependent on the programme selected and the students involved.

Word Reading and Comprehension

In selecting an appropriate intervention for a student, teachers need to be aware of the student's key areas of deficit and select an intervention accordingly. One simple and helpful assessment is discriminating between word reading and reading comprehension. lt is suggested here that all struggling readers should be assessed on both measures, so that teachers can identify relative strengths and weaknesses. Data collected here would suggest that SNIP, Toe by Toe and ARROW may be particularly suitable for those with difficulties with word reading, while SNIP appears unsuited to those with comprehension difficulties.

Selecting an Intervention

The five interventions reviewed here appear to be effective, but there are many other evidence-based interventions available, for example, Phono Graphix, Reading Recovery and inference training. Brooks (2007) provides a most comprehensive review. Teachers need to select interventions, taking account of a range of factors. The following structure may be helpful in guiding decision making:

- What interventions are readily available to me? (Resources and training)
- Which of these interventions is suited to student's the age group?
- Does the intervention appear to target the student's greatest level of need? (phonological knowledge, word reading, comprehension)
- Are there particular reasons why a student might respond better to one approach rather than another? (Preference for work on computer / novelty value etc)
- Can the learning support timetable offer the type of structure required by this intervention?

Some new approaches can be implemented at very low cost (SNIP), without any time delay, while other approaches may require longer-term investment and training (ARROW). It is suggested here that teachers aim to build a repertoire of effective interventions, so that they can be responsive to individual needs. This is not the same as adopting an eclectic approach, where multiple elements of different programmes are combined, which has been found to be less effective. Rather, the teacher systematically delivers an evidence-based intervention and after review, either continues with this programme or offers an alternative evidence-based approach for a further block of time. It is certainly the case that students (and teachers) may tire of particular approaches after an intensive block of intervention, and may be more responsive to novel approach after a period of time.

Conclusion

These action research projects showed that targeted, structured interventions can have a positive impact of the progress of struggling readers, across the primary and secondary age range, even when implemented over a relatively short time. The challenge for teachers is to extend their repertoire of evidence-based interventions, so they can most effectively respond to a diversity of struggling readers.

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MARY NUGENT

Dr. Mary Nugent is a senior educational psychologist with the National Educational Psychological Service, based in the Waterford office. She has a particular interest in effective interventions for children with reading difficulties and completed her doctorate in this area. In recent years she has been working with colleagues to develop action research projects in the Waterford area which explore the effectiveness of reading interventions in use in Irish primary and secondary schools.

Working memory training improves arithmetic skills and verbal working memory capacity in children with ADHD

Magnus Ivarsson and Stefan Strohmayer

Previously published by Stockholm University

Abstract

Children with ADHD diagnosis often display working memory deficits, as well as reading and mathematical disabilities. Previous studies have demonstrated that computerized working memory training (WMT) is a promising intervention. The present study aimed at exploring the effects of WMT on working memory, scholastic skills and behavioral symptoms in children with ADHD. Thirty-two children, aged 6 to 11, were randomized to WMT or a control condition. WMT consisted of nine tasks taxing working memory with adaptive difficulty level. All children trained in their homes, with their parents acting as supervisors. Children who completed more than 20 days of training in 5-8 weeks (8 in the WMT condition and 13 in the control condition) were considered compliers. Assessments were conducted before and after intervention. Results indicated that WMT lead to significant gains of verbal working memory and arithmetic skills. More research is needed to further investigate the effects of WMT.

Computerized working memory training (WMT) is a relatively new intervention and the subject of a growing field of research. WMT software is available in Swedish schools and hospitals and is used by both children and adults. The present study is a randomized controlled trial of WMT in children with ADHD. Effects of WMT and reading training (RT) on working memory capacity, scholastic skills and behavioral symptoms were compared.

Attention Deficit Hyperactivity Disorder (ADHD) is a developmental mental disorder characterized by inattention and/or hyperactivity/impulsivity (American Psychiatric Association, 1994). At least six out of nine diagnostic criteria regarding attention or six out of nine diagnostic criteria regarding hyperactivity/impulsivity need to be met in order to be diagnosed. Three subtypes are thereby stipulated; ADHD-predominantly hyperactivity-impulsive type (ADHD-H), ADHD-predominantly inattentive type (ADHD-I) and ADHD-combined type (ADHD-C). Hyperkinetic disorder, a term used by The World Health Organization (1993) contains similar criteria as the DSM-IV diagnosis. In the review of earlier research below, Hyperkinetic disorder will not be differentiated from ADHD.

A recent meta-analysis of the prevalence of ADHD (Polanczyk, de Lima, Horta, Biederman, & Rohde, 2007) concluded that around 5% of children and adolescents world-wide fulfill diagnostic criteria for ADHD. A significant association between gender and prevalence was found in the same study, revealing that boys were more than twice as likely to be diagnosed with ADHD as girls.

Even though ADHD-symptoms seem to decrease in adulthood, problems persist in some degree in a substantial part of cases (Faraone, Biederman, & Mick, 2006). The distribution of subtypes have varied in studies, but in one study investigating different subtyping methods (Rowland, et al., 2008), ADHD-H was the least common subtype, and either ADHD-C or ADHD-I were most common depending on subtyping procedure.

ADHD has often been associated with the presence of one or more comorbid disorders and scholastic disabilities. Correlations have been found between ADHD and for example oppositional defiant behaviors, autistic traits, motor coordination problems, anxiety (Gillberg, et al., 2004), reading problems (Rommelse, et al., 2009), mathematical disabilities (Faraone, et al., 1993) and Tourette's syndrome (Kadesjö & Gillberg, 2000).

ADHD theories

Several different theories of the developmental paths and mechanisms of ADHD have been suggested. Barkley's (1997) influential model proposed that behavioral inhibition was the primary deficit of ADHD. Behavioral inhibition was considered to be fundamental since it was thought to create a delay in responding and thus a time window in which executive functions could become activated. The theory specified four separable executive functions based on prior research: verbal working memory, nonverbal working memory, the self-regulation of affect/motivation/arousal, and reconstitution (analyzing behavior and creating novel behavioral responses). The primary impairment in behavioral inhibition was hypothesized to cause secondary impairments in executive functioning which in turn resulted in failures in motor control, fluency and syntax.

Another core deficit of ADHD was later proposed by Sagvolden, Aase, Zeiner and Berger (1998). Based on the fact that the effect of reinforcement decreases when the time window between response and reinforcement grows, the authors hypothesized that, ADHD children would be more sensitive to reinforcement in close proximity and less sensitive to distal reinforcement compared to children without the diagnosis. The altered reinforcement hypothesis further suggested that the often observed hyperactivity and problems with sustained attention in the ADHD population could be explained by the sensitivity to delay of reinforcement.

A later proposed theory (Sonuga-Barke, 2002) suggested a synthesis between the theories of executive dysfunction and delay sensitivity, comprising a dual pathway model of ADHD-C. The reason for joining the two processes in one model was that they both seemed to relate to ADHD even though they did not correlate with each other. Thus the dual pathway model stated that symptoms labeled as ADHD could be the result of either of the two independent developmental paths. The first pathway described how inhibitory dysfunction leads to cognitive and behavioral dysregulation. The cognitive dysregulation then resulted in poor quality task engagement, while the behavioral dysregulation resulted in the ADHD symptoms. The second pathway to ADHD stated that the sensitivity to delay (shortened delay gradient) in combination with contextual demands of waiting and delay resulted in repeated failures. This resulted in an acquired generalized delay aversion through mechanisms of associative conditioning. The delay aversion in turn led to the ADHD symptoms.

Another theory is the cognitive-energetic model, put forth by Sergeant (2000), which also included components of delay aversion and behavioral inhibition. The model stipulated that the problems associated with ADHD were evident on three different levels: the executive system (for example behavioral inhibition and working memory), state factors and the computational mechanisms of attention. The state factors, or energetic pools as they were also called, consisted of effort, arousal and activation. The cognitive-energetic model suggested that dysfunction in the state factors might be underlying the behavioral inhibition evident in ADHD.

One implication of the behavioral inhibition deficit theory was that executive dysfunction ought to be found, in some degree, in all cases of ADHD. A comprehensive meta-analysis (Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005) recently came to the conclusion that, although executive dysfunction is significantly related to ADHD, it is neither necessary, nor sufficient to cause ADHD. Instead, executive dysfunction was shown to be one of several important deficits characterizing ADHD. The executive functions that were found to have the strongest effects were response inhibition, vigilance, working memory, and some measures of planning. Another recent meta- analysis (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005) also investigated working memory impairments in ADHD and found strong impairments in spatial working memory and moderate impairments in verbal working memory. Consequently, a conclusion based on the theoretical models of ADHD and the above mentioned meta- analysis concerning executive dysfunction in ADHD, is that working memory deficits are common in ADHD.

ADHD treatment

The most common treatment for ADHD has been pharmacological, such as methylphenidate (Bedard, Jain, Hogg-Johnson, & Tannock, 2007) or atomoxetine (Cheng, Chen, Ko, & Ng, 2007). Different forms of psychosocial, primarily behavioral, treatments have also been employed in both school and home environment. The effects of behavioral interventions on ADHD have been a subject of controversy for several years. Fabiano et al. (2009) performed a meta-analysis including studies with different designs (single subject, pre-post, between group and within-subject) and concluded that behavioral interventions in different settings had a positive effect on ADHD symptoms. Examples of included behavioral interventions were parent training with emphasis on social learning principles, behavior modification techniques and behavioral classroom interventions. A meta-analysis by Van der Oord, Prins, Osterlaan, and Emmelkamp (2008) compared the effects of different forms of cognitive and/or behavioral interventions with the effects of methylphenidate. Effects were found on ADHD- symptoms in school-aged children for both treatments but not on academic functioning. However the psychosocial treatments did not add to the effects of methylphenidate.

Another meta-analysis (Schachter, Pham, King, Langford, & Moher, 2001) concluded that the use of methylphenidate in some cases caused loss of appetite, insomnia, and to a lesser extent stomach ache, headache and dizziness. Effects of long-term use beyond 14 months, in randomized controlled conditions, have not been sufficiently investigated.

Corcoran and Dattalo (2006) have examined the effects of parent-involvement in treatment of ADHD. According to the results of their meta-analysis, including studies of cognitive-behavioral interventions, parent-involvement was associated with a weak positive effect on ADHD and externalizing problems. Effects in the moderate range could be seen on outcome measures such as internalizing symptoms and academic performance, although the results on the later measure were described as tentative.

Working memory

Probably the first mention of working memory was by Miller, Galanter and Pribram (1960). However the most influential model of working memory is the multi-component model presented by Baddeley and Hitch (1974). The model comprised of three components; the central executive and its two slave systems the phonological loop and the visuo-spatial sketchpad. Later a third slave system, the episodic buffer, was added to the model (Baddeley, 2000). Figure 1 gives an overview of the revised multi-component model of working memory. Despite the fact that the original model is quite simple and over thirty years old it has continued to develop and to be a subject for research and debate (Baddeley, 2003). There are several additional models of working memory. For a comprehensive review on different models of working memory see Miyake and Shah (1999).

Baddeley (1992) defined working memory as follows: "The term working memory refers to a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning and reasoning" (p. 556).

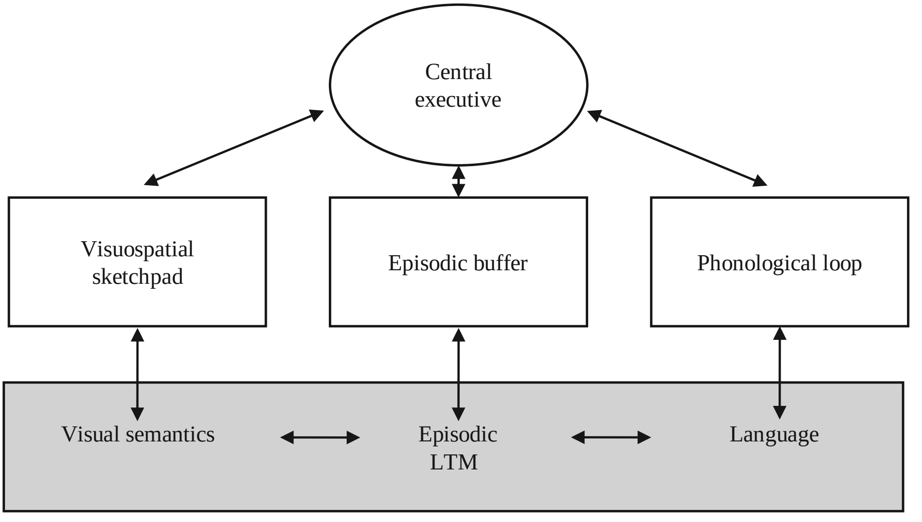


Figure 1. The multi-component working memory model. The grey area represents crystallized cognitive systems, and the white areas represent fluid cognitive systems (Baddeley, 2000).

The phonological loop has been described as consisting of two subsystems. The first system is the phonological store which is capable of holding acoustic information for about two seconds. The second system is the articulatory control process which has two functions. It repeats information in the phonological store subvocally to maintain the information for longer periods of time. The second function of the articulatory control process is to transform visually presented nameable information (such as letters or words) to enable subvocal repetition (Baddeley, 1992).

The visuospatial sketchpad has been assumed to serve the same function as the phonological loop, but regarding visual and spatial stimuli and information. Although debated, at least two separate components seem to exist: one component dealing with the spatial location of objects and the other component dealing with visual representation of objects. However the research on the visuospatial sketchpad is less extensive than on the phonological loop and yet other components have been suggested in the visuospatial subsystem (Baddeley, 2007).

The central executive, although being the most important component of working memory, is also the least understood (Baddeley, 2003; Baddeley, 2007). The attentional control of behavior is however a key aspect of the central executive (Baddeley, 1992). Dividing and focusing attention are the two most investigated subcomponents of current attentional theories and seem likely to be linked to the central executive. The capacity to switch attention is probably not explained solely by one executive function (Baddeley, 2007).

The episodic buffer was introduced to explain the connection between working memory and episodic long term memory. In contrast to the other slave systems it is not associated with a specific kind of stimuli. The episodic buffer is assumed to be a limited-capacity store capable of integrating information from a variety of sources. It is assumed to feed and retrieve information from episodic long term memory. The information is integrated as episodes that can be extended over space and time (Baddeley, 2000).

The existence of a link between working memory and episodic memory, such as the episodic buffer, could imply that primary deficits in attention processes and working memory would lead to secondary impairments in areas such as verbal learning and episodic memory. Baddeley (2000) was not the first to have suggested such a connection. Atkinson and Shiffering's (1969) influential model of memory also contained a connection between short-term memory and long-term memory. The model stipulated three different memory stores: the sensory registry, the short -term store, and the long-term store. The sensory registry was believed to be able to store information for milliseconds, the short-term memory for up to 30 seconds, and the long-term memory permanently. The model demonstrated the importance of short-term memory for processes such as encoding and retrieval o f memories in long-term memory. Mealer, Morgan and Luscomb (1996) revealed that a group of boys diagnosed with ADHD performed worse than controls on some neuropsychological test measuring different aspects of the memory system. The authors concluded that although problems with initial processing and short-term storage were apparent, no deficits in long-term memory were evident. The children had no difficulties retrieving information from the long-term store.

Difficulties associated with working memory

Several studies have investigated the connection between working memory and arithmetic skills. Results have consistently showed that working memory is a strong predictor of mathematical performance (DeStefano & Lefevre, 2004; Passolunghi, Vercelloni, & Schadee, 2007; De Smedt, Janssen, Bouwens, Verschaffel, Boets, & Ghesquière, 2009). In a large meta-analysis comprising of data from 77 studies with over 6000 participants Daneman and Merikle (1996) concluded that working memory is also a strong predictor of reading comprehension.

Gathercole and Alloway (2008) have described how children with poor working memory struggle when developing reading and mathematical skills. There are several key aspects involved when learning to read. Spelling patterns of individual words must be learned. Furthermore mappings between sounds and individual letters and letter combinations need to be mastered. Particularly the learning of these connections develops slowly in children with poor working memory. In activities desig ned to attain basic literacy, children with poor working memory often fail due to high demands on working memory. When a sentence or a fragment of text is to be understood the child needs to keep all the information in working memory long enough to interpret what has been read and at the same time understand each word. Children with poor working memory therefore have even more difficulties in interpreting the meaning of a text since they often have difficulties with both decoding individual words and keeping the whole sentence in memory. In mathematics, particularly addition, subtraction, division and multiplication propose difficulties for children with poor working memory. Working memory overload often occurs in exercises designed to develop knowledge of basic number rules. This results in frequent errors and slows down the acquisition of basic skills. Arithmetic puts high demands on working memory as well as retrieval and application of these rules that are likely to not have been learned. Children with po or working memory therefore often use strategies such as finger counting which puts higher demands on working memory than retrieving rules.

One of the most commonly described problems for children with poor working memory is the ability to follow instructions (Gathercole & Alloway, 2008). Many tasks in school involve instructions in several steps. For example the instruction to color the first flower on the paper red, then color every third flower red and all other flowers blue. Children with poor working memory often fail to remember all steps of such instructions and fail to complete the task. This in combination with poor academic skills lead to difficulties in monitoring the quality of work performed.

Computerized working memory training

In recent years several studies on WMT have been published, although only three of these studies examined effects of such training on children diagnosed with ADHD. A first preliminary, double-blind, non-randomized study (Klingberg, Forssberg, & Westerberg, 2002) showed promising results. The children participating in the study were between 7 and 15 years of age. Children placed in the treatment group (n=7) trained with a computerized training program consisting of four different tasks: three tasks taxing on different aspects of working memory (span-board, letter-span and backwards digit-span) and a choice reaction time task (a mixture between a reaction-time task and a go/no-go task). The children in the treatment group trained for approximately 25 minutes per day on a total of 24.3 occasions on average distributed over five to six weeks. It is unclear whether the children trained at home, in school or at another location. A key feature of the computer program given to the children in the training group was that the difficulty level (number of presented items) of the training constantly and automatically changed based on performance on prior training rounds. Therefore the training was always performed in proximity of the individual child's maximum working memory capacity. The control group (n=7) were given a very similar computer program without the key feature of adjusting difficulty levels. In the placebo version of the program, training remained on the initial low level with two or three stimuli to remember on the different tasks during the entire training period. A flaw of this early study was that the children in the control group's daily training (less than 10 minutes) didn't nearly match the time the children in the treatment group spent on training. However the results indicated that difficulty-adapted training could be used to improve visuo-spatial working memory (span-board), non-verbal complex reasoning (Raven's Progressive Matrices) and inhibition (accuracy on the Stroop task). Difficulty-adapted training also led to a reduction of number of head movements.

The findings from the preliminary study were replicated in a later double-blind, randomized study (Klingberg, et al., 2005) with a greater number of participants (n=44 completers). Although the design of the study resembled the design of the preliminary study it differed in certain aspects. Firstly, inclusion/exclusion criteria were different. The age span of the participating children was smaller (between 7 and 12); medication with psychoactive drugs was not accepted, etc. Secondly, certain adjustments had been made to the WMT program. It now consisted of a greater number of solely verbal and visuospatial working memory tasks. Thirdly, participants completed more tasks per day (90) and trained for a longer period of time each day (about 40 minutes). Mean number of training days was 25.2 (sd=2.2) in the treatment group and 26.6 (sd=2.6) in the comparison group. As in the earlier study, the control group trained with a non- difficulty-adjusted version of the same program as the training group used. Fourthly, new outcome measures (digit span and Conner's Parent and Teacher Rating Scales) were added to the ones in the preliminary study. Fifthly, the later study contained three assessment points (pre-, post- and follow-up at three months) instead of two as in the earlier study. All significant results from the preliminary study were replicated except the observed decrease of head movements, which was non-significant in the later study. Furthermore the later study reported significant treatment effects on verbal working memory (digit span) and parent ratings of ADHD-typical behavior.

In the third published study (Holmes, Gathercole, Place, Dunning, Hilton, & Elliott, 2009) examining the effect of computerized WMT on children with ADHD, focus was turned to the issue of co-occurring medication. The age span of the participating children (n=25) was 8-11 years. All participating children were on either some form of methylphenidate or dexamphetamine medication. The procedure was as follows: first all children were assessed with neuropsychological tests while off medication (stopping at least 24 hours prior to assessment). Then the children were tested a second time on their usual medication. The training period started after the second assessment. The computerized WMT program used was in this case essentially the same as used by Klingberg, et al. (2005). The children then trained for an average of 23.72 days over a period of between 6 and 10 weeks in school. The children completed 115 trials split across different tasks on each training occasion. All participants were then assessed post-training and at 6-month follow up. No control group existed in this study. Working memory was measured using the Automated Working Memory Assessment and performance and verbal IQ was measured using the Wechsler Abbreviated Scales of Intelligence. Significant treatment effects were found for both WMT and medication. The WMT led to improvements in all measured aspects of working memory. The results also indicated that the effects were maintained 6 months after training in three out of the four measured aspects of working memory (not verbal short-term memory). No effects were found on the measures of verbal and performance IQ.

A fourth unpublished study (Lucas, et al., 2008) was presented at the meeting of the American Psychiatric Association in May 2008. The study compared the effects of visuo-spatial and verbal WMT on a group of 46 children attending a summer camp for children with ADHD diagnosis. Results indicated that visuo-spatial WMT was superior to verbal WMT and that visuo-spatial WMT led to greater gains in working memory capacity and positive outcomes on behaviors as measured by a reward system used in the camp the children were attending.

Other studies concerned with computerized cognitive training have focused on non- ADHD patient groups and/or other forms of interventions. Holmes, Gathercole and Dunning (2009) investigated whether children with impairments in working memory would gain from the same sort of training as described by Klingberg et al. (2005). The children that trained with the difficulty-adapted working memory program showed improvements in all aspects of working memory and the ability to follow instructions at post-training assessment. All gains except in verbal short-term memory were maintained at a 6 months follow-up assessment. Moreover mathematical reasoning was improved at the follow-up.

The effects of computerized visuo-spatial WMT and inhibition training on a group of preschoolers have also been investigated (Thorell, Lindqvist, Bergman, Bohlin, & Klingberg, 2008). WMT, but not inhibition training, showed effects on non-trained working memory tasks.

The same kind of WMT as described by Klingberg et al. (2005) has also been tried out on adults having suffered from a stroke (Westerberg, et al., 2007). The authors concluded that adaptive WMT led to improvements in working memory, attention and the subjective experience of cognitive functioning in everyday life in the examined population. Different kinds of computerized WMT programs have also been showed to improve performance on non-trained working memory tasks in old age (Li, Schmiedek, Huxhold, Smith, Lindenberg, & Röcke, 2008; Buschkuehl, et al., 2008) and lead to a maintenance of effects on trained tasks for as longs as 18 months after training (Dahlin, Nyberg, Bäckman, & Stigsdotter Neely, 2008) Jaeggi, Buschkuel, Jonides, and Perrig (2008) have studied the effects of a different cognitive training program (based on the *n*-back task) that also contained the key feature of adaptation of difficulty level based on prior performance. In their study healthy adults were subjected to a series of two sets of simultaneous stimuli: letters (auditory) and spatial locations marked on a computer screen (visuo-spatial). The participants were to decide if the combination of auditory and visuo-spatial stimuli had occurred on a specific position earlier in the series of parallel stimuli. Training with this alternative version of adapted WMT led to an improvement of working memory and fluid intelligence. An interesting finding was that the effects of training appeared to be dose specific; that is, more training resulted in bigger gains.

Another kind of computerized cognitive intervention that has commonalities to computerized WMT is computerized attentional training. Computerized training of attention has been associated with improvements in reading comprehension, passage copying and parents rating of inattention in children with ADHD (Shalev, Tsal, & Mevorach, 2007) and executive attention and intelligence in normal 4 and 6 year old children (Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005). Both interventions contained some sort of adaptation of difficulty-level.

The Swedish Council on Technology Assessment in Health Care (SBU) recently published a review on scientific studies concerning computerized WMT and its effects on ADHD-symptoms. SBU stated that the number of scientific studies on computerized WMT was insufficient to draw conclusions on whether the intervention could decrease ADHD-symptoms or not. Several studies were excluded because they did not investigate the ADHD-population or did not meet criteria for scientific design according to the SBU-principles (SBU Alert, 2009).

Evidence in support of computerized WMT being capable of improving actual working memory capacity is growing. However the existence of transfer effects is more uncertain. As stated above there are indications that computerized WMT may lead to improvements in complex reasoning, inhibition (Klingberg, Forssberg, & Westerberg, 2002) and reductions of inattentive and hyperactive/impulsive behavior as rated by a parent (Klingberg, et al., 2005) in children with ADHD. These findings have so far not been replicated in other studies with participants fulfilling diagnostic criteria for ADHD.

It is a reasonable conclusion that more research needs to be done on the subject of computerized WMT in children with ADHD. The research referred to above lends many implications for which questions the present paper and future research should focus on. It is noteworthy that a substantial part of the studies uses slightly modified versions of the exact same computer program. It is difficult to conclude which aspects of the computerized training programs are necessary in order to improve working memory. One reasonable hypothesis is that the adaption of difficulty is a key feature of any computerized cognitive training program. One weakness of the entire body of research to date is the diversity in inclusion and exclusion criteria.

The aim of this study

The general aim of this study was to further explore the effects of WMT in children with ADHD. The participating children were randomized to 25 days of either computerized WMT (experiment condition) or computerized RT (control condition). The computerized RT was chosen as control condition in the present study since it was believed to be less tedious for the participants than the non-adaptive versions of the WMT that has sometimes been used as a control condition in previous studies (Klingberg, et al., 2005; Holmes, Gathercole, & Dunning, 2009; Klingberg, Forssberg, & Westerberg, 2002). The RT was also believed to be a more active control condition than the non-adaptive WMT, possibly affecting scholastic skills such as word - and letter decoding in a positive direction.

The ADHD population was of particular interest considering the previous promising results of WMT and the connections between ADHD and poor working memory. The high prevalence of ADHD, the difficulties associated with the disorder, the flaws of some of the frequent forms of treatment and the fact that ADHD does not automatically dissolve itself in adulthood constitute strong arguments for developing additional treatments for the disorder.

Improvements of working memory could be expected to have positive effects on episodic memory and verbal learning, not by improving the long-term store per se, but by optimizing initial processing and encoding of information. The connection between working memory capacity and mathematical performance and reading also makes it probable that WMT could lead to improvements in these areas. If working memory can be considered a fundament for more complex, goal-directed behavior, as suggested by Barkley (1997), then WMT should also have an effect on behavioral symptoms.

The tests chosen as outcome measures were meant to assess the above mentioned problems associated with ADHD, namely working memory deficits, poor scholastic skills and behavioral symptoms. Tests were assessed in a preliminary evaluation study prior to the recruitment of participants in the actual study.

Selection of participants was made striving for a high ecological validity. Therefore common comorbid disorders or stimulant medication were not considered as exclusion criteria.

Three hypotheses were tested in the present study:
1. WMT improves working memory capacity in children with ADHD.
2. WMT improves scholastic skills in children with ADHD.
3. WMT decreases diagnostic symptoms in children with ADHD.

METHOD

The present study was approved by the regional ethical review board in Stockholm. All participating children were informed about the voluntary nature of the study, that all research data would be treated with confidentiality and that they were free to terminate participation at any given time. Written consent was obtained from all participating parents and children.

Participants

38 potential participants were screened on telephone and 32 met the inclusion/exclusion criteria (Table 1, Figure 2). The participating families were instructed to bring summaries of neuropsychological assessments, stating the children's DSM-IV diagnosis. All reported diagnoses were based on these summaries. SNAP parent ratings (see Outcome measures) were used to assess current symptomatology. Since most children were on medication, the SNAP ratings were not thought to reflect the actual degree of difficulties concerning inattention and/or hyperactivity/impulsivity and the SNAP scores were thus not used in the inclusion/exclusion procedure. Despite medication, the majority of participants (n=25) were rated above the cut-off value for the combined subscale (≥1.67). Of the remaining 7 participants, 3 were rated above the cut-off value for the inattention subscale (≥1.78), 2 for the hyperactive/impulsive subscale (≥1.44) and 2 were not rated above any of the cut-off values. The cut-off values were recently validated in a study of the psychometric properties and normative values of the SNAP scale (Bussing, et al., 2008).

The inclusion criteria were: 1. ADHD-diagnosis (including all three different subtypes and Hyperkinetic disorder). 2. Year of birth 1999-2003. 3. Access to PC computer at home. The exclusion criteria were, 1. Previous structured computerized cognitive training for more than five days. 2. Mental retardation diagnosis. 3. Autism diagnosis (Asperger syndrome and pervasive developmental disorder were not considered as exclusion criteria). 4. Change of dose, or starting use of Methylphenidate, Atomoxetine and/or Prometazin five weeks before the trial and until the end of the study.

Table 1. Participant characteristics.*

	WMT	RT	Total
Boys	7 (6)	11 (3)	18 (9)
Girls	1 (1)	2 (1)	3 (2)
ADHD combined	8 (7)	11 (3)	19 (10)
ADHD inattentive	0 (0)	1 (1)	1 (1)
Hyperkinetic disorder unspecified	0 (0)	1 (0)	1 (0)
Aspergers syndrome	1 (0)	1 (0)	2 (0)
Pervasive developmental disorder NOS	0 (1)	1 (0)	1 (1)
Developmental coordination disorder	1 (0)	2 (0)	3 (0)
Tourette's syndrome	2 (0)	0 (0)	2 (0)
Phonological & grammatical LI	1 (0)	0 (0)	1 (0)
Methylphenidate	6 (4)	7 (2)	13 (6)
Atomoxetine	1 (0)	2 (2)	3 (2)
Mean age, years	8.25 (8.75)	8.75 (9)	8.50 (8.83)
Mean time passed since diagnosis, years	1.51 (2.31)	1.87 (0.58)	1.73 (1.68)
Computer use, hours per week (m)	5.94 (7.93)	7.81 (11.75)	7.10 (9.32)

*Data for completers (to the left) and for drop-outs (within parentheses).

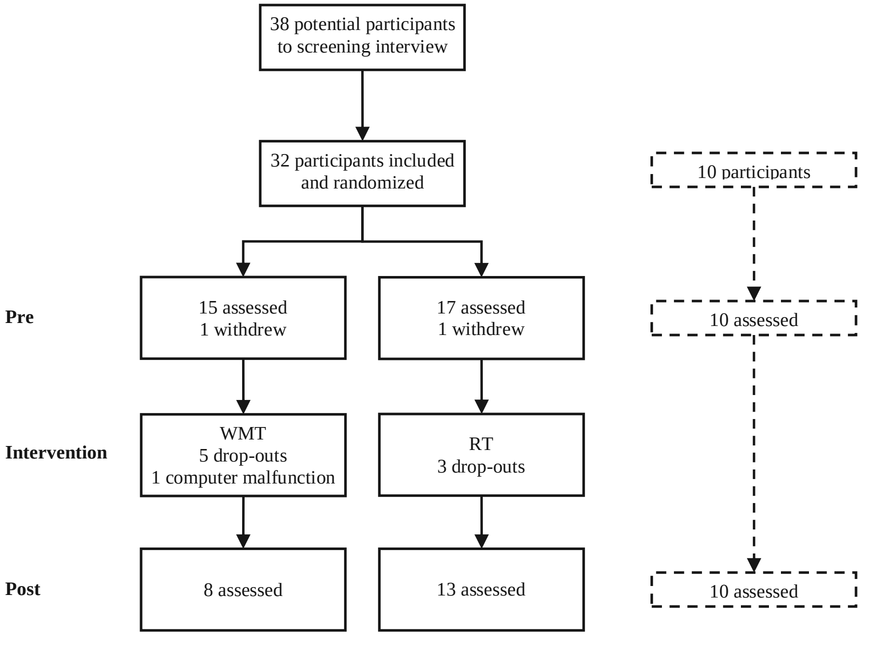


Figure 2. Design of the study and flow of participants throughout the study. Dotted boxes represent the preliminary evaluation of outcome measures.

Recruitment

Children were recruited through an ADHD-specialized information center, a national support group for neuropsychological disorders, elementary schools and children's psychiatric clinics. Information regarding the study was sent via mail to all parents that were enlisted at the ADHD-specialized information center and who had children in the target age group. The letter contained a short description of the study and contact information for getting more information concerning the project. The same letter was also placed in waiting-rooms at the children's psychiatry clinics and was sent from schools to potential participants parents. Finally, informat ion was posted on the webpage of the above mentioned national support group for parents of children with neuropsychological disorders. The parents were instructed to contact the instigators of the study for further information.

Procedure

Each parent who contacted the instigators of the study and whose child was considered to be a possible participant was screened for inclusion/exclusion criteria in a structured telephone interview. Parents whose children were included in the study were asked to keep dosing of their childrens' medication stable until post testing and not to start any new medication until after post assessment. The included participants were randomized to a WMT group (n=15) and a RT group (n=17). Each child was assessed pre-training (m=5.5 days pre-training, sd=2.8) and parents participated in one hour of education in adjunction to the first assessment. A 5 to 8 week long period of computerized training started within one week after the first assessment. Post-training assessment followed as soon as possible after completed training (m=5.8 days after training, sd=4.0). See Figure 2 for a schematic overview of the design of the study.

Each child was randomized to be assessed by one of two assessors. The assessors were graduate clinical psychology students. Pre- and post-testing for each child was conducted by the same assessor in order to control for effects of the relation between administrator and child. The assessors had previously trained in administering all the outcome measures on a total of ten occasions each with five undiagnosed, nine year old children, at an elementary school.

One hour was dedicated for each assessment. While the children were assessed the parents filled out two rating scales in a waiting-room. At the first assessment parents also filled out a form with background data. Children were scheduled to test at the same time of the day at all assessments to control for medication effects and circadian rhythm. The tests were performed in a quiet room with only the child and the assessor present. At a specified point in the assessment a small break was planned. During the break the assessor and the participating child stayed in the testing room. The assessments lasted in average 33 minutes (sd=4.1) At the second assessment parents and children were instructed not to give information to the assessors regarding what type of training program that was used to ensure that the assessors were blind to which form of training the child participated in. After each assessment parents were given a teacher rating scale for the child's primary teacher to fill out in school. The rating was then brought to the next assessment.

Evaluation of outcome measures

Preliminary evaluation of the outcome measures was conducted at an elementary school with a group of 9-year old children (n=10). All children attended the same class and were selected to participate by their primary teacher. The teacher was instructed to only select children without a documented neuropsychiatric diagnosis. The children were assessed at their school on two separate occasions with 5 weeks in-between. All parallel versions of the tests were used in the evaluation and no child was assessed with the same version on pre- and post-assessment. The evaluation served two purposes: Firstly to train the assessors on administration procedures and secondly to investigate test-retest effects and statistical characteristics of the outcome measures. Based upon this evaluation the primary outcome measure on the word span task was altered from maximum correct words in a series to total number of correct trials since the childrens' results on maximum correct words in a series were too homogenous. Block-tapping was replaced with a computerized span-board task, primarily to standardize test administration. The other tests used in the evaluation were the same as in the final study. No parent or teacher ratings were administered. Paired samples t-tests revealed that there were no significant differences between mean results at pre- and post- assessment on any of the outcome measures, except Letter-chains and Word-chains (see Table 2). The children participating in the evaluation of the outcome measures completed significantly more chains on Letter- and Word-chains at the second assessment than at the first.

Table 2. Mean values, standard deviations and t-values on paired samples t-test of the first and second assessment in the outcome measures evaluation.

	Pre m	sd	Post m	sd	T-test t_9
AVLT words reproduced	44.3	9.72	44.8	7.60	-.885
AVLT delayed recall percent recollected	86.2	24.7	78.2	20.3	1.02
Word span max. words recollected	3.90	.738	4.00	.667	-.361
Word span correct trials	4.90	1.45	5.00	1.05	-.176
Arithmetic highest level achieved	11.5	2.88	12.1	1.73	-.627
Letter-chains correct chains	30.5	4.99	36.1	4.12	-5.59*
Word-chains correct chains	25.2	6.48	29.8	6.58	-4.01*

*p<0.01

Outcome measures

The order in which the tests were administered was the same for pre- and post-intervention assessment. The intention for a set order was to control for such factors as tiring during testing and getting approximately the same amount of time between the verbal learning test (AVLT) and the delayed recall. The administration order of the tests was: 1. AVLT. 2. Span-board. 3. Arithmetic. 4. Word span. 5. Letter-chains. 6. Word- chains. 7. AVLT delayed recall. Parallel, similar but on certain key-features different, versions were created for some of the tests – (a), (b), (c), and (d) – in order to minimize test-retest effects. Randomization determined which of the parallel versions the participants were to complete at each assessment point, so that the effect of possible variations in the degrees of difficulty of the parallel versions of tests (a-d) was reduced.

Working memory

(a) A computerized span-board task was used to measure visuo-spatial short term memory. Red dots were presented in sequences in a four-by-four grid. After each sequence was finished the child was to reproduce the sequence by using the computer mouse and clicking in the same squares and in the same order that the red dots had appeared. Initially two different sequences consisting of two dots were presented as a trial round. Then two sequences consisting of two dots, two sequences with three dots and so forth were presented. The test was discontinued when the child failed to reproduce two sequences on the same level of difficulty. The interstimulus time for this test was set for 750 ms and the red dots appeared on the screen for 2250 ms. The outcome measure for the span-board task was total number of correct clicks.

(b) A word span task was administered in order to measure verbal working memory. This test is a variant of the Digit Span subtest from WISC-III (Wechsler, 1991) in which the test person is to repeat a serious of nouns instead of numbers. The test was constructed as described in Thorell and Wåhlstedt (2006), but only using the backward condition. As with the AVLT-adaptation described above three separate versions of the test were constructed. Each wordlist usedthe same set of monosyllabic Swedish nouns, but the words were randomized in different orders for each version. The nouns were recorded by the same person as in the AVLT in wav-files, which were then played for the child through headphones with 1000 ms interstimulus time. At first the child was to repeat 2 words in a reversed order 2 times, then 3 three words 2 times and so on. The test was discontinued when the child failed both trials on the same difficulty level. Number of correctly repeated trials was the outcome measure for the word span task.

Scholastic skills

(c) Verbal learning was assessed using the Auditory Verbal Learning Test (AVLT; Lezak, 1995). Three parallel wordlists with 15 frequently occurring Swedish nouns in each was created. Each child was tested with a different word list on each test occasion. All 45 words were recorded in wav-files by a person who otherwise didn't participate in the study. The child was instructed to put on headphones before the test started. The words were then played with 1000 ms interstimulus time. The administration of the test differed somewhat from the standard administration of the AVLT. The word span task (b) was considered to be a sufficient interference and therefore only one wordlist was used in the AVLT per assessment. The outcome measure of the AVLT was total number of correctly reproduced words over the 5 trials.

(d) An arithmetic test was constructed according to the same pattern as the subtest Arithmetic from WISC-III (Wechsler, 1991). The test was used in order to assess mathematical reasoning and applied verbal working memory (remembering the question asked while simultaneously working on the solution). All questions were administered verbally without any visual support available. Three parallel versions of this t est were created. Numbers were slightly changed between each parallel version of every question, with caution in order not to change the difficulty-level. Nouns were also replaced so that parallel questions seemed more different. An example of two parallel versions of a question was: "How many are 4 pencils and 5 pencils together?", and "How many are 3 rubbers and 4 rubbers together?" The questions were ordered in ascending difficulty level. The outcome measure of the arithmetic test was the number of the most difficult question solved.

(e) Letter-chains (Bokstavskedjor) from Reading-chains (Läskedjor; Jacobson, 2001) was intended to measure letter decoding speed. In this task the child was to visually search chains of letters (e.g. AEKKFJEEN) for letter repetitions (e.g. KK) and to draw a line between the letters in every occurring letter pair. The child was to finish as many letter-chains as possible during two minutes. The measurement in this test was the total number of chains with correctly drawn lines.

(f) Word-chains (Ordkedjor) from Reading-chains (Jacobson, 2001) was used to assess word-decoding ability. In this task the children were instructed to scan chains consisting of 3 words of 2-4 letters each (e.g. catballmum) and then draw lines where one word ended and the next started. The child was to finish as many word-chains as possible in 2 minutes time and the total number of chains with correctly drawn lines were then counted and used as the outcome measure of the test.

(g) Storage and retrieval of episodic memories was measured by dividing the maximum number of recollected words in a single trial with the number of correctly recollected words on the delayed recall part of the AVLT (Lezak, 1995).

Diagnostic symptoms

(h) SNAP Parents and Teachers Rating Scale (Swanson, et al., 2006) was used in order to assess ADHD-symptoms as described in the DSM-IV (American Psychiatric Association, 1994). The Swedish version of SNAP was obtained from the national registry of treatment evaluation for ADHD (Swanson, n.d.). Parents and teachers were to rate 18 statements concerning the child on a 4-point Likert scale, from 0 ("Not at all") to 3 ("Very much"). High ratings reflect presence of hyperactivity/impulsivity and inattention. The outcome measures were the total sum of the nine items concerning inattention and the total sum of the nine items concerning hyperactivity/impulsivity.

(i) Leiter-R Parents Rating Scale (Roid & Miller, 2001) was used to assess other aspects of behavioral symptoms relating to ADHD. The scale consisted of 8 subscales constituting 2 composite scales with a total of 51 items. Each item consisted of descriptions of 2 opposing behaviors and the parents were to choose if either of the behaviors were more typical for their child or if both behaviors were common. Low scores reflect difficulties. The first composite scale (Cognitive/Social) consisted of the 4 subscales Attention, Level of Activity, Impulsivity and Social Ability. The second composite scale Emotions/Regulation consisted of the 4 subscales Adaptation, Mood and Self-confidence, Energy and Emotions and Sensibility and Self-regulation. The outcome measures were the raw score on the Cognitive/Social composite scale and the attention subscale.

Trained tasks

(j) The parents of the participants in the RT group were instructed to copy the number of attempts and correct responses from the computer software for each trial executed during training. The total number of correct responses was then divided by the total number of attempts in the first and last 5 days of training respectively. In order to assess changes in the performance on the trained tasks in the RT condition the resulting ratios were compared.

(k) Maximum number of recollected items forwards and backwards for each trained task was registered in the computer software. Since the number of tasks backwards differed somewhat between participants, no calculations were made on the backward tasks. Mean values on all forward tasks in the first and last 5 days of training were computed and used to measure effects on the trained tasks in the WMT condition.

Interventions

At least one parent of each participating child was required to attend one hour of education where instructions for using the different computer programs were presented. The educational meeting also included instructions for how to administer rewards for completed training weeks, how to coach the child and give feedback during training, and how to register training on a training schedule. The education was conducted by a certified psychologist, who is one of the designers of the programs. Separate but similar educations were given depending on which group the parent's child was randomized to, for two reasons. The first to keep the parents blind regarding what intervention the other group received and the second that information specific for each program was given.

Both training interventions were performed at home with the child and parent training together. The training was scheduled to last 5 days a week, 5 consecutive weeks. At least 20 days of training during a period of at the most 8 weeks was a requirement for final inclusion in the study. Each parent was phoned 2 times during training by the certified psychologist who was in charge of the educations, to follow up on the process of training and to answer questions if the parents had any.

Both training interventions included a reward-system external to the training programs. Each parent was to decide a suitable reward for each completed week of training to increase compliance and motivation in the children.

Working memory training

The children in the WMT group used Memory Games Senior (Läramera Program AB; Leripa AB; Kognitiva Kompaniet AB, 2008), a computer program designed for training working memory according to the same basic principles as other working memory programs that have shown positive effects on working memory (Backman & Truedsson, 2008; Holmes, Gathercole, & Dunning, 2009; Klingberg, et al., 2005; Thorell, Lindqvist, Bergman, Bohlin, & Klingberg, 2008).

The program contained 9 tasks that were to be completed on each day of training. The number of trials per task was 10. Average training time was 44.3 minutes (sd=10.6) per training day. The general objective of the training tasks was to memorize and reproduce the order of a number of presented items. The tasks differed in lay-out, type of items presented, if the items were presented visually or verbally and if the items were visible during presentation. The item presentation order was randomized in all tasks. The difficulty of all tasks was continuously adapted depending on the child s performance. After a set number of correct responses the items to be remembered increased. The levels were also adjusted down if a set number of incorrect responses were made. The purpose of this adaptation was to constantly maximize the load on working memory. If the child reached a certain level of difficulty the child was instead required to click on the items in reverse order. The reverse condition applied to about half of the exercises.

In tasks 1, 2 and 3 the items presented were visual on screen (fish blowing bubbles, lamps blinking and Egyptian symbols being marked). Each task had only 1 sound corresponding to all items in the task. Sequence memorization based on sound was therefore not possible. In tasks 4 and 5 items (letters and colors) were presented verbally while not visible on screen. Immediately after presentation, visual items equivalent to the verbally presented stimuli and distractors appeared on the screen. The sixth task consisted of a piano playing random melodies. The keys moved as the melodies were played and the keys had letters representing the tones written on them. Task 7 contained verbally presented letters and digits in alternate order (see Figure 3). The object of the task was to recall the letters first in correct order, and then the digits in correct order, requiring the child to sort the presented stimuli into categories before recalling them, while at the same time keeping track of the positions of each item. Tasks 8 (see Figure 3) and 9 contained visual items that each had a unique sound (i.e. a lion roaring, a pianist playing the piano). In the eighth task the items had fixed positions on screen and in the ninth exercise localization were randomized.

Figure 3. Screen shots from task 7 (to the left) and task 8 (to the right).

Feedback was included in the program in several forms. After each correct response an encouraging voice gave the child a positive comment, and after an incorrect response the child was encouraged to keep trying. Each training day after the nine tasks were completed the child was allowed to play a computer game included in the program for approximately 5-10 minutes as a reward. Each correct click in the training gave one point and the points were then converted to lives used in the reward game. The program also kept track of the best results in both the reward game and on each task and biggest improvements on a single task for each day of training to further facilitate motivation.

A log-book was used which contained a schedule for the external rewards, some information about WMT and an overview for each week of training where the best results and improvements for each day of training were to be entered. Also a training schedule was used where the time of training for each day, and on what dates the training took place were to be entered. Detailed results were also stored in a file in the computer program. To make sure all necessary information was provided a checklist was used guiding through all steps that were required to be taken on each day of training.

Reading training

The children in the RT group used Reading World (Läramera Program AB; Leripa AB, 2003), a program designed for language and literacy development. The program consisted of 21 exercises divided into three categories: Practice Whole Words, Practice Letters and Build Words.

Practice Whole Words consisted of 6 different exercises, in which the child was to practice for example sorting words in alphabetical order (see Figure 4), matching a word to the right picture amongst a number of pictures, and matching a picture to the correct word.

Practice Letters contained 6 different exercises that allowed the child to practice for example selecting a picture amongst three where the first letter of the selected picture matches a letter presented above the pictures, finding the correct letter on the keyboard when a letter is presented on the screen (see Figure 4) and sorting letters in a scrambled word to form the correct word.

Build Words consisted of 9 different exercises that required the child to practice for example puzzling together words from separated and scrambled syllables, building a word letter by letter and figuring out what letters are included in a word.

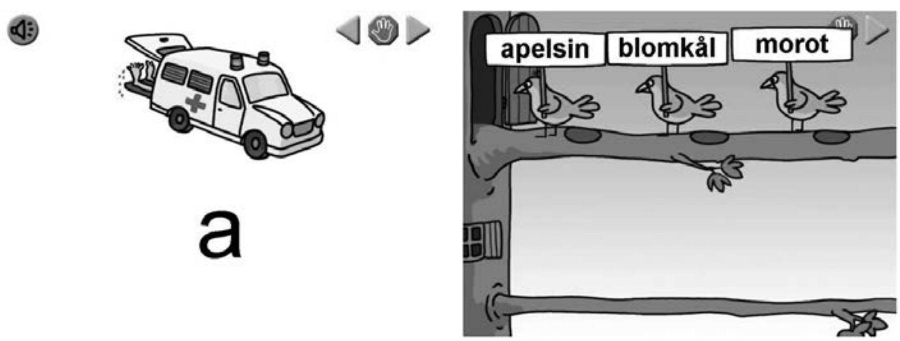


Figure 4. Screen shots from a task in the Practice Letters category (to the left) and a task in the Practice Whole Words category (to the right).

Wordlists of about 400 different words were included in the program and were used in all of the exercises. Feedback was included in Reading World in slightly different forms. Correct responding was followed by an encouraging melody and incorrect responding resulted in a toot-like sound.

The participants randomized to the RT were instructed to undertake one exercise from the Practice Whole Words category, one exercise from the Practice Letters category and two exercises from the Build Words category for about 5 minutes per exercise and training day. Average training time was 25.3 minutes (sd=6.2) per training day.

To keep track of the training, a schedule was used where time for training, what dates training took place and results on the different exercises were to be entered day by day. A separate form was used to keep track of the external rewards. To make sure all necessary information was provided a checklist was used guiding through all steps that were required to be taken on each day of training.

The control condition in the present study was meant to resemble the WMT condition in several aspects without specifically training working memory. Both computer programs used were made by the same illustrator, pedagogue and programmer. They were commercially available and used in Swedish elementary schools at the time of the study. The programs were not adapted from the original commercially available versions for the purpose of this study. RT was also chosen because reading disabilities is a commonly occurring problem in the ADHD population. Therefore it was assumed that RT would have high face validity, and that parents and children would be motivated to complete training. The intent was for both interventions to be perceived as active treatments for all participants.

Statistical analysis

One-tailed paired samples t-tests were performed for all tests and rating scales comparing pre- and post-intervention scores in the WMT and RT group separately. Delta-values were calculated by subtracting the pre-intervention score from the post- intervention score. One-tailed independent samples t-tests were performed comparing the delta-values between the WMT and RT condition. The choice of one-tailed t-tests was made in accordance with the hypothesis of the study and based upon results from previous studies. There is nothing that indicates that WMT could have adverse effects on any of the outcome measures.

In order to investigate differences on the trained task, one-tailed paired samples t-tests were performed comparing results on the first and last 5 days of training. Results on the first 5 days of training were then subtracted from results on the last 5 days of training in order to obtain delta-values. Results on the trained tasks were ranked based upon scores on the first 5 days of training and divided into top half and bottom half in each condition. One-tailed independent samples t-tests were performed comparing the delta values of the top and bottom half in each condition separately. Results on the trained tasks were investigated to assess if possible effects on tests and rating scales were linked to improvements on the trained tasks.

Z-scores were calculated on all tests and rating scales with tendencies or significant differences within or between groups. Raw mean of pre-intervention assessments were used as an estimate of the populations mean.

Table 3. Outcome measures at pre- and post-intervention assessment.

	n	Pre m (sd)	Post m (sd)	Pre-post t-test[a]	Delta t-test[b]
AVLT words reproduced					
WMT	8	33.8 (4.98)	37.3 (11.1)	-.911	-.695
RT	13	35.8 (9.10)	36.8 (11.2)	-.632	
Span-board correct clicks					
WMT	7	22.9 (12.0)	32.9 (13.4)	-1.81[d]	-1.56[d]
RT	13	17.8 (13.1)	18.7 (16.0)	-.553	
Span-board reaction time[c]					
WMT	7	535 (97.4)	537 (79.0)	-.047	-.036
RT	13	520 (105)	520 (92.3)	.007	
Arithmetic highest level achieved					
WMT	8	7.63 (4.21)	10.0 (3.38)	-2.30*	-2.04*
RT	13	8.53 (4.84)	8.53 (3.73)	.000	
Word span task correct trials					
WMT	8	3.13 (.354)	4.00 (1.20)	-2.20*	-1.86*
RT	13	3.08 (.954)	3.08 (1.50)	.000	
Letter-chains correct chains					
WMT	8	25.3 (9.51)	30.6 (13.2)	-2.47*	.361
RT	13	25.5 (10.6)	31.7 (10.7)	-5.87**	
Word-chains correct chains					
WMT	7	12.9 (7.82)	17.0 (9.68)	-4.10**	-.537
RT	10	15.1 (10.6)	18.3 (12.6)	-2.50*	
AVLT delayed recall percent recollected					
WMT	8	75.4 (20.6)	66.7 (11.8)	1.35	.636
RT	13	76.3 (22.2)	73.7 (25.0)	.376	
SNAP parent hyperactivity/impulsivity					
WMT	8	16.1 (2.47)	12.5 (3.74)	2.83*	.984
RT	12	16.4 (5.33)	14.9 (6.30)	.977	
SNAP parent inattention					
WMT	8	14.5 (5.48)	11.7 (3.58)	2.71*	.000
RT	12	18.1 (4.14)	15.3 (3.45)	1.61[d]	
SNAP teacher hyperactivity/impulsivity					
WMT	5	11.2 (8.56)	13.4 (7.47)	-1.28	-.176
RT	8	12.1 (7.62)	13.9 (9.78)	-1.03	
SNAP teacher inattention					
WMT	5	14.6 (3.91)	14.2 (4.92)	.266	.671
RT	8	15.6 (6.90)	17.0 (8.18)	-.743	
LEITER-R attention					
WMT	8	17.6 (3.74)	18.9 (3.18)	-1.67[d]	.302
RT	12	14.7 (3.17)	16.3 (3.14)	-1.66[d]	
LEITER-R cognitive/social					
WMT	8	48.8 (7.32)	51.9 (4.58)	-1.82[d]	-.248
RT	10	44.4 (7.28)	46.8 (6.30)	-1.08	

[a]Paired samples t-tests comparing means at pre- and post-intervention assessment (one-tailed).
[b]Independent samples t-tests comparing the pre-post change (delta) in the WMT condition with the pre-post change in the RT condition (one-tailed).
[c]Milliseconds.
[d]p<.1
*p<.05
**p<.01

RESULTS

Some of the statistical analyses were calculated with less than the maximum observed values. The data was lost due to different reasons. A few (n=4) of the participators could not read or refused to execute Word-chains and values for 1 participant on the span-board task was lost due to computer malfunction. A number of parents (n=2) failed to fill out some of the items in Leiter-R and 1 parent failed to fill out the SNAP and Leiter-R rating scales. A number of teachers (n=8) did not fill out or return the SNAP rating scale.

To investigate possible dissimilarities between the WMT and RT groups, independent samples t-tests with all outcome measures, average computer use per week, age, number of days of training and total number of days between first and last day of training as dependent variables and type of intervention as independent variable was performed. Fisher s exact test was performed for type of ADHD-diagnosis, all co-morbid disorders, medication, gender and special support in school. No statistically significant differences were found on any of the background variables or pre-intervention assessment scores.

Raw data for all tests and rating scales and t-scores for all t-tests are presented in Table 3. Z-scores are presented in Figures 6-8. Table 4 contains data for the trained tasks.

Hypothesis 1: WMT improves working memory capacity in children with ADHD
The performance of the WMT group increased significantly on the word span task from pre- to post-intervention assessment (see Table 3). The gain of the WMT group was significantly greater than the change in the RT group. The effect size of the difference between the groups on the word span task was calculated using Cohen s delta and was d=0.89. There were no significant improvements in either group on the span-board task, but there was a tendency in favor of WMT, both when comparing number of c licks at pre- and post-intervention assessment and when comparing the improvement of the groups. The effect size of the tendency towards improvement was d=0.80. The results indicate that WMT leads to greater improvements of verbal working memory performance than RT, in part supporting hypothesis 1.

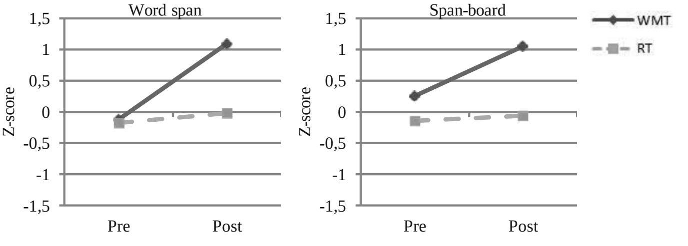


Figure 6. Mean values on tests measuring working memory capacity at pre-training and post-training.

Hypothesis 2: WMT improves scholastic skills in children with ADHD

When comparing mean scores on the arithmetic test at pre- and post-intervention assessment, the WMT group significantly improved, while the RT group scored equally at both assessment points (see Table 3). An analysis of the change of the groups' performances revealed that the WMT group improved significantly more than the RT group (d=0.89). There were no other statistically significant differences between the delta values of the groups on any of the other tests measuring different aspects of scholastic skills. However, both groups significant ly improved on Letter- and Word-chains. In conclusion, WMT lead to significantly greater improvements on mathematical reasoning than RT, thereby lending support to part of hypothesis 2.

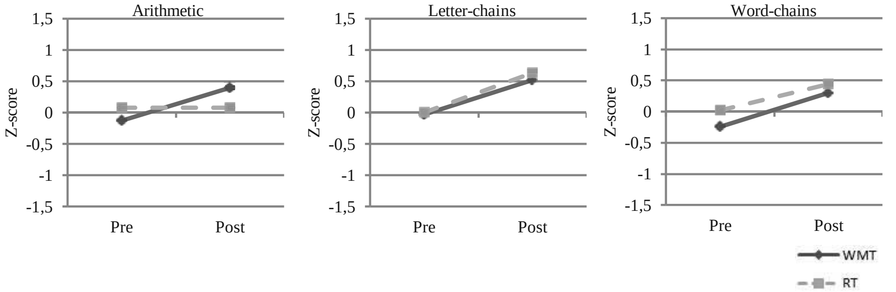


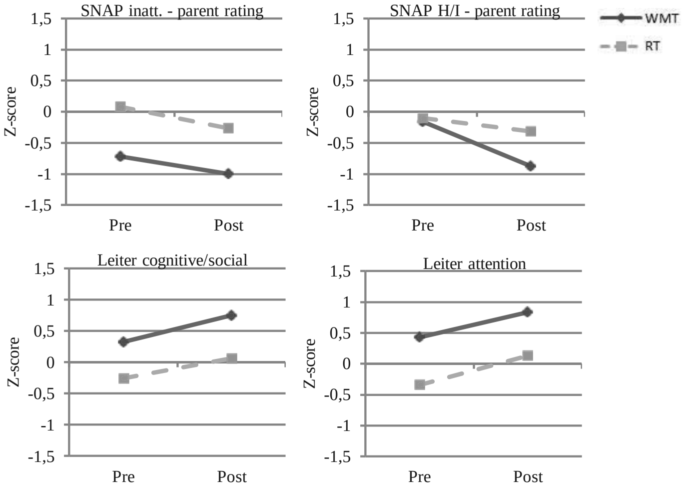
Figure 7. Mean values on tests measuring different aspects of scholastic skills at pre-training and post-training.

Hypothesis 3: WMT decreases diagnostic symptoms in children with ADHD

No significant differences were found between the delta values of the groups on any of the parent or teacher rating scales (see Table 3). The participants in the WMT group were rated by their parents to have a significantly decreased prevalence of behavioral symptoms of both inattention and hyperactivity/ impulsivity as measured by SNAP after the intervention. There were tendencies of symptom reduction in the WMT group on the Leiter-R inattention and cognitive/social scales as well as tendencies of both measures of inattention as rated by parents in the RT group. In summary, hypothesis 3 was not supported in the present study. There was no significant difference between the RT and WMT groups regarding decrease of ADHD-symptoms.

Effects on the trained tasks

The WMT group performed significantly better on the trained tasks during the last 5 days of training compared to the first 5 days of training (see Table 4). There were no significant differences on the mean improvement of results on the trained tasks when comparing the top and bottom half of the WMT group. However, the bottom half, but not the top half improved significantly. Since no differences between top and bottom half in the WMT group were found, no further statistical analysis on the subgroups were performed. In contrast the



RT **Figure 8. Mean values on parent ratings of behavioral symptoms at pre-training and post-training assessment points. In the SNAP rating, lower scores indicates decrease of symptoms, and in the Leiter rating, higher scores indicates decrease of symptoms.**

group did not generally improve on the trained tasks. The bottom half significantly improved performance on the last 5 days of training compared to the first 5 days of training and the improvement was significantly greater than the top half. Although not statistically significant, the top half somewhat lowered performance on the trained tasks.

Table 4. Results on trained tasks at first and last 5 days of training.

	n	First 5 days m (sd)	Last 5 days m (sd)	Pre-post t-test[a]	Delta t-test[b]
Working memory training					
Maximum items	7	4.87 (.601)	5.71 (.758)	-4.91**	
Top half	3	5.42 (.399)	6.12 (.542)	-2.15[c]	
Bottom half	3 4.	33 (.218)	5.18 (.319)	-3.36*	-.341
Reading training					
Percent correct trials	12	74.2 (2.81)	77.3 (13.0)	-.799	
Top half	6	81.9 (4.43)	77.8 (12.8)	.863	
Bottom half	6	66.6 (6.94)	76.9 (14.5)	-2.23	2.17*

[a] Paired samples t-tests comparing means at pre- and post-intervention assessment (one-tailed).
[b] Independent samples t-tests comparing the pre-post change (delta) in the bottom half with the top half in the WMT condition and in the RT condition (one-tailed).
[c] p<.1
*p<.05
**p<.01

Drop-out analysis

For the participants who withdrew before post-training assessment, a drop-out analysis was conducted. Independent samples t-tests were performed for all outcome measures comparing mean values of completing participants and participants who withdrew showing no statistical differences on any of the outcome measures at pre-intervention assessment.

DISCUSSION

This study explored the effects of adaptive WMT on working memory, scholastic skills, and ADHD-symptomology in children diagnosed with ADHD. An intensive training period, consisting of at least 20 training occasions spread across 5-8 weeks, lead to improvements in verbal working memory and mathematical reasoning.

The most important new finding of this study was the improvements concerning mathematical reasoning. It should be acknowledged that there might be superior measures of arithmetic skills, such as grades or results on national tests but neither was available in the present study. The improvements in mathematical reasoning are of special interest since mathematical disabilities are frequently seen in children with ADHD (Faraone, et al., 1993). Solving verbally presented arithmetic problems involves keeping information in the phonological loop, retrieving arithmetic rules from long term memory and using the information to solve the problem at hand. It is thus reasonable that gains in verbal working memory can lead to improvements in mat hematical reasoning.

The improvements in verbal working memory apparent in the present study is in line with findings in earlier studies of the effects of WMT on ADHD-children (Klingberg, et al., 2005; Holmes, Gathercole, Place, Dunning, Hilton, & Elliott, 2009). Increasing verbal working memory capacity would be helpful for many children with ADHD, since they often display difficulties with following instructions, developing reading skills and other areas involving verbal working memory.

Visuo-spatial working memory did not significantly improve, although the results indicated a tendency for the WMT group to have a larger effect. There are at least three possible explanations for the lack of significant gains in visuo-spatial working memory. Firstly, the span-board task only required forward repetition. It could be argued that forward repetition only includes storing of information and not processing and thus only measures one of the key aspects of working memory. Secondly, although the effect size was large on the span-board task, standard deviations in the groups were substantially unequal and thus no significant effects were seen. When calculating effect size based upon the higher standard deviation of the WMT group, 13 participants in each group would have been needed to ensure statistically significant effects, given that the results would continue in the same direction. A third explanation is that there are no significant differences regarding the gains of the two groups. This third explanation seems unlikely based on the fact that the span-board task is similar to the trained tasks in the WMT group and that the WMT group significantly improved performance on the trained tasks.

It is difficult to say whether improvement of performance on working memory tasks following WMT reflects an actual improvement of working memory capacity or the acquisition of new strategies. The word span task is slightly similar to the task with verbally presented digits in the WMT. It would be hard to reject the notion that effects are merely due to development of new strategies if the improvements were limited to the working memory outcome measures. The fact that the children in the WMT group also improved on the arithmetic test make it less plausible to conclude that strategy development is the only explanation of the improvements. Since improvements were found on tasks similar to those in the WMT intervention and tasks less similar, it is more likely that the improvements are due to actual gains of working memory capacity. Nonetheless even if the improvements could be fully explained by strategy development, these strategies seem applicable in diverse situations and the argument of strategy-development would hardly be in disfavor of WMT. One possible explanation to why training of a specific cognitive function such as working memory can lead to changes in other functions, suggested by Olesen, Westerberg and Klingberg (2004), is that the cortex that is affected by the computerized WMT can be considered multimodal, and thus relating to more than just one cognitive function.

The significant decrease of parent-rated inattentive symptoms of ADHD found in an earlier study (Klingberg, et al., 2005), were not replicated in the present study. The tendency was for both groups to decrease symptoms of inattention, and the WMT group was rated to have significantly less symptoms of hyperactivity and impulsivity at post- intervention assessment than pre-intervention assessment as rated by parents. These results allow different interpretations. It is possible that both the RT and WMT conditions affect ADHD-symptomatology in a positive direction. Also, the parents of all participating children have gained the experience of seeing their children completing a repetitive task on a number of occasions. This could explain the fact that the parents tended to rate their children as more attentive.

It's noteworthy that the arithmetic test is, as most neuropsychological tests, not a measure of one specific cognitive function. Working memory capacity is essential in solving both sorts of tasks. Provided that the child masters the basic rules of arithmetic, the arithmetic test can be considered essentially a test of applied working memory. The child is required to keep the question in the phonological loop while working on solving the problem. The fact that the demands on working memory is much greater concerning the arithmetic test compared to Word-chains, Letter-chains, or AVLT is one possible explanation to the lack of effects on the later tests. Another possible explanation of the non-significant differences between the WMT and RT groups on Reading-chains is that the RT intervention improves the performance on the skills related to performance on the Reading-chains tests. The statistically significant improvement evident in both Letter- and Word-chains in the evaluation of outcome measures indicates that performance is enhanced even without any intervention. Since the participants in the earlier evaluation were undiagnosed, it is difficult to draw any conclusions on whether or not the gains in diagnosed children in the RT and WMT groups were due to test-retest effects or actual improved abilities.

This study had problems with high levels of drop-out. The rate of drop-outs was higher in the WMT group than in the RT group. WMT is an extensive intervention putting high demands on the children as well as the adults supervising the training. There are several possible explanations for children not completing training. For example conflicts between parent and child and lack of endurance could pose problems. In most Swedish families both parents work full time and it can be difficult to find the time needed for training in an already stressful everyday-life. Both the child and the parent supervising the training need to be fully motivated. The WMT program used in this study consisted of only 9 exercises that the child performed on each day of training. Some children may have found the lack of variation tiring.

It is possible that locating WMT to schools, with professional pedagogues functioning as supervisors instead of training with parents at home could diminish drop-outs. When WMT adds to the already high demands of school there is a risk that the total work load will be too much for the child to manage. Professional pedagogues are trained to motivate children and using pedagogues as supervisors would minimize role conflicts that can appear when parents act as supervisors to their own children. The effects on verbal working memory and mathematical reasoning motivate the extra efforts demanded by schools to offer WMT as an option in the school curriculum. Many of the children in this study already receive extra support and attention from pedagogues and school staff who could serve as supervisors for the training. Therefore the economic costs would not necessarily constitute a problem in introducing WMT in school. It is however possible that the rated decreases of ADHD-symptomatology reflect a positive effect of parent-child interaction that would be lost if WMT was located to schools. In one previous study children training both at home and in school were included (Klingberg, et al., 2005). No differences based on training location were found on the outcome measures in the study. Possible connections between drop-out rates and training location and the number of participants training at home and in school was not accounted for. Effects of training location must be further investigated to draw any certain conclusions on where training should be located.

Even though the present study did not aim at explaining the underlying mechanisms of ADHD, the results have implications on ADHD theories. The fact that effects on trained tasks in the WMT condition and gains in verbal working memory did not lead to significantly greater decreases of behavioral symptoms in the WMT condition than in the RT condition, corresponds better to multiple pathways theories of ADHD (Sergeant, 2000; Sonuga-Barke, 2002) than with Barkley's (1997) theory focusing on executive functioning as a primary deficit. If working memory deficits would account for all ADHD symptomatology, larger effects following WMT would be expected.

Since working memory deficits is not evident in all cases of ADHD and since no significant differences were found between the groups concerning reduction of ADHD symptoms, there may be better grounds for selecting WMT participants than the presence of an ADHD diagnosis. It is likely that assessing working memory and offering WMT to those with poor working memory is a better method.

Limits of the study

There are a few limits to this study which are of interest to mention. The first limitation regards experimental control. This study strived for a high ecological validity. The generalizability of the results is considerable since the sample in this study quite well resembles the actual seekers of care for ADHD related problems. The downside of aiming at ecological validity is partial loss of experimental control. All children trained in their home environment and such aspects as distractors, to which degree parents participated in the training and the amount and quality of feedback from the supervising parent during training could thus not be fully controlled. The effects of such aspects as mentioned should be evenly distributed across the interventions and not have any significant effects on the comparison of the groups.

The second limit of this study is that the training time per training occasion differs in the two interventions. The number of occasions for training was the same in both groups, but the WMT group trained longer periods of time per training day. The RT group showed no or marginal gains on all outcome measures except parent rating scales. It is highly unlikely that substantially larger gains in the RT condition would occur by simply increasing the amount of time used for training. If this was the case, tendencies towards improvement should have been apparent in the present study. The RT is not primarily designed for intensive training and the amount of words in the program would have made the training to repetitive if longer training time per day was required. The benefits of equal training time were not considered more valuable than the risk of extensive drop-outs in the RT.

The modest number of participants constitutes the third limitation of this study. Significant results might not be expected on some outcome measures with small effect sizes and small groups. The entire body of data from the tests, except delayed recall part of the AVLT, changed in a direction in favor of the WMT condition. It is possible that some actual gains did not yield statistical differences as a result of the low number of participants.

Future research

Other WMT studies have also had difficulties with relatively high drop-out rates (Klingberg, et al., 2005). Therefore it is essential to maximize the appeal of software aiming at training working memory for children. The external reward system seems to be an important aspect of the training but not sufficient to ensure compliance. The rewards included in the computer software could be further improved. More variation regarding training exercises would also be preferable. The function of the adult supervising the training could be better standardized and evaluated.

So far studies on WMT have mainly compared the effects of WMT and control conditions without any expected effect. One study (Holmes, Gathercole, Place, Dunning, Hilton, & Elliott, 2009) also included effects of medication but did not make a direct comparison. Future research should focus on the differences between WMT and other commonly used interventions for the ADHD-population.

Future research should also investigate how much training is needed to obtain maximum improvements. One study (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008) compared different number of days of training, but had 19 days as maximum dose of training. It remains unclear if further training would have resulted in greater improvements. Another aspect of training dose that has not been thoroughly investigated is how long a training session should be to optimize the effect of WMT. As little as 15 minutes per day (Thorell, Lindqvist, Bergman, Bohlin, & Klingberg, 2008) and as much as about 40 minutes of training (Klingberg, et al., 2005) has shown results.

So far most studies of WMT have not explored long term effects. Follow-up assessments have at the most been conducted 6 months post training for children (Holmes, Gathercole, & Dunning, 2009) and 18 months for adults (Dahlin, Nyberg, Bäckman, & Stigsdotter Neely, 2008). More studies are needed to further explore the long term effects on WMT.

Another aspect of WMT that needs to be further examined is the effects of different types of exercises. Preliminary results indicate that visuo-spatial exercises are superior to verbal exercises (Lucas, et al., 2008). Also, Thorell et al. (2008) found effects on verbal working memory following training with only visuo-spatial WMT exercises. The research on this subject has as of yet been insufficient to draw any certain conclusions. The effectiveness of different types of visuo-spatial and verbal exercises may also differ. The *n*-back task used by Jaeggi et al. (2008) is quite different to those used in this and other studies. No study to this date has addressed the question of exercise design.

Focus of research on WMT for children has mainly been on either the ADHD-population (Klingberg, et al., 2005) or children with poor working memory capacity (Holmes, Gathercole, Place, Dunning, Hilton, & Elliott, 2009). Since not all children diagnosed with ADHD have working memory deficits, it would be of interest to further investigate the effectiveness of WMT in different subgroups of the ADHD-population. Previous research indicates that working memory capacity can be improved in a normal population of children (Backman & Truedsson, 2008) and adults (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008). No study has compared the effect size of WMT for participants with and without working memory deficits within a single study. It would also be of interest to examine whether WMT is as effective in the adult ADHD- population as in the child ADHD-population. There are also other psychiatric disorders involving working memory deficits, such as dyslexia (Smith-Spark & Fisk, 2007), and it would be of interest to explore possible gains of WMT in psychiatric disorders associated with working memory deficits.

It is noteworthy that many of the authors of earlier published WMT studies have had connections to the software developers. Studies performed by completely independent researchers would give stronger credibility to the WMT research field.

Conclusion

The result of the present study indicate that computerized WMT may lead to improvements of mathematical reasoning and verbal working memory in children diagnosed with ADHD. WMT did not result in significantly greater effects than RT on other measures of scholastic skills, visuo-spatial working memory or symptoms of inattention or hyperactivity/impulsivity. Studies on WMT with larger samples are needed to further investigate the effects of WMT.

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Disclosure

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