Abstract

This research project explored the connection between working memory and children’s learning. The project created a resource titled *Working Memory Strategies for the Junior/Intermediate Educator: A Handbook* based on a literature review, the deconstruction of theoretical and empirical studies, teacher resources, and findings from a needs assessment completed by teachers that together show there is insufficient support for teachers working with students who have deficits in working memory along with other common classroom learning disabilities. As learning disabilities become more common in the classroom that increasingly affect working memory in a majority of cases, teachers must be prepared not only to address specific symptoms of the conditions, but also to help students learn how to navigate and become aware of their working memory ability. The handbook thus was developed as a useful resource for teachers looking to expand their knowledge about how learning occurs. A needs assessment completed by junior and intermediate division teachers in Ontario helped determine what educators found most important for inclusion in the handbook, and the same teachers were offered the opportunity to review the completed handbook. Teacher participants provided constructive feedback and indicated that the handbook would be a valuable resource for them and their colleagues when working with students who have working memory issues. It was suggested that the handbook would be useful when creating students’ Individual Education Plans and that the assessment checklist included in the handbook would be an excellent resource for teachers collecting data regarding students’ working memory and ability to learn.
I would like to take this opportunity to thank a few people who have provided encouragement and support through this intriguing time.

I would like to thank my advisor, Michael John Savage, for finding time to answer my questions, reminding me of what I can do, and encouraging me to do better. It is because of your time and effort that I have been able to complete this major research paper (MRP).

I would like to thank my second reader, Dr. Ann-Marie DiBiase. She is the one who encouraged me to switch from completing a course-based Master into an MRP Master and helped me find an advisor who would take me on. Your encouragement and time in the last 2 years has been greatly appreciated.

I would like to acknowledge members of my family who I have always looked up to and who have inspired me to continue learning, possibly without realizing it. My grandfather, Gordon (Geoff) Wilkinson, was president of the Ontario Secondary School Teachers’ Federation in the 1970s. From my memories of him and the stories I hear, he always encouraged learning. I would also like to acknowledge my uncle, Dr. Derek Wilkinson, who had put money aside for me to ensure that a postsecondary school education was possible. He was an avid supporter of continuing to learn and I have always been in awe of his ability to read so quickly. But I would never be here without my mother, Wendy Wilkinson-Haynes. It was she who encouraged me to follow my dreams of teaching and my desire to complete my Master of Education degree. Without her, I would not have been able to do it.

Thank you to everyone who has helped me along this path and encouraged me beyond belief.
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CHAPTER ONE: INTRODUCTION

Working memory (WM) is a function of the brain that controls emotions, brings awareness of the needs of others, connects names to faces, supports the construction and execution of plans, supports mental math, and much more (Alloway & Alloway, 2013). A deficit in WM, diagnosed by a psychologist or psychiatrist, would assist in designating a student as having a learning disability (LD), as it is correlated with an LD in mathematics and literacy. Beyond academics, a deficit in WM may also cause difficulty in daily life as it may affect cognitive functions such as fluid reasoning, attention, processing, and coping (Dehn, 2008; Pickering, 2006). Many students who have weak or deficient WM are often overlooked in the classroom, as teachers are not being trained how to identify and assist children with specific needs.

Background to the Problem

Alloway and Alloway (2013) believe that elementary students with a WM deficit are often misjudged. These students present common characteristics of conditions such as Attention Deficit Hyperactivity Disorder (ADHD), challenging emotional and behavioural disorders such as Oppositional Defiant Disorder (ODD), or can be labeled or categorized as generally uninterested in classroom learning when in fact they are displaying symptoms of poor WM (Alloway & Alloway, 2013). These students can be mislabeled, or be seen as nuisances in the classroom when really the students’ WM is overloaded and needs a break. With over 176,000 students receiving Special Education services in the elementary school system and 130,000 in the secondary system, ensuring our teachers are well equipped to help students succeed is important (Bennett, Weber, & Dworet, 2013). Educating teachers in WM and recognizing when symptoms of a WM
overload arise is important in ensuring that each child receives adequate and appropriate education.

During a teacher’s training in preparation for certification, WM is discussed within the educational psychology credit as it relates to memory and storage of information. This content is learned through reading and discussing the role of working memory but teachers are often left without a solid understanding of the significance it really has and how to adjust their teaching accordingly (van der Donk, Hiemstra-Beernink, Tjeenk-Kaiff, van der Leij, & Lindauer, 2013). This information can also be missed in other professional development courses such as Additional Qualifications in Special Education, where common classroom conditions may be discussed, but the underlying issue with WM is not addressed. As van der Donk et al. (2013) suggest, many teachers are unprepared and uneducated on executive functioning and working memory in order to assist their students efficiently. In researching resources to help with students who have been designated as having special needs and learning disabilities, very few resources are available that specifically relate to WM and how to support students with their WM issues. The few resources that are available either are too large and time consuming for a busy teacher or are not relevant to the Canadian/Ontario school systems (Alloway, 2011 Dehn, 2008; Gathercole & Alloway, 2007, 2008). With growing literature and research available to academics, this information needs to be formatted and available to teachers.

**Purpose of the Study**

The purpose of this project was to create a handbook that will augment existing knowledge of educators and assist Junior/Intermediate teachers in developing strategies
and interventions for students with varied WM abilities in a classroom setting. The handbook includes an outline of what WM is, why it is significant in learning, different issues students with poor WM may face, and how teachers can help these students thrive both in an academic and non-academic setting.

**Rationale**

WM is something that everyone has and uses throughout everyday life. While the WM system doesn’t change in different people, what does differ is the capacity (Alloway & Alloway, 2013). Knowing how WM works, and what to do when it is overloaded is therefore important knowledge for any educator (Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2007, 2008). This information is being neglected in teacher education and professional development (Alloway & Alloway, 2013; van der Donk et al., 2013). Roughly 85% of Ontario’s Special Education students have conditions that impact WM (Bennett et al., 2013). Many of these students receive their education in mainstream classrooms that have a variety of abilities that a teacher must address (Kohen, Uppal, Khan, & Visentin, 2006). It is the responsibility of the educator to ensure that students are learning and retaining information to the best of the students’ ability. With WM’s strong connection to learning and retrieving information from long-term memory, it is vital that educators be given the right resources and strategies to ensure that their students’ WM is well supported (Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2007, 2008). A growing number of interventions related to WM are entering the market—such as Brain Age (Alloway, 2011; Nouchi et al., 2013) and Cogmed (Dunning, Holmes, & Gathercole, 2013)—but these systems are computer-based training programs and are being questioned as to whether they foster transferable long-term improvements or not (van der
There are few resources to support teachers in the classrooms and none that are Canadian based. Having a resource that teachers can access to find the information they need is important, whether they are searching for WM in general or for specific information regarding a student’s dyslexia.

Theoretical Framework

Working memory, defined by Alloway and Alloway (2013), is the conscious processing of information. The general concept of WM was developed by Baddeley and Hitch in 1974 and since then has stood against criticism and research (Dehn, 2008). When we want to learn something, we absorb the information through our senses and then have to rely on our WM system to retain and store the information (Archibald, 2013). With a deficit in WM, it may take longer to learn new information than normally developing individuals (Kohen et al., 2006). Compared to standard age-appropriate WM, someone with a WM deficit would have limitations to capacity, or storage abilities.

While assessing a student for a learning disability, psychologists often look to cognitive functioning to determine what may cause learning troubles (Proctor, 2012). Many of the assessments that include WM are based on the Cattell-Horn-Carroll (CHC) theory of cognitive ability. This theory has cognitive abilities in a hierarchal structure with general intelligence at the top (Stratum I), 10 broad abilities such as short-term memory in the middle (Stratum II), and 70 narrow abilities such as WM at the bottom in Stratum III (Dehn, 2008; Proctor, 2012). The CHC theory is one of the most recognized theories related to intelligence and each ability has a place in learning (Dehn, 2008; Proctor, 2012). Baddeley and Hitch’s theory related to WM provides an understanding of the storage and rehearsal of new information as well as its interaction with prior
knowledge. The central executive that directs the phonological loop and visuospatial sketchpad runs the model while the episodic buffer interacts with long-term storage. Using the CHC theory and the WM model of Baddeley, WM has been connected with many learning processes such as reading and mathematics. With WM being instrumental to students’ learning, more information and guidance needs to be provided to teachers in order to notice and support these students in their learning. Using the working theory from Baddeley (Alloway & Alloway, 2013), a handbook was created in order to provide guidance for teachers. With a focus on Junior/Intermediate teachers, it is more likely that students will equipped with the right strategies and support early enough in their education in order to create regular habits and assist their learning through future schooling.

**Importance of the Study**

Some teachers do not know enough about executive functions and how they impact academics or behaviour (van der Donk et al., 2013). Their naivetés will put students at risk as frustration will build with academics and often result in academic failure and issues in other areas of a person’s life. Many students are being mislabeled by teachers as slow, troublemaker, or non-listener, which can follow a child around in school for years (Alloway & Alloway, 2013). While many teachers do not do this intentionally, it is their responsibility to acknowledge that this behaviour is irregular of typically developing children and that something needs to be done to remedy it. It has been estimated that 85.5% of elementary and secondary students in Ontario who are receiving services for special education have conditions that involve deficits in WM (Bennett et al., 2013). Of those 85.5%, only 6% in secondary schools and 6.5% in elementary schools are
in self-contained classrooms meaning that the majority of the students with WM deficits are sitting in inclusive classrooms being taught by regular teachers (Bennett et al., 2013). Ensuring that our educators are fully knowledgeable about cognitive functioning such as WM and how it relates to learning is important; having them armed with strategies to help their students is essential.

**Scope and Limitations of the Study**

A limitation that applies to this study is lack of generalization. The development of the *Working Memory in the Junior/Intermediate Classroom* resource was based on responses from a needs assessment completed by teachers. While the researcher is satisfied with the number of participants (n=7) over two school districts, the number of teachers in each district is very lopsided with six in one district and one in another. This would not allow for equal representation of the professional development opportunities in the underrepresented school board.

**Objectives of the Handbook**

The *Working Memory in the Junior/Intermediate Classroom* handbook was developed to ensure that educators met the following objectives:

1. Educators will identify characteristics of students struggling with WM issues.
2. Educators will identify strategies that support WM to help their students learn.
3. Educators will adapt their classroom practices in order to ease students’ WM.
4. Educators will evaluate the handbook for functionality, effectiveness, and relevance to a classroom setting.

The information provided to assist educators in meeting these objectives would be discussed in chapters 3 and 5.
Outline of the Remainder of the Document

This document is set up to provide an extensive review of what the researcher did to accomplish the handbook. The introductory chapter provides basic information relating to this study, outcome, and issue. Chapter 2 is a literature review that explores theories related to Cattell-Horn-Carroll as well as Baddeley’s WM model. It examines themes in empirical research between assessment of WM and other cognitive abilities, connections between WM and learning difficulties, intervention possibilities, and resources that are currently available for educators. Chapter 3 outlines the methodology and research design used to gather data from current Junior/Intermediate teachers. The chapter discusses details regarding responses to the needs assessment and how they influenced the creation of the handbook. Chapter 4 presents the handbook *Working Memory in the Junior/Intermediate Classroom*. Chapter 5 explores the responses from teachers about the handbook, implications, a conclusion to this project, and calls for future research.

Definition of Terms

The following terms are used throughout the document and have the meanings set forth below:

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Anxiety</td>
<td>A vague, highly unpleasant feeling of fear and apprehension (Santrock, J., Woloshyn, V., Gallagher, T., Di Petta, T., Marini, Z., 2010).</td>
</tr>
<tr>
<td>Attention</td>
<td>Ability to maintain focus (Alloway, 2011).</td>
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<tr>
<td>Attention Deficit Hyperactive Disorder (ADHD)</td>
<td>A disorder that includes inattention, impulsivity, and hyperactivity (Kauffman &amp; Landrum, 2013).</td>
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<tr>
<td>Autism Spectrum Disorder</td>
<td>Pervasive developmental disorder with onset before age 3 in which there is qualitative impairment of social interaction and communication and restricted, repetitive, stereotyped patterns of behaviour, interests, and activities</td>
</tr>
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</table>
• Autistic Savant: Someone who is autistic with a special skill, usually related to memory (Alloway, 2011).

• Automaticity: Automated responses that improve speed and efficiency of tasks (Dehn, 2008).

• Baddeley’s Working Memory Model: A model that represents the system within WM including a central executive, phonological loops, visuospatial sketchpad and episodic buffer (Dehn, 2008).

• Cattell-Horn-Carroll Theory (CHC): Most recognized intelligence theory. Cognitive taxonomy with three levels, general intelligence at the top (Stratum I), followed by 10 broad abilities in the middle (Stratum II) and 70 narrow abilities that are subsumed by broad abilities are at the lowest level (Stratum III) (Dehn, 2008; Proctor, 2012).

• Central Executive (CE): A limited capacity attention control system responsible for attention control in WM (Baddeley, 2006).

• Chunking: Concept whereby LTM is used to bind together clusters of items (Baddeley, 2006).

• Cognitive Processes: Cognitive abilities such as phonological processing, auditory processing, linguistic processing, visuospatial processing, processing speed, successive processing, executive processing, fluid reasoning, general intelligence, and attention (Dehn, 2008).

• Comorbidity: Two or more disorders occurring together (Kauffman & Landrum, 2013).

• Deficit: Significantly lower than normal functioning that is also a relative weakness for the individual (Dehn, 2008).

• Episodic Buffer: Temporary storage system that uses a multi-dimensional code to create integrated representations based on information from perception, the subsystems of WM, and LTM (Baddeley, 2006).

• Intermediate Division: Grades 7-10 in the Ontario school system (ages 12-15) (Ontario College of Teachers, 2014).

• Intervention: Method or strategy used in treatment (Kauffman & Landrum, 2013).
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<td>Junior Division</td>
<td>Grades 4-6 in the Ontario school system (ages 9-11) (OCT, 2014).</td>
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<td>Long-Term Memory (LTM):</td>
<td>Memory for experiences that occurred at a point in time prior to the immediate past, and also for knowledge that has been acquired over long periods of time. Includes episodic memory, autobiographical memory, semantic memory, and procedural memory (Gathercole &amp; Alloway, 2008).</td>
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<tr>
<td>Mainstream Classroom:</td>
<td>A neighbourhood school classroom (Bennett et al., 2013). Now often considered an inclusive classroom when students of varying abilities are attendees and accommodated (Kohen et al., 2006).</td>
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<td>Metacognition:</td>
<td>Thinking about thinking. Awareness and analysis of one’s thought process. Controlling one’s cognitive processes (Kauffman &amp; Landrum, 2013).</td>
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<tr>
<td>Phonological WM:</td>
<td>Capable of holding and rehearsing sound and speech-based information (Baddeley, 2006).</td>
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<tr>
<td>Reading Comprehension:</td>
<td>Understanding of text that has just been read (Gathercole &amp; Alloway, 2007, 2008).</td>
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<td>Short-term Memory (STM):</td>
<td>The ability to hold information in mind for short periods of time (Gathercole &amp; Alloway, 2007, 2008).</td>
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<tr>
<td>Visuospatial WM:</td>
<td>Capable of holding, rehearsing, and manipulating visual and spatial information (Baddeley, 2006).</td>
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<td>Working Memory (WM):</td>
<td>A system for holding information and allowing it to be used to perform a wide range of cognitive tasks, including transfer into, and retrieval from, LTM (Baddeley, 2006).</td>
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<td>Working Memory Capacity (WMC):</td>
<td>The limit on the amount of information that can be help in WM. Each sub-component of WM has its own (Gathercole &amp; Alloway, 2007, 2008).</td>
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CHAPTER TWO: REVIEW OF THE LITERATURE

This chapter presents the theoretical framework explored by the researcher along with empirical research and academic and teacher-focused resources that outline the needs of students with WM issues. The basic concept and definition of a WM deficit is explored along with other related issues that learners face. The theoretical framework explored is a combination of the Cattell-Horn-Carroll (CHC) theory on cognitive intelligence and Baddeley and Hitch’s (2007) theories on WM. Academic resources provided an outline for the theoretical framework while research and teacher-focused resources provided an insight into the struggles of students with WM deficits and what teachers need to help their students succeed. It is from this collection of information that the basic framework of the handbook was created.

Overview of Working Memory Deficits in Children

This section will outline what WM is, the prevalence of poor WM in school-aged children, and overview the correlations between exceptionalities and WM.

What Is Working Memory?

Baddeley (2006), one of the founding theorists of the most commonly used WM theory, explains that WM is “a system for holding information and allowing it to be used to perform a wide range of cognitive tasks, including transfer into, and retrieval from, LTM” (p. 4). It has also been described as “active memory” (Dehn, 2008), our potential to learn, and our brain’s Post-it note (Alloway, 2011). Within the concept of WM, there are two subcomponents with specific duties related to domains: Visuospatial Sketchpad (VSS) and Phonological Loop (PL). There is a Central Executive (CE), which is believed to be the centre of the WM process as it manages and keeps order (Dehn, 2008). The
Episodic Buffer (EB) is the liaison between LTM and WM (Alloway, 2011; Baddeley, 2006; Dehn, 2008; Gathercole & Alloway, 2007, 2008; Pickering, 2006). A more in-depth analysis of each component is presented further on in the literature review.

It is suggested that WM is the cornerstone for learning as it allows for information to be absorbed and stored in STM while the information is manipulated, thought over, applied, and used (Alloway, 2011; Baddeley, 2006; Dehn, 2008; Pickering, 2006; Quas & Fivush, 2009). Here the information is used to supply other cognitive functions and draws on information stored in LTM to create connections with previous knowledge (Alloway, 2011; Baddeley, 2006; Dehn, 2008; Gathercole & Alloway, 2008). WM is responsible for the rehearsal of learned information in order to prevent it from being forgotten (Baddeley, 2006; Dehn, 2008). The consensus view seems to be that WM is essential to learning as significant correlations are present with regard to mathematic skills, reading, writing, comprehension, and communication (Alloway, 2011; Alloway & Alloway, 2013; Baddeley, 2006; Baddeley & Hitch, 2007, Dehn, 2008; Dovis, Van der Oord, Wiers, & Prins, 2013; Flanagan, Alfonso, & Reynolds, 2013; Flanagan, Fiorello, & Ortiz, 2010; Gathercole & Alloway, 2008; McGrew & Wendling, 2010; Miller, 2008; Pickering, 2006; Proctor, 2012; St. Clair-Thompson, 2011; van der Donk, et al., 2013; Wang & Gathercole, 2013).

Different brain regions become activated during WM-based activities that relate to specific domains (Dehn, 2008; Pickering, 2006; Quas & Fivush, 2009). Processes related to the PL can be found in the left hemisphere of the brain with the VSS processes on the right hemisphere (Dehn, 2008; Pickering, 2006). The left hippocampus (Dehn 2008; Quas & Fivush, 2009) and right middle temporal lobe show correlations to the EB,
while the dorsolateral prefrontal lobe and anterior cingulated cortex are related to the CE (Dehn, 2008; Pickering, 2006). Goldman-Rakic (1992) suggests that WM relies on a dopamine, a neurotransmitter, as it regulates cell activity associated with WM. For the purpose of this project, a WM deficit will refer to a learner’s below-average age-level WM performance as determined by an educational psychologist.

**Prevalence of Poor Working Memory**

With current statistics being out of date by almost 10 years, it is hard to estimate how many children in the current public school system have deficits in WM in Ontario or in Canada. Kohen et al. (2006), as Statistic Canada’s Health Analysis Measurement Group, used information collected from the 2001 Child component of the Participation and Activity Limitation Survey to create a nationally representative sample of Canadian children who receive special education services. Access to educational services for these children was assessed based on national and provincial trends and the comparison with location of residence (urban versus rural) (Kohen et al., 2006). A regression analysis was used to determine the correlation of the type of condition and the complexity of the conditions, on accessible educational and its barriers (Kohen et al., 2006). During the analysis, family socio-demographic factors and province of residence were used as control factors. From these data, out of a sample of 4,040 children, learning/developmental issues were present in 68% of the participants while 32% had psychological issues, 43% had speech issues, and 20% had dexterity issues (Kohen et al., 2006). There were more statistics available, but these are the only categories where WM would be a part of their diagnosis. In the sample from around Canada, 81% of them receive services for learning disabilities, and 41% for emotional/psychological/
behavioural issues (Kohen et al., 2006). In the sample that came from Ontario, 87% of special education students receive services for learning disabilities, 43% for developmental disabilities or disorders, and 40% for emotional/psychological/behavioural issues (Kohen et al., 2006). Since a WM deficit is a condition that is difficult to “fix,” these data suggest that a large number of people in Canada, let alone the world, are currently functioning with mild to severe deficits in WM.

Students who fall into the categories listed through Kohen et al.’s (2006) study take longer to achieve present levels of education or even have to take a lighter course load. Unless comorbid with additional disorders that make learning or being in a social setting difficult, most students are kept in mainstream classrooms (Kohen et al., 2006).

Data collected by Bennett et al. (2013) from the Ministry of Education in January 2010 suggest that through the province of Ontario, 176,228 (13.1%) of all 1,343,303 elementary students received special education services. As WM is not listed as a specific area of exceptionality, the following areas were extrapolated due to their connections with deficits in WM: behaviour, autism, learning disability, mild intellectual disability, developmental disability, multiple exceptionalities, and non-identified students. Based on the number of students receiving services within these areas, it is estimated that 150,682 elementary students are receiving services for conditions that involve WM issues. While all of these students receive their services within Ontario funded schools, 9,650 of them are segregated from mainstream classes by being placed in fully self-contained classrooms. That leaves the remainder of 141,032 to be educated by generalist teachers in mainstream inclusive classrooms.
Bennett et al. (2013) from the Ministry of Education collected the same data regarding secondary school students. It was reported that 130,792 (18.2%) of all 718,087 secondary students received special education services. Using the same areas of exceptionalities as above to extrapolate connections with WM, it was estimated that 111,832 secondary students (85%) had conditions that may involve WM issues, with 6,734 in fully self-contained and 105,098 in mainstream inclusive classrooms.

**Correlations to Exceptionalities and Working Memory**

All individuals have WM, but it is how the WM operates on an individualistic basis that can assist or limit learning. Deficits in WM have been connected with a large variety of specific learning disabilities as well as disorders. Kohen et al.’s (2006) data collected from across the country showed that of the 4,040 children in the study, 70% of them had more than one disability, while 30% of them have more than four. Children who face comorbid conditions are less likely to attend mainstream classrooms and have more difficulty accessing services. Children with deficits in WM will often have issues with reading and mathematics, which can result in learning disabilities such as dyslexia and/or dyscalculia (Alloway, 2011; Autin & Croizet, 2012; Bergman-Nutley & Klingberg, 2014; Dehn, 2008; Dunning et al., 2013; Gathercole & Alloway, 2007, 2008; Proctor, 2012; St. Clair-Thompson, 2011; Wang & Gathercole, 2013). It is estimated that around 50% of children with math issues will also have difficulties in reading (Alloway, 2011) and 70% of children with reading issues score low on WM (Gathercole & Alloway, 2007, 2008). Children with ADHD have difficulty with control of attention, which is governed by the central executive and has connections with visuospatial WM (Dehn, 2008; Dovis et al., 2013). Visuospatial WM can be deficient in people with
Autism as some get distracted by simple movements (Alloway, 2011; Dehn, 2008). Some Autistics become “savants” who have an extraordinary knowledge base for what they are interested in, which can cause an increase in WMC (Alloway, 2011). Working memory in low functioning Autistics is harder to assess (Dehn, 2008). Working memory has also arisen in schizophrenia research related to issues in WMC, phonological WM, and emotional memory (Dehn, 2008). Deficits in WM can also antagonize anxiety issues caused by maladaptive coping (Quas & Fivush, 2009).

**Assessment and Diagnosis**

According to Kohen et al. (2006), 63% of assessments for disabilities throughout Canada are completed by psychologists or psychiatrists. In Ontario, 62% of assessments are completed by psychologists or psychiatrists (Kohen et al., 2006). Most WM assessment tools used involve some type of storing and manipulating information (Gathercole & Alloway, 2007). The three most common assessment batteries for WM are the Wechsler Intelligence Scale for Children (WISC), Woodcock Johnson Cognitive Ability Test (WJ Cog), and the Automated Working Memory Assessment (AWMA) (Alloway, 2011; Dehn, 2008; Flanagan et al., 2013; Gathercole & Alloway, 2008; McGrew & Wendling, 2010; Nadler & Archibald, 2014). For a comprehensive list of alternate assessment measures, see Dehn (2008). The WISC is a comprehensive standardized battery that is targeted to children ages 6-16 (Alloway, 2011; Flanagan et al., 2013). The tasks involved in the WISC include an arithmetic, digit-span, and letter-number sequencing test (Alloway, 2011; Flanagan et al., 2013). The WJ Cog has three subtests that measure WM including the number reverses, auditory WM, and memory for words tasks (Alloway, 2011; Flanagan et al., 2013; McGrew & Wendling, 2010). The
AWMA measures all abilities associated with WM in children and young adult ages 4-22 (Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2008; Nadler & Archibald, 2014). It is computer based and easy for teachers to administer. The 12 subtests take 45 minutes to complete (Alloway, 2011).

**Theoretical Framework**

There are two main theories related to cognition and working memory that this research project reflects on: the Cattell-Horn-Carroll theory that relates to general intelligence and cognition, and Baddeley’s Multi-Component Model of Working Memory.

**Baddeley and Hitch Theory of Working Memory**

The most current theories regarding WM are credited to Baddeley and Hitch who created the model shown in Figure 1 (Baddeley, 2006). Several additional theories have stemmed from this model by other theorists, but none of them have held up against criticism as well as Baddeley and Hitch (Dehn, 2008). The model consists of the central executive, which is responsible for attention control, shifting, and inhibition (Alloway & Alloway, 2013; Baddeley, 2006; Baddeley & Hitch, 2007; Proctor, 2012). The central executive is accompanied by two subsystems called the phonological loop and the visuospatial sketchpad. The phonological loop is used to store, process, and manipulate verbal information while the visuospatial sketchpad stores, processes and manipulates visual and spatial information (Alloway & Alloway, 2013; Baddeley, 2006; Baddeley & Hitch, 2007; Proctor, 2012). Since the creation of the initial model, Baddeley has added a fourth factor to the system called the “episodic buffer” which serves as a go-between for the central executive, subsystems, and long-term memory (Alloway & Alloway, 2013; Baddeley, 2006; Baddeley & Hitch, 2007). The current model is illustrated in Figure 1.
Figure 1. Multi-component model of working memory (Alloway & Alloway, 2013).
This theoretical framework shows the relationship between the storage areas of information and how they interact with attention (Baddeley & Hitch, 2007). WM capacity develops over time, peaks in the teenage and young adult stages of maturity, and declines towards old age (Alloway & Alloway, 2013; Gathercole & Alloway, 2007, 2008).

The visuospatial sketchpad is responsible for information regarding vision, space, and movement (Dehn, 2008; Gathercole & Alloway, 2008). This part of our memory stores images, pictures, and information about locations and is commonly used for math skills, learning language, and remembering events and patterns (Alloway, 2011; Baddeley, 2006; Dehn, 2008; Proctor, 2012). Originally called the “scratchpad,” the name was changed to “sketchpad” as its function was deemed more as making visual notes and drawing than just the latter (Baddeley & Hitch, 2007).

The sketchpad is located in the right hemisphere of the brain across from verbal short-term memory, which is stored on the left (Baddeley, 2006; Gathercole & Alloway, 2008). It is comprised of a temporary storage and an active rehearsal compartment with information decay taking place within seconds (Baddeley, 2006; Dehn, 2008). Within the sketchpad, the storage framework is divided into two (visual and spatial), with the visual responsible for static information such as objects, shapes, and colours, whereas the spatial storage focuses on motion and directions (Baddeley, 2006; Dehn, 2008). It has been suggested that spatial tasks are able to gauge success in careers such as engineering, architecture, and in daily tasks such as using directions and knowing/learning how to ride a bicycle (Baddeley, 2006).

Within the sketchpad’s ability to store spatial patterns, Logie (1996) suggests that it is also responsible for motor control. It is believed that the sketchpad is essential when
reading as it encodes the printed words and allows the reader to not lose their place in the text (Dehn, 2008). While the phonological loop is needed to store and rehearse visuospatial information, the sketchpad relies more dependently on the central executive. The sketchpad and central executive work together to produce and manipulate mental images. The phonological loop is important to the sketchpad, as verbal coding of visual objects is needed in order to rehearse and retain information (Baddeley, 2006; Dehn, 2008).

The phonological loop rehearses and stores information related to spoken language including numbers, words and sentences (Dehn, 2008; Gathercole & Alloway, 2008; Proctor, 2012). The visuospatial sketchpad relies on the loop to process visual items into word names to assist with association (Baddeley, 2006; Dehn, 2008). This is the system that is used to remember instructions and perform complex tasks (Alloway, 2011). In theory, the loop is divided into two mini loops; a temporary, passive storage compartment and a subvocal, articulatory rehearsal loop (Baddeley, 2006; Dehn, 2008). It is important for learning that rehearsal of information in the loop is regular as items can be as easily forgotten within 2 seconds, regardless of age (Baddeley, 2006; Baddeley & Hitch, 2007; Dehn, 2008). If a word is longer or has no meaning to the learner, it is easier to forget as it takes up more space in the loop (Baddeley, 2006; Baddeley & Hitch, 2007; Dehn, 2008). Influences on loop performance include prior knowledge in long-term memory; this positive influence helps to build associations and chunking, where individual pieces are grouped into larger clusters (Baddeley, 2006; Dehn, 2008).

Beyond these influences, having words that sound similar can also contribute to memory loss. Normal phonological processing finds remembering lists of similar words difficult (Dehn, 2008). Issues within the phonological loop can make learning languages
difficult (Baddeley, 2006). The loop contributes to other skill acquisition such as reading, text comprehension, and grammar (Baddeley, 2006). Logie (1996) suggests that this tells us that encoding and remembering verbal information is phonetically based and would often be remembered through rehearsal. A part of the rehearsal process is when the information is put into the system gets coded and matched with existing codes in long-term memory, which is also associated with meaning representations (Dehn, 2008). Even though the use of words and language is primarily a phonological loop responsibility, stringing words together to express an idea is the responsibility of the central executive (Dehn, 2008).

The central executive is housed in the frontal lobes, and is responsible for all mental activities and cognitive functioning (Amichetti, Stanley, White, & Wingfield, 2013; Baddeley, 2006; Dehn, 2008; Gathercole & Alloway, 2008). The central executive is used any time information is being engaged, especially when information is being processed or stored (Dehn, 2008). Baddeley and Hitch (2007) suggest that the main functions of the central executive are: focusing attention, which allows focus on the relevant information and ignoring disruptions; dividing attention, which allows coordination or multiple activities in a single timeframe; decision and implementation of plans; moving attention between tasks; and linking the current coded information within WM with the coded information in long-term memory (Baddeley, 2006; Baddeley & Hitch, 2007; Dehn, 2008). The function of the central executive is similar to the Supervisory Attentional System (SAS) as it guides the use of resources within WM and attempts to dispel distractions (Baddeley & Hitch, 2007; Dehn, 2008). As tasks (such as reading or driving a car) become routine, they become easier and less stress is placed on
the central executive (Baddeley, 2006; Dehn, 2008). This skill is also important when completing complex math problems, holding information while completing another step, and then bringing that information back to apply to the remainder of the question (Proctor, 2012).

It is also the responsibility of the central executive to switch tasks quickly in order to respond to emergencies (Baddeley, 2006). Working with the slave systems of the visuospatial sketchpad and the phonological loop, the central executive can often become stressed with attention control and stimuli (Gathercole & Alloway, 2008). When the central executive is required to perform multiple tasks at a time, the process can be slowed and performance decreased (Dehn, 2008). The central executive is a part of the retrieval of information from long-term memory (Alloway & Alloway, 2013; Baddeley, 2006; Dehn, 2008; Gathercole & Alloway, 2008; Proctor, 2012). It assists with deciding what information is relevant and connects relevant coding between new and old data (Dehn, 2008). Similar to the subcomponents of WM, the process capacity of the central executive is limited (Baddeley, 2006). In 2000, Baddeley made the addition of an episodic buffer where the central executive can temporarily store information and connect with long-term memory on a more efficient scale (Alloway & Alloway, 2013; Baddeley, 2006; Baddeley & Hitch, 2007; Dehn, 2008).

The episodic buffer acts as storage for the central executive (Baddeley & Hitch, 2007; Dehn, 2008). It networks with the long-term memory, phonological loop, and the visuospatial sketchpad to join data and create new representations of information (Baddeley, 2006; Dehn, 2008). Any access the buffer has to the subsystems comes through the central executive (Baddeley, 2006). If the buffer is holding information and
attention is drawn away, the information will be quickly lost (Baddeley, 2006). The buffer combines the visual and auditory input that is processed by the other components and connects the data to long-term memory (Dehn, 2008). The episodic buffer is believed to be the basis of conscious awareness as it works to bring current information and prior knowledge into the immediate present (Baddeley, 2006). This part of WM builds on what Miller calls “chunking” to assist with recall (Baddeley, 2006; Baddeley & Hitch, 2008; Dehn, 2008). This is thought to improve memory span, as items in chunks are easier to recall than if they were individual items (Baddeley, 2006).

Cattell-Horn-Carroll Theory of Cognitive Ability

Cattell-Horn-Carroll theory of cognitive ability (CHC) is the blend of the Cattell-Horn Gf-Gc theory and the Carroll Three-Stratum theory of cognitive ability (McGrew, 2009; Miller, 2008). The CHC theory demonstrates a hierarchal framework of cognitive ability through Carroll’s three strata (Miller, 2008; Proctor, 2012). These strata include general intelligence, 10 broad cognitive abilities and 70 narrow cognitive abilities, which are subdivided under the broad abilities (Dehn, 2008; Miller, 2008; Proctor, 2012). Broad abilities are based on general characteristics that control behaviour in that cognitive sphere, while narrow abilities are more specific to how personal experiences and learning affect the outcome in that broader ability (Miller, 2008).

For the purpose of this paper, and due to time constraints, the main component of the CHC theory that will be discussed will relate to WM, and STM. While outlining CHC theory components, McGrew (2009) defines STM and WM as:

The ability to apprehend and maintain awareness of a limited number of elements of information in the immediate situation (events that occurred in the last minute
or so). A limited-capacity system that loses information quickly through the decay of memory traces, unless and individual activates other cognitive resources to maintain the information in immediate awareness. (p. 5)

Currently, WM is deemed a subdivision of STM under the CHC framework (Dehn, 2008; Flanagan et al., 2010; Flanagan et al., 2013; McGrew, 2009; & Wendling, 2010; Miller, 2008). Dehn (2008) believes that this is an outdated framework because since CHC theory development, WM has been specifically pointed out as a primary factor in intelligence.

As the CHC theory is used to measure human cognitive ability in school and professional settings using intelligence battery tests and the results are believed to predict learning and achievement (Dehn, 2008; Flanagan et al., 2013; McGrew, 2009; McGrew & Wendling, 2010; Miller, 2008). Current tests that measure WM based on CHC theory include the *Stanford-Binet Intelligence Scales (5th Ed.); Differential Ability Scales (2nd Ed.); Kauffman Assessment Battery for Children (2nd Ed.);* and the *Woodcock-Johnson III Test of Cognitive Abilities* (Dehn, 2008).

Flanagan et al. (2010) suggest that CHC should be used to measure, diagnose, and support students with specific learning disabilities (SLD) and that any basic intelligence testing that does not include all aspects of CHC are not sufficient enough to recognize the overall cognitive abilities of a person and therefore should not be used. Flanagan et al. (2010) support CHC based assessment for SLD as the validity of the CHC theory is solid; it is already commonly used in the field, many intelligence batteries are already founded in CHC, and the correlation between the abilities outlined in CHC and academic outcomes are continually being connected in current research. This belief supports the
rising notion that a traditional IQ test does not distinguish an individual’s potential, or actual intelligence, as a person with an LD could have an average level of intelligence (Alloway, 2013; Flanagan et al., 2010; Gathercole & Alloway, 2008; McGrew & Wendling, 2010). A cognitive assessment, such as one based on the CHC theory, would be more accurate in attaining specific information related to academic issues (McGrew & Wendling, 2010).

Through research based on the CHC theory, WM, along with other narrow abilities, have been suggested to be highly significant to reading and mathematics achievement (Flanagan et al., 2013; McGrew & Wendling, 2010). With these two abilities being the cornerstone of modern education, ensuring success in these fields is important. As we learn, there is a strong dependency on certain cognitive abilities as they strengthen, but once an optimal age is reached, these abilities start to decline (Dehn, 2008; Flanagan et al., 2013; Miller, 2008).

**Empirical Research Involving Working Memory**

This section will explore findings regarding WM in academic references, research, and current teaching resources.

**Academic References Concerning Working Memory**

With growing information in the fields of neuroscience, psychology, and education, actual implementation of the information is lacking. Several studies have examined the impact of WM on learning, Working Memory Capacity (WMC), and whether WM can be improved. Alloway and Alloway (2013) have co-edited a book, *Working Memory: The Connected Intelligence*, which provides an in-depth understanding of how WM affects all aspects of human life from leading scientists. This academic
collection contains works from 33 researchers in fields ranging from psychology to behavioural and cognitive neuroscience. Alloway and Alloway describe what WM does as “the conscious processing of information” (p. i) and explore WM’s abilities to foster success or failure in life (2013). Alloway and Alloway use this opportunity to argue that WM is primary cognitive skill that intertwines human behaviours and abilities. Specific to education, there are chapters dedicated to WM and development over the lifespan that addresses capacity, distractions, classrooms, learning, anxiety, self-esteem, behaviour, LDs, and training WM (Alloway & Alloway, 2013).

*Working Memory and Education*, edited by Susan J. Pickering (2006), is another academic source with chapters written by 17 researchers including leading experts in the WM field including Alan Baddeley, Peter Jong, Susan Gathercole, and Tracy Alloway. The articles in this book were collected for two reasons: (a) to address the growing interest in what we know about academic knowledge and how children perform for a range of readers, and (b) to provide additional support to the recently developed WM test battery created by Pickering and Gathercole in 2001, *Working Memory Test Battery – Children* (Pickering, 2006). All articles present Baddeley and Hitch’s WM framework as the foundation for their work. While each researcher provides a similar yet different view on what WM is, the collection of works address issues that relate to reading, comprehension, mathematics, impaired populations, assessment, and remediation. The articles presented in this collection support the concepts that WM is significantly important to children’s skills in decoding print, comprehension of reading, and arithmetic while providing support to impaired populations who have LDs, are deaf, or have attention disorders. Pickering specifically addresses the wish that readers from varying
backgrounds are able to use the book and benefit from the information provided including teachers, academics, and students (2006).

*The Development of Working Memory in Children*, written by Lucy Henry (2012) provides an excellent summarization of research relating to the revised working memory model from Baddeley in typical and atypical children. With the prime purpose of exploring the development of WM in children of all abilities, it specifically focused on intellectual disabilities (ID), dyslexia and specific language impairments (SLI), Downs and Williams Syndrome, and ASD (Henry, 2012). While discussing alternative WM models, Henry clearly states the revised model from Baddeley was used due to the ease in using it for comparing abilities and explaining the development of memory span in children, the structural framework does not change through age, and it is widely supported in the research community. While the addition of the EB fills the gap regarding prior knowledge connecting with WM development, Henry addresses that some gaps in the framework still remain such as metamemory and memory strategies, calling for further research in these fields.

After reviewing relevant research related to WM and the four components, Henry (2012) summarized that there is a phonological STM weakness in children with ID, dyslexia, SLI, and Downs. Due to mixed results in research, it is still undetermined if there are consistent issues with the VSS STM in ID, SLI, ASD children (Henry, 2012). Central executive problems are present in dyslexia, SLI, and ASD but not all conditions have the same issues (Henry, 2012). While questioning whether the revised WM model is universal for all types of development, Henry tentatively answers yes while stipulating that more research needs to be conducted on the development of the VSS, CE, and EB
through maturity. Henry also stresses that one of the main areas of development in research should be related to intervention for weak WM.

Assessments and Diagnosis

McGrew and Wendling (2010) have summarized research completed in the last 20 years related to the CHC theory and its connection with academic achievement. The goal of their work was to ask what CHC abilities should be included in early screening to help predict SLD. Their purpose was to compile research related to CHC cognitive achievement and expand on another review of current research completed by Flanagan, Ortiz, Alfonso, and Mascolo in 2006 (McGrew & Wendling, 2010). McGrew and Wendling used PsycINFO and the Institute for Applied Psychometrics databases to collect relevant research with specific key words. ProQuest Digital Dissertation database was used to collect unpublished doctoral dissertations using the same key word searches (McGrew & Wendling, 2010). An appeal for copies of published or unpublished work was advertised in the CHC and the National Association of School Psychologists (McGrew & Wendling, 2010). Upon collecting all relevant research through the previously listed resources, the references within these works were reviewed to ensure that nothing applicable was missed in the initial three search options (McGrew & Wendling, 2010).

Five criteria for the research were included in the current study: (a) dated between 1988 and 2009; (b) specifically designed using the CHC theory/framework; (c) must empirically investigate the relationship between primary CHC ability variables and achievement variables in reading and math; (d) report quantitatively; and (e) include five or more of the main abilities outlined in the CHC theory framework (McGrew & Wendling, 2010). Out of all the research collected, only 19 articles were included in the current study.
Out of the number of analyses collected from the 19 research studies, 126 out of the 134 (94%) used the WJ-R or WJ III to analyze data (McGrew & Wendling, 2010). These data suggest that the Woodcock-Johnson III battery is one of the most recommended tests for determining SLD. All data were coded based on four achievements: basic reading skills, reading comprehension, basic math skills, and math reasoning (McGrew & Wendling, 2010). A “vote tally” method was used to determine CHC independent variable significance (McGrew & Wendling, 2010).

For basic reading skills, McGrew and Wendling (2010) found the following CHC broad abilities to be constantly significant through all age groups: comprehension-knowledge, long-term retrieval, processing speed, and STM. While comparing the sample age ranges, the data suggested that while long-term retrieval and processing speed may be important while learning to read, comprehension and STM continue to be significant throughout development (McGrew & Wendling, 2010). The CHC narrow abilities that showed significance at all ages were in basic reading skills-phonological awareness processing, general information, WM, and perceptual speed (McGrew & Wendling, 2010).

The only broad CHC ability that was consistently significant for reading comprehension was comprehension-knowledge (McGrew & Wendling, 2010). Other broad abilities that showed significance at one age group or another consisted of auditory processing, long-term retrieval, and STM (McGrew & Wendling, 2010). The narrow abilities identified as significant for reading comprehension were WM, phonological processing, phonetic coding, and listening ability (McGrew & Wendling, 2010). Narrow abilities pertaining to the long-term retrieval were periodically significant through age groups but not continually (McGrew & Wendling, 2010).
The CHC broad abilities that were found to be consistently significant for basic math skills were comprehension knowledge, fluid reasoning, and processing speed (McGrew & Wendling, 2010). Narrow abilities that were significant for basic math skills at all ages included phonological processing and WM (McGrew & Wendling, 2010).

For math reasoning, the broad CHC abilities that were identified as significant in one or more age groups consisted of comprehension-knowledge, fluid reasoning, processing speed, and short-term memory (McGrew & Wendling, 2010). Phonological processing, memory span, and working memory were the identified narrow abilities that showed significance in predicting math reasoning (McGrew & Wendling, 2010). A special note was made regarding the important role the phonological loop and visuospatial sketchpad play in math reasoning (McGrew & Wendling, 2010). The fact that visuospatial processing, which is a broad CHC ability, was not found to be significant when predicting reading or math achievement seemed to concern the researchers as previous studies suggested it was one of the core abilities related to math achievement (McGrew & Wendling, 2010).

The main limitation of the study outlined by McGrew and Wendling (2010) relates to the “mosaic of methodological approaches” (p. 668) that were used in the studies. The researchers did not focus on how the data in the previous studies were identified as significant. The main points summarized at the end of the study emphasize that this research has extended the previous work of Flanagan and colleagues: a large amount of work has been done related to the CHC theory; a large amount of the research currently available uses one type of cognitive battery test (Woodcock-Johnson); focus should not be taken away from narrow abilities as their designated broad ability may not
apply to the skill used but is still significant; intelligence testing needs to extend to more
cognitive abilities to fully understand ones intelligence; and that there is a future
relationship between using CHC ability identification in early screening for at-risk
students (McGrew & Wendling, 2010).

**Assessment: Issues and Concerns**

A psychologist or psychiatrist preferably does the assessment for WM. It is
common for less formal evaluations to be done in the classroom or school by a teacher or
Learning Resource Teacher (LRT). Flanagan et al. (2013) discussed two commonly used
battery tests for intelligence—the *Wechsler Intelligence Scale for Children – Fourth
Edition* (WISC-IV) and the *Wechsler Adult Intelligence Scale – Fourth Edition* (WAIS-
IV)—conducted by Weiss and colleagues to show the factorial variance between the
populations. The more significant and relevant realization that came out of this study is
what these batteries do and do not measure and if there would be a more appropriate test
to use instead.

While Flanagan et al. (2013) agree that the Wechsler Scales measure narrow
abilities (as defined by the CHC theory), not all of them are included that should be. Out
of the 19 narrow CHC abilities and neuropsychological processes that are believed to be
most relevant to reading achievement, only 10 are addressed through the WISC-IV
battery, while 13 are covered in the *Developmental NEuroPSYchological Assessment II*
(NEPSY-II) subtest, and 16 are covered in the *Woodcock-Johnson III* battery (WJ III)
(Flanagan, Alfonso & Reynolds, 2013). While these tests are used to diagnose Specific
Learning Disabilities among school-aged children, it is very important that they cover as
many abilities within the CHC theory as possible. This large discrepancy in which the
CHC narrow abilities related to academic achievement are covered has Flanagan et al. (2013) suggesting that more CHC narrow abilities need to be integrated into WISC testing and that the integrated WISC needs to become standardized with other tests including the WJ III and NEPSY-II. Each of these assessments does cover WMC. The WISC-IV has a large gap where no direct measure can be found for long-term storage and retrieval as well as executive functioning that relate to reading (Flanagan et al., 2013). The NEPSY-II has no direct measures for processing speed whereas WJ III covers some aspect of all abilities related to reading (Flanagan et al., 2013).

**Assessment of verbal and visuospatial working memory in school age children.** Acknowledging WM’s significant role in learning, Nadler and Archibald (2014) created a study that replicated the work of Alloway, Gathercole, and Pickering from 2006 when they combined tasks to assess WM and its models. The purpose of Nadler and Archibald’s study was to “provide-independent validation of these tasks in a North American group” (p. 263). The theoretical framework was based on Baddeley and Hitch’s WM theory involving the central executive, phonological loop, visuospatial sketchpad, and episodic buffer (Nadler & Archibald, 2014). The purpose of this study was to provide an independent review of the *Automated Working Memory Assessment* (AWMA) that was previously used by Alloway, Gathercole, and Pickering as well as to determine the assessments cultural sensitivity to a Canadian sample (Nadler & Archibald, 2014). The AWMA holds 12 subtests that assess phonological short-term memory, verbal working memory, visuospatial working memory, and visuospatial short-term memory (Nadler & Archibald, 2014).

The sample consisted of 178 students, ages 5 to 9, randomly derived from a larger
pool of participants for another study that were not selected to proceed (Nadler & Archibald, 2014). Twenty Ontario schools were involved to geographically represent the ratio of urban and rural schools in the province with 16 urban schools and four rural schools (Nadler & Archibald, 2014). Out of the 176 students, 82 were male, 96 were female, and 18 spoke English as their second language (Nadler & Archibald, 2014). Reports on the mothers’ final education status were used to determine socioeconomic status (Nadler & Archibald, 2014). The original study being replicated had a larger sample size \((n=503)\) (Nadler & Archibald, 2014).

Each student completed the AWMA within a 50-minute session in a private room within their school (Nadler & Archibald, 2014). The only changes that were made to the AWMA were that all auditory components were recorded in an adult Canadian female voice (Nadler & Archibald, 2014).

A multivariate analysis of variance (MANOVA) was used on the raw data while holding sex and age as separate factors in the analysis (Nadler & Archibald, 2014). On the visuospatial WM, visuospatial short-term memory and phonological short-term memory tasks, a significant Hotelling’s Trace of age \((p<.001)\) but no significant effect of sex \((p=.77)\) and no significant interaction of age and sex \((p=.12)\) were found (Nadler & Archibald, 2014). The MANOVA for the verbal WM tasks were different showing a significant effect of age \((p<.001)\) and sex \((p=.03)\) but no significant interaction between the two \((p=.72)\) (Nadler & Archibald, 2014). There was performance growth, as the students got older. Good internal validity was determined as within-construct coefficients suggested the measures did use all four WM components (Nadler & Archibald, 2014). A principal components analysis (PCA) was used on the raw data as
well as the Kaiser-Meye-Oikin measure determined the sample was sufficient for the analysis (Nadler & Archibald, 2014).

A MANOVA was used to compare the Canadian and British sample (Nadler & Archibald, 2014). Culture was used as a fixed variable, with age and SES as covariates (Nadler & Archibald, 2014). Culture was deemed a significant Hotelling’s Trace ($p=<.001$) as well as age ($p=<.001$). An analysis of variance (ANOVA) was used and a Bonferonni adjustment was made to control against Type 1 error rates for multiple comparisons so a significance level of .004 was used. Overall, the ANOVA showed that Canadian students scored higher on the phonological short-term memory component ($p=<.001$) as well as on specific components of the visuospatial short-term and the visuospatial WM tasks (Nadler & Archibald, 2014). In regards to verbal WM, Canadians did not score significantly higher (Nadler & Archibald, 2014).

The findings of Nadler and Archibald (2014) were coherent with the findings of Alloway, Gathercole, and Pickering; however, the Canadian sample scored higher on phonological short-term memory and several components of the visuospatial short-term memory and WM tasks regardless of adjustments made for age and SES (Nadler & Archibald, 2014). The tasks specifically related to WM did not seem to be affected by cultural difference as findings suggest that it was processing demands that impacted data (Nadler & Archibald, 2014). Due to these discrepancies, Nadler and Archibald suggest caution when applying the AWMA across cultures.

Research related to how SLDs and other cognitive abilities are assessed is important. Batteries such as the WJ III and the AWMA (two of the more comprehensive batteries) assess academic abilities and prospects, not IQ, which can help in identifying
at-risk students and allow professionals to assist them (Flanagan et al., 2013; McGrew & Wendling, 2010; Nadler & Archibald, 2014). The research explored by McGrew and Wendling (2010), Flanagan et al. (2013), and Nadler and Archibald (2014) support that when assessments for SLD are occurring, attention needs to be paid on the CHC cognitive abilities and more specifically some of the narrow abilities such as WM.

**Correlation Between Working Memory, Cognitive Functions, Behaviour, and Learning Difficulties**

This section will explore empirical research that link WM with other cognitive functions, ADHD, and learning disabilities that involve mathematics and reading.

**Inhibition, planning, attention, shifting, and working memory.** In the last 10 years, a plethora of research has been conducted on aspects of WM, executive functions, and the impact on learning. St. Clair-Thompson (2011) discovered that poor WM affects some executive functions such as planning and attention in children but not shifting and inhibition. St. Clair-Thompson aimed to examine executive functioning in children with poor WM and to examine the relationships between WM behaviours and cognitive measures of executive functions. The four elements assessed in this study include inhibition, planning, attention, and shifting (St. Clair-Thompson, 2011). The sample consisted of 76 children with a mean age of 10 years and 2 months with a standard deviation of 9 months (St. Clair-Thompson, 2011). The sample was divided into two groups (20 females and 18 males in each), 38 of them had designated poor WM by their scores on a counting recall task from the *Working Memory Test Battery for Children* with a test-retest reliability of .74 (St. Clair-Thompson, 2011). These scores had to be below one standard deviation of the mean in order to be considered poor (St. Clair-Thompson,
The other 38 children were a part of the control group and were assessed as having normal scores in WM (St. Clair-Thompson, 2011). All children came from the same schools in order to minimize SES concerns (St. Clair-Thompson, 2011).

The students were assigned seven tasks related to executive functioning. Some tasks were completed alone, and others were completed in small groups (St. Clair-Thompson, 2011). Shifting was assessed using the plus-minus task and local-global task previously used by St. Clair-Thompson in 2006. This test was assessed in a small group of four to five but completed individually. Inhibition was assessed alone using a stop-signal (previously used by Logan in 1994) and Stroop task (designed by Streep in 1935) (St. Clair-Thompson, 2011). A split-half reliability was recorded for the stop-signal task of .81 (St. Clair-Thompson, 2011). Planning was also assessed alone using a replication task called Tower of London (St. Clair-Thompson, 2011). Attention was assessed in small groups but completed individually using the Bells Test (as previously used in Gauthier et al. in 1989).

To compare the results of each task between the two groups, a one-way ANOVA was used. Significance was found between the two groups on the shifting task when focusing on local-global single list \( (p<.05) \) and the alternating list \( (p<.01) \) (St. Clair-Thompson, 2011). Significance was found when focusing on planning with the Tower of London tasks \( (p<.01) \) as well as the attention task \( (p<.01) \) (St. Clair-Thompson, 2011). There was significant correlation between the two shifting tasks \( (p=.01) \), two inhibition tasks \( (p<.01) \), and the two recordings from the planning task \( (p<.01) \). The measures also identified significant correlation between WM, planning, and attention with \( p<.01 \) in each pairing (St. Clair-Thompson, 2011).
With regards to the first aims of St. Clair-Thompson’s (2011) study, the findings suggested that children with poor WM did not perform significantly different from their control group counterparts on all levels of executive functioning. St. Clair-Thompson suggests that students with poor WM do not have deficits in shifting or inhibition but do struggle with planning and attention. The second aim of St. Clair-Thompson’s study was to compare the behaviours and cognitive executive functioning of the two groups. While the classroom teachers assessed that the experimental group did have behavioural issues in the classroom, St. Clair-Thompson suggests that based on the earlier findings of this study, there is a difference between WM related behaviours and behaviours related to shifting and inhibition. St. Clair-Thompson suggests that weaknesses in planning and attention may come from constraints of other functions that require processing and storage of information that WM also impacts. Another suggestion made by St. Clair-Thompson is that issues related to poor WM for children could also come from processing speed. St. Clair-Thompson made suggestions for teachers of students with deficits in WM to assist with managing the workload of classroom activities, giving short and simple instructions, and providing memory strategies and techniques that work for students (2011). This study supports the connection between WM and issues that students with poor WM face in the classroom.

**Working and long-term memory.** Long-term memory is another important component to learning as that is where the bulk of what has been learned in the past is stored. Working memory sifts through LTM in order to recall previously learned knowledge. Unsworth, Brewer, and Spillers (2012) completed a study that focused on the connection between WMC and LTM by looking at different search processes in timed
LTM tasks. In the naming tasks, focus was on generation of self-directed cues, strategies used to generate names, how searches began, and differentiation in clusters of people with high and low WM (Unsworth et al., 2012). After the initial experiment, another experiment was completed to expand on the initial findings (Unsworth et al., 2012).

In the first experiment, the sample was chosen from a participant pool from the University of Georgia. After completion of three complex span tests (operation span, symmetry span, and reading span), participants that fell in the high and low quartiles of scoring were chosen to continue (Unsworth et al., 2012). This was done to determine who in the group had the highest and lowest WM scores for comparison (Unsworth et al., 2012). The composite scoring was determined by z-transforming the three complex span scores of an individual participant. They were then averaged together to create quartiles through computing average distribution (Unsworth et al., 2012). The groups resulted with 21 participants in each with a mean age of 18.4 years (Unsworth et al., 2012).

The participants were asked to name as many animals as possible in a five-minute time frame. The chosen names where to be typed into a computer and recorded. There were no cues provided regardless of grouping (Unsworth et al., 2012). The participants were told to name animals in any sequence they wish. After the 5 minutes were up, the participants were given a list of the animals that they had remembered. They were asked to code their responses based on a provided list of possible categories, allowed animals to be listed in more than one if the participant felt it was appropriate, and also allowed the participant to name new categories if the one desired was not available (Unsworth et al., 2012). The participants were also asked to identify any of the animal names that were remembered in sequence. Along with this information, there was also a section where the
participant was able to make additional notes regarding each animal name (Unsworth et al., 2012). After this section was completed, participants answered a questionnaire regarding their search strategies. The questions pertained to how participants completed the task and identifying specific strategies that may have been used (Unsworth et al., 2012). This portion of the task was allowed as much time as the participant needed.

An analysis of recall latency variables suggest that high-WMC recalled more animal names at a faster rate over the 5-minute time period even though both participant groups started recall around the 2.5 second mark ($p=.<01$) (Unsworth et al., 2012). It was determined that the majority of the first recalls were related to the “pet” category. Category was deemed significant ($p=.<01$) by an ANOVA by looking at the two WMC groups and the seven categories, showing that there was no deviation in how the two participant groups recalled their first name (Unsworth et al., 2012). It was deemed by another ANOVA that the two ability groups did not significantly recall a different amount of animals per category (Unsworth et al., 2012). When analyzing retrieval strategies, a questionnaire was used. While high-WMC participants frequently reported using strategies that were general and then became more specific, low-WMC participants reported often not using a strategy at all and having the name “pop” into their head (Unsworth et al., 2012). ANOVA determined that strategy was significant in overall performance ($p=.<01$) (Unsworth et al., 2012). Another ANOVA determined that the combination of WMC and strategy was significant (($p=.<05$) (Unsworth et al., 2012).

It can be suggested from these results that high-WMC individuals are more likely to use strategic searches to recall information then low-WMC individuals (Unsworth et al., 2012). This strategic search leads to self-guided cues and cluster recalls of information.
When difference in strategies was covaried out of the equations, WMC did not have any significance in results (Unsworth et al., 2012). It is therefore suggested that there is no variance in how different people search for information using their WMC; it is the internalized strategies that they employ that make the difference (Unsworth et al., 2012).

The second experiment was implemented in order to expand on the findings of the first in relation to how differences in WMC relate to self-guided cues in LTM (Unsworth et al., 2012). The sample was selected the same way as experiment one, but different people were used. Three groups were created, each with subgroups of high- and low-WMC participants. The control group repeated experiment one, the free-cue condition was given a list of categories to provide cues that remained on the computer screen continually that were there as an option to use, and the forced-cue condition was given category cues for 20 seconds that they were required to use before it would change to another category for 20 seconds (Unsworth et al., 2012). The groups contained 19 high- and 19 low-WMC participants in the control group, 18 high- and 18 low-WMC participants in the free-cue group, and 16 high- and 16 low-WMC participants in the forced-cue group (Unsworth et al., 2012). Each of the tasks was 5 minutes in length.

The results from the three different conditions were subject to a 2 (WMC) x 3 (condition) ANOVA that supported the suggestion that when the cues became available and/or mandatory, the difference in WMC in the participants became irrelevant ($p<=$.01) (Unsworth et al., 2012). In the free-cue condition, there was still a significant difference in performance between the high- and low-WMC participants ($p<=$.05), whereas in the forced-cue condition, that difference was eliminated ($p<=$.63) (Unsworth et al., 2012).
Providing cues for the participants in the forced-cue condition not only increased performance, but also allowed the gap between high- and low-WMC participants to close (Unsworth et al., 2012). Unsworth et al. (2012) suggest that the main difference between the two WMC participant groups is their ability to self-generate cues when searching their LTM for previously learnt knowledge. When these cues were provided, there were no difference in their ability, whereas when the participants are left to their own devices, the difference is significant (Unsworth et al., 2012).

Between the two experiments, Unsworth et al. (2012) suggest that it is WMC that holds a part of the responsibility to select and use retrieval strategies when searching LTM. It is possible that a failure related to WMC prevents affective search and retrieval from occurring (Unsworth et al., 2012). While no limitations of the study are discussed, there is a call for additional research to be conducted relating to the role of WMC and LTM. This research is significant for classroom teachers as it provides clear support to the notion that providing students with cues for answers will not only help answering a question, but also closes the gap in achievement between different WM abilities.

**Working memory and Attention-Deficit/Hyperactivity Disorder.** Assisting students to discover and maintain their own strategies for their WM deficits is important, but it can be difficult when a motivational deficit may also be involved. As previously mentioned, poor WM is a common comorbid condition. Students with ADHD display related symptoms to poor WM, most significantly impacting the visuospatial functioning (Dovis et al., 2013). Working memory has the ability to affect goal-relevant information in a student that is attempting to achieve (Dovis et al., 2013). Dovis et al. used Baddeley’s WM theory as a base in a study regarding motivational deficits and its impact
on visuospatial STM and WM in students with ADHD. The study also focuses on whether there is a change in visuospatial WM while using reinforcement and if it is caused by central executive, visuospatial STM, or both (Dovis et al., 2013). Using two sample groups, Dovis et al., hypothesized that in the feedback only group, ADHD students would have weaker WM and STM scores than the typically developed students. It was also hypothesized that in the same group, the difference in WM and STM levels within the ADHD scored children would be more significant than compared to their counterparts within the same sample (Dovis et al., 2013). Dovis et al. believed that the difference between the ADHD students and typically developed students in the “money offered” sample would be smaller than the feedback only sample. Dovis et al. still expected the ADHD students in the “money offered” sample to have lower STM and WM scores than the typically developed students in the same sample. Due to the monetary motivation, Dovis et al. also expected that the difference in scores between the ADHD and typically developed students in the “money offered” sample would be smaller than the feedback only sample.

The sample was collected through outpatient mental-healthcare centres and elementary schools (Dovis et al., 2013). The researchers collected 148 children aged between 8 and 12 (Dovis et al., 2013). Eighty-six of them were diagnosed with ADHD by a psychologist or psychiatrist using the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR) by the American Psychiatric Association, attained an acceptable score on the Disruptive Behavior Disorder Rating Scale (DBDRS) by teachers and parents within the 95th to 100th percentile, confirmed combined-type of ADHD by having parents complete the Diagnostic Interview Schedule for Children (PDISC-IV),
had no inclination of Conduct Disorder based on PDISC-IV findings or autism spectrum disorder based on the DSM-IV-TR and child psychologist or psychiatrist (Dovis et al., 2013). Sixty-two children were considered typically developed with scores in the normal range on ADHA, ODD, and CD according to parent and teacher analysis using the DBDRS along with no previous diagnosis of psychiatric disorders or autism (Dovis et al., 2013). Both groups of participants needed to achieve an IQ score of greater than 80 by the Dutch Wechsler Intelligence Scale for Children (WISC-III) (Dovis et al., 2013). Two subtests on Vocabulary and Block Design were used to determine Full Scale IQ (Dovis et al., 2013). The children were not taking any medication beyond methylphenidate and did not have signs of neurological disorders or sensory or motor impairments (Dovis et al., 2013). Participants who were taking methylphenidate discontinued use 24 hours before each session in order to allow the medication to “wash-out” of the body (Dovis et al., 2013).

The ADHD and typically developed children were divided but grouped into reinforcement conditions: verbal and monetary (Dovis et al., 2013). Once the ADHD students completed the DBDRS, they attended a 100-minute test session with their parents. STM and WM tasks were presented to all the participants in the first 60 minutes, divided by a 5-minute break between tasks (Dovis et al., 2013). After the 60-minute period, and a 10-minute break, the WISC-III subtests were given to the participant and the parents of ADHD children completed the PDISC-IV (Dovis et al., 2013). Once successful matching of the sample criteria was met, the data were included. Children with ADHD participated at their mental-healthcare centre while typically developed participants participated at their elementary school. Eight orders of presentation were
arranged to balance the order of administration (Dovis et al., 2013). No parent or child was given an indication of anything to do with monetary value or expectancy before the testing began (Dovis et al., 2013). Participants in the “money offered” group were told at the beginning of the task that they could receive 10 euros if they completed the tasks well (Dovis et al., 2013).

Participants completed the two versions of the Chessboard task relating to STM and WM (Dovis et al., 2013). An introduction to the task is presented to the participants followed by a trial period. After the trial period, specific instructions based on the participants’ condition group were presented (Dovis et al., 2013). If the children were in the monetary motivation group, they were told that if they got enough right answers, they would earn 10 euros (Dovis et al., 2013). Coins were placed in view of the participant above the computer keyboard. The participant was told that the computer decides how many correct answers were needed in order to attain the money and once it was satisfied, the screen would turn green, meaning they could keep the money, or red indicating that they would have to leave the money behind (Dovis et al., 2013). If the participants were in the verbal reinforcement group, they were asked to complete the questions to the best of their ability (Dovis et al., 2013). The participants then completed 30 trials of the first task taking 10 minutes. The second task was introduced and trialed by the participants. The same motivational instructions were given based on the participants’ condition and then 30 trials of the second task were completed (Dovis et al., 2013). In both groups, participants received visual and auditory feedback and were able to view their overall performance on a bar at the bottom of the computer screen (Dovis et al., 2013). The auditory feedback was a guitar note for correct answers and a buzzer for wrong answers.
(Dovis et al., 2013). The first 12 trials of the tasks were used to get to the participants’ optimal level of performance, so these data were omitted from analysis. The mean used in analysis was based on the remaining 18 trials of each task (Dovis et al., 2013).

Covariates used included IQ, gender, and weekly spending money, as there was a large difference between the two classifications (Dovis et al., 2013). Due to concerns regarding using IQ as a covariate, the analysis was completed a second time omitting IQ (Dovis et al., 2013). An ANCOVA was used to analyze dependent measures between experimental condition and participant classification (ADHD/typical development) and the two difference tasks as within-subject factors (Dovis et al., 2013). The covariates were added after the mean WISC, gender, and weekly spending money scores were determined (Dovis et al., 2013). Central executive performance was determined using the ANCOVA between-participant classification of the two tasks (Dovis et al., 2013). For the within-group analysis, central executive performance was determined by removing the mean WM performance from the mean STM performance for each participant (Dovis et al., 2013). Partial Eta squares effect size were reported for all analyses (Dovis et al., 2013).

Dovis et al. (2013) suggest that ADHD children have less central executive capacity, motivational deficit, and visuospatial STM than typically developing children and require further motivational support to reach higher achievements relating to STM and WM. Even with additional motivational incentives, students with ADHD will still have lower achievement levels than typically developing children (Dovis et al., 2013). Dovis et al. support providing students with WM and STM training. A limitation discussed was the lack of consideration regarding gender composition of the two condition groups (Dovis et al., 2013). There was concern regarding the fact that
participants were not screened for internalizing disorders such as anxiety and depression, which could have affected their performance on the task (Dovis et al., 2013).

While it should not be expected that all students, regardless of ability, should be continually offered money for achievement, this concept does bode promise in an educational setting. Finding something that students value and using that to help them work towards their goals is important, regardless of ability.

**Working memory and mathematics.** Due to the sample being college-aged and not in the Junior/Intermediate division, Proctor (2012) will be discussed briefly. Proctor focused his research on the seven main CHC abilities as well as WM to predict math achievement in an LD college-aged group. Proctor collected 158 students with an LD in Mathematics based on the WJ-III-COG and WJ-III-ACH but showed normal cognitive intelligence. It is suggested that WM, but not its broader ability, short-term memory, impacts mathematic abilities. Proctor concludes that certain abilities under the CHC framework were significantly related to mathematic achievements. Specifically, WM and Processing Speed were significantly related to math calculation-skills while WM, comprehension-knowledge, and fluid reasoning are significantly related to math reasoning (Proctor, 2012). Providing support for these abilities would be important to success when underachievement or deficiencies exist in a learner.

**Working memory and reading difficulties.** As deficits in WM have a negative impact on academics, literacy and numeracy are two of the more affected areas. It is extremely common for a child with poor WM to have either or both LDs in reading and comprehension or mathematics (Alloway & Alloway, 2013). Using Baddeley’s model of WM, Wang and Gathercole (2013) asked if WM was the centre of reading issues and if
so, where does it come from? Wang and Gathercole hypothesize that children with reading issues will have a deficit in their central executive. This hypothesis was tested by assessing central executive capacity in children with and without reading difficulties.

The sample consisted of 689 children, ages 8 to 10, in the English public primary school system (Wang & Gathercole, 2013). Schools that participated had higher than the national average statistics in free school meals and special education students. In order to participate, children completed the single work reading subtest of the Wechsler-Objective Reading Dimension (WORD) and the matrix reasoning subtest of the Wechsler Abbreviated Scale of Intelligence (WASI) (Wang & Gathercole, 2013). Criteria for participating was a score of 85 or below on WORD (which is considered below average) and a minimum t score of 40 on the WASI subtest (Wang & Gathercole, 2013). Out of the 689 students who participated, 46 were chosen for the reading difficulty group (17 girls/29 boys) while 45 students were selected for the typical reader group (24 girls/21 boys) (Wang & Gathercole, 2013). Children selected for the typical reader group scored 95 or higher on WORD and had a t score greater than 40 on the WASI subtest (Wang & Gathercole, 2013). While the difference in scoring on WORD was significant ($p = <.001$), the groups were comparable in age ($p = .614$) as well as in WASI scores ($p = .883$) (Wang & Gathercole, 2013). Teachers reported no other developmental issues with participants and all students had English as their first language (Wang & Gathercole, 2013).

The first component of the study involved completing four subtests from the Automated Working Memory Assessment (AWMA) in a quiet room located in the school (Wang & Gathercole, 2013). This session did not last longer than 30 minutes. These four tasks assessed span procedures, verbal short-term memory (digit recall),
verbal WM (backward digit recall), visuospatial STM (dot matrix), and visuospatial WM (spatial recall) (Wang & Gathercole, 2013). Scores were indexed and standard scores were assessed for each task. Test reliability was determined at .89 for digit recall, .86 for backward digit recall, .85 for dot matrix, and .79 for spatial recall (Wang & Gathercole, 2013).

The second component of the study involved dual task coordination. A paradigm from Baddeley and colleagues was adapted, where the participants completed a digit recall task and a reaction times task (Wang & Gathercole, 2013). Participants completed three conditions of this component. The first condition was considered the baseline where the child’s digit span and arrow reaction speed were assessed (Wang & Gathercole, 2013). The participants listened to a list of numbers at a rate of one per second starting with one number and increasing by one after the participant successfully recalled all previously heard numbers. This baseline assessment continued until failing to exactly recall at least two of the three trials at a given sequence length (Wang & Gathercole, 2013). This is how the digit span was assessed for each participant. The reaction times task involved the participant viewing the direction of an arrow in the centre of a computer screen and pressing the matching arrow on the keyboard (Wang & Gathercole, 2013). Participants completed this task 20 times and the mean reaction times were determined using the correct reactions (Wang & Gathercole, 2013). At first, the participants completed these two tasks separately. After the two tasks were completed, the participants then had to complete the two at the same time, recalling the digits while pressing the corresponding arrows (Wang & Gathercole, 2013). Both tasks lasted 90 seconds each. When the tasks were put together, the length remained 90 seconds. The
number of correct arrow answers and correct digits recalled in the correct sequence were scored (Wang & Gathercole, 2013).

In all AWMA, the typical reader group scored significantly higher than the children with reading difficulties: verbal STM \((p=.002)\), verbal WM \((p=.001)\), visuospatial STM \((p=.005)\), and visuospatial WM \((p=.003)\) (Wang & Gathercole, 2013). An analysis of covariance (ANCOVA) was used and after STM was designated a covariate, visuospatial WM and verbal WM still remained significant (Wang & Gathercole, 2013). Two separate two-factor analyses of variance (ANOVA) were used on the STM and WM scores where reading ability was used as a between participant factor and task domain (verbal vs. visuospatial) as a within-participant factor (Wang & Gathercole, 2013). When considering the STM results, the main effect of group reflecting poorer performance of the children with reading difficulties was significant \((p<.001)\) and no significance was found of task domain or interaction between group and task (Wang & Gathercole, 2013). When considering the WM results, a significant effect of group \((p<.001)\) and ask domain \((p<.001)\) were found whereas the group by domain interaction was not significant (Wang & Gathercole, 2013). A significant correlation was found between the measures of verbal WM and visuospatial WM in the reading difficulties group (Wang & Gathercole, 2013). This supports to notion that these are the areas of deficit in WM for this condition (Wang & Gathercole, 2013).

In the single task version of the dual task performance, the typical readers did significantly better on the digit span task \((p=.001)\) but not in the arrow reaction timing (Wang & Gathercole, 2013). There was no significant difference between the two groups in the single task versions (Wang & Gathercole, 2013). During the dual task, the reading
difficulty group performed twice as poorly as the typical readers and this showed a significant correlation with the children’s individual WM composite scores ($p=.034$) (Wang & Gathercole, 2013). A significant group effect was found after analyzing the data with an ANOVA, but not in both single tasks (Wang & Gathercole, 2013). To ensure that the reading difficulty participants weren’t given a harder arrow task, the reaction times were entered as a covariate and the difference between the two participant groups remained significant ($p=.007$) (Wang & Gathercole, 2013).

In a two-factor ANOVA, groups (reading difficulties versus typical readers) were used as a between-participant factor and type of task (single versus dual) was used as a within-participant factor when focusing on the digit recall and arrow reaction times separately (Wang & Gathercole, 2013). The digit recall showed a significant main effect in task ($p=<.001$), group ($p=.008$), and interaction between the two ($p=.010$) (Wang & Gathercole, 2013). Scores on the arrow reaction time were entered as a covariate due to their close means. The ANCOVA determined significance of the main effect of type of task ($p=<.001$), the main effect of group ($p=.033$), and interaction between the type of task and group ($p=.042$) (Wang & Gathercole, 2013). When considering the arrow reaction times task, the main effect of type of task was significant ($p=<.001$), the effect of group was significant ($p=.011$), and the interaction between the type and group was significant ($p=.040$) (Wang & Gathercole, 2013). These data suggest that during the dual task, the children with reading difficulties performed poorer during both tasks than the typical readers (Wang & Gathercole, 2013).

Another two-factor ANOCA was performed to determine if there was an unbalanced decrement between the two tasks for reading difficulty participants (Wang &
Gathercole, 2013). The group (reading difficulties versus typical readers) was used as a between-participant factor and the lower performance between the single task condition and the dual task condition as a within-participant factor (Wang & Gathercole, 2013). A significant group effect was found ($p=.004$) with no significance of type of task or between the two factors (Wang & Gathercole, 2013).

Wang and Gathercole’s (2013) hypothesis of there being a deficit in the central executive of children with reading difficulties was supported. This was supported by poor performance in complex span tasks by the participants with reading difficulties as well as their lack of ability to coordinate two cognitively demanding tasks at once (Wang & Gathercole, 2013). This study is important to this paper as it supports the need for WM assistance to children with reading difficulties. Providing students with strategies and practice could enable them to perform to a higher standard and achieve more academically.

The research in this portion of the paper explores WM and its connection to different areas of learning and subjects. Researchers such as Proctor (2012), St. Clair-Thompson (2011), Unsworth et al. (2012), Dovis et al. (2013), and Wang and Gathercole (2013) have identified or recognized important ways that WM deficits can be acknowledged within the classroom and how it impacts learners. The next step from identifying that there is a problem is to look at the interventions that can be used to help these students.

The studies discussed in this section of the chapter suggest that there is a connection between WM and academic performance. With strong ties to reading, mathematics, LTM, and more, WM is a cognitive function that needs to be supported in the classroom to ensure that optimal learning and performance are being reached in our
students. A handbook for teachers would provide support to them in order to make sure that this happens.

**Interventions for Poor Working Memory**

Interventions are where schools and teachers are crucial in assisting students with WM deficits. Their goals are to educate their students to the curriculum and ensure that they learn the content. With the increasing demand on teachers’ time, it can be hard to adhere to Individual Education Plans (IEPs), meet all curriculum requirements, plan lessons, mark students’ work, and find ways to help struggling students. This is where researchers like Dunning et al. (2013), Autin and Croizet (2012), and Bergman-Nutley and Klingberg (2014) have dedicated their research efforts. These are the studies that explore interventions related to WM that will help teachers and their students.

**Low working memory, training, and generalized improvements.** Dunning et al. (2013) completed the first randomized, controlled trial to explore whether different intensities of training on WM would create a transfer effect and benefit students in other untrained areas of learning. Another goal of this study was to see how long any of these changes remained (Dunning et al., 2013). The intervention used was a computer program called Cogmed Working Memory Training (CWMT). The screening process involved 810 children using two tests (backward digit recall and Mr. X) of the Automated Working Memory Assessment (AWMA) (Dunning et al., 2013). Ninety-four of the students were identified within the bottom 15th percentile on both tests (Dunning et al., 2013). These students all had English as their first language.

After the pre-training assessment (T1) the chosen sample was divided into three conditions: adaptive training, non-adaptive training, and no intervention (Dunning et al.,
2013). The adaptive and non-adaptive condition experienced 6 weeks of training. After the 6-week mark, all groups completed the post-training assessment (T2) (Dunning et al., 2013). Twelve months after T2, 15 participants in the adaptive and 19 participants in the non-adaptive groups completed a re-test (T3) (Dunning et al., 2013). Research assistants, blind to intervention status, completed all assessments (Dunning et al., 2013). The condition the participant was placed in was determined by which school they attended. This cluster randomization was done to diminish any contamination between the two adaptive groups and dilution effects (Dunning et al., 2013). Intra-cluster correlations were calculated for T1 measures to measure the variance between clusters and moderate to strong agreement (Dunning et al., 2013).

Cogmed Working Memory Training was used for 20-25 sessions for the adaptive training groups (Dunning et al., 2013). These sessions lasted between 30 and 45 minutes with 15 trials on eight exercises in each session (Dunning et al., 2013). The software, out of a bank of 12, presented eight exercises that were preset (Dunning et al., 2013). The software matched ability level of the participant in a trial-by-trial basis. The CWMT that was used in the non-adaptive condition was developed for trial evaluations (Dunning et al., 2013). The only difference between this condition and the adaptive training is that the non-adaptive group’s exercises were set at a low span level and did not change throughout the training exercises (Dunning et al., 2013). The exercises were completed in small groups of 6-12 with a researcher present. All participants received small tokens of gratitude after completing sets of five training exercises. This motivation feature was not taken into consideration during analysis (Dunning et al., 2013).
Measures used to assess participants include the AWMA, the Wechsler Abbreviated Scales of Intelligence (WASI), the Wechsler Objective Number Dimensions test (WOND), the Wechsler Objective Reading Dimension (WORD), the Neale Analysis of Reading Ability test (NARA), Kauffman Test of Educational Attainment (KTEA), the Continuous Performance Test (CPT), the Delis-Kaplan Executive Function System (D-KEFS), and Classroom-based tasks (Dunning et al., 2013).

At T1, before interventions, the following measures were used: eight subtests from the AWMA over two sessions (verbal STM: digit and word recall, visuospatial STM: dot matrix and block recall, verbal WM: counting recall and backward digit recall, visuospatial WM: Mr X and spatial span), three classroom-based tasks (following instructions, detecting rhymes, and sentence counting and recall), four subtests from the WASI (verbal IQ: Similarities and Vocabulary, performance IQ: Matric Reasoning and Block Design), two subtests from WOND (Mathematical Reasoning and Number Operations), one subtest from WORD (Basic Reading), the NARA (to assess reading accuracy, comprehension, and rate), one subtest from KTEA (Written Expression), the CPT, and one subtest from the D-KEFS (Visual Scanning) (Dunning et al., 2013).

In T2, after interventions, the previously mentioned measures were used from T1 except for the subtests from the AWMA. Only four subtests were repeated from T1 (verbal STM: digit recall, visuospatial STM: dot matrix, verbal WM: backward digit recall, visuospatial WM: Mr X), with the new addition of four other subtests (verbal STM: nonword recall, visuospatial STM: mazes memory, verbal WM: listening recall, visuospatial WM: odd-one-out) (Dunning et al., 2013).

In T3, 12 months after T2, the participants repeated the following measures:
classroom-based tasks, two subtests from WASI (Similarities and Matrix Reasoning), a subtest from WORD (Basic Reading), a subtest from WOND (Number Operation), the NARA, CPT, and a subtest from D-KEFS (Visual Scanning). Students in the no intervention group did not complete these measures (Dunning et al., 2013).

One-way ANOVAs were completed for each measure in T1 as a function of group (adaptive, non-adaptive, and no intervention) (Dunning et al., 2013). There were significant differences between the groups in visuospatial STM ($p=.02$) where the non-adaptive group performed higher than the no-intervention group ($p=.01$), and verbal working memory ($p=.02$) where the non-adaptive and no intervention group scored higher than the adaptive group (Dunning et al., 2013). There was a significant group difference in the CPT ($p=.01$) and Visual Scanning ($p=.04$) tasks scored at T1 (Dunning et al., 2013). A general linear model was used to test group effects on training gains on T2 measures (Dunning et al., 2013). These scores were entered as dependent variables and the T1 scores entered at the independent variables. Measures with significant group differences at baseline were added to the model. Significant training effects were found for visuospatial STM, verbal WM, and visuospatial WM in favour of the adaptive group (Dunning et al., 2013). Basic Reading scores were found to be significantly predicted by group at T2 (Dunning et al., 2013). There were no other significant training effects.

Measures from T3 were analyzed using one-way ANOVAs, which compared scores from each measure from T1 that was retested at T3 (Dunning et al., 2013). General linear models were used to test the effect of group on each of the T3 measures separately. Scores from T3 were entered as the dependent variable with scores from T1 and group were entered as independent variables (Dunning et al., 2013). A significant predictor of
group was found in T3 scores for verbal WM and the part of the sentence counting tasks that related to processing in favour of the adaptive group (Dunning et al., 2013). A Bonferroni correction reduces the probability criterion for significance to .003 at both T2 for all participants and T3 for the participants involved. The only finding that remains after this correction is verbal WM at T2 (Dunning et al., 2013). Effect sizes (Cohen’s $d$) were considerable at T2, ranging from .67 to .99 between the adaptive and non-adaptive condition participants and .57 to 1.63 between the adaptive and no intervention condition participants (Dunning et al., 2013).

These data suggest that the adaptive training of WM improved performance in untrained WM tasks in this low-WM population (Dunning et al., 2013). The initial improvement was significant and a difference in achievement was sustained for 12 months (Dunning et al., 2013). The participants in the adaptive condition showed significant improvements in measures of visuospatial STM, verbal WM, and visuospatial WM compared to the other participants (Dunning et al., 2013). Based on their results and the work of others, Dunning et al. (2013) suggest that WM training does not impact verbal STM performance. It is suggested that verbal STM does not place a large demand on the central executive and is connected with vocabulary acquisition instead of academic learning (Dunning et al., 2013). The WM training did make an impact on verbal WM as improvements lasted over the 12 months after training. This suggests that this type of intensive intervention can provide lasting improvements to verbal WM which will in turn support learning due to the strong dominance of verbalization in our classrooms at all educational levels to share information (Dunning et al., 2013). Even though there were major enhancements in complex span in relation to literacy and mathematics, no
significant impact was seen on the participants’ standardized reading and mathematics tests in the T2 and T3 measures. The way CWMT was implemented showed no improvements in visual scanning, non-verbal reasoning, or in attention control (Dunning et al., 2013). Dunning et al. suggest that their study supports that training in WM for low-ability children will lead to general improvements in a wide range of tasks that involve WM, and that these improvements do not convert as improvements to capacity or in academic achievement.

Even though Dunning et al. (2013) do not support that WM training will make improvements in academic achievements, it cannot be denied that improvements in WM (especially verbal) were found in their version of intervention using CWMT. Other researchers such as Klingberg et al. (2005), Holmes et al. (2010), Dahlin (2011), Mezzacappa and Buckner (2010), and Holmes, Gathercole, and Dunning (2009) have found data that suggest CWMT can provide improvements in WM in a variety of abilities and can condition populations of students. Dunning et al.’s work provides additional support to the creation of a handbook for teachers on WM to ensure that teachers know how to support and expand on WM training provided in programs such as CWMT.

**Training on working memory, arithmetic, and following instructions.** Bergman-Nutley and Klingberg (2014) believe that previous research on WM and mathematics have not been efficient enough to provide a large effect size and therefore too small a sample to find a significant effect. In this study, Bergman-Nutley and Klingberg aimed to have a large enough sample, over a wide age range, to compare with a control group in order to determine a large effect size and significance in relation to the intervention used. It was hypothesized that an effect of training would be found, but the correlation would
be smaller than the effect of WMC since arithmetic relies on more than just WM.

The sample included 480 children collected from two sources (Bergman-Nutley & Klingberg, 2014). The training group was collected through clinicians in the Cogmed network (a computer program company). The participants were asked to assist in piloting transfer effects (Bergman-Nutley & Klingberg, 2014). Children who appeared to have inattention and WM issues were asked to participate. No clinical measures were used to confirm diagnosis of disorders or conditions beyond parental completion of symptoms using the Disruptive Disorder Behavioural Checklist (Bergman-Nutley & Klingberg, 2014). The group finished with a total of 176 participants with the mean age of 11.1 and a standard deviation of 2.4 (Bergman-Nutley & Klingberg, 2014). Training took place in the summer of 2012 with clinicians and compliance with the program was high with the mean day of participation at 24.89 (Bergman-Nutley & Klingberg, 2014). Using the Cogmed newsletter database was how the control group was found. An email was sent out to ask for classroom teachers to participate with their students. As a reward, classes with high enough participation received money to put towards a class trip. Out of all respondents, a class of roughly 25 per age group was selected to participate (Bergman-Nutley & Klingberg, 2014). Researchers selected a few additional classes in certain age groups, but did not mention why. The control group finished with a population of 304 with a mean age of 11.01 and a standard deviation of 2.2 (Bergman-Nutley & Klingberg, 2014). Compliance with the testing procedure was adhered to at 90%. Age and gender were collected for all 480 participants but researchers were unable to distinguish which statistics belonged to an individual (Bergman-Nutley & Klingberg, 2014).

Both groups of participants completed three transfer tests. These three tests were
completed once a week for 5 weeks (Bergman-Nutley & Klingberg, 2014). The only difference between the groups was that during the 5 weeks, the training group received an intervention. This intervention was the Cogmed Working Memory Training program (CWMT) (Bergman-Nutley & Klingberg, 2014). This program had 12 verbal and visuospatial WM tasks that were training on for 5 days per week during the 5 weeks (Bergman-Nutley & Klingberg, 2014). Only eight to 12 tasks were used during each training session to increase variability (Bergman-Nutley & Klingberg, 2014). Two tasks were regularly repeated (a visuospatial task and backwards design) that were used to measure the improvement of the participant. Scores were calculated with an internal algorithm. The difficulty of the tasks increased as the participants’ abilities improved.

Each training session lasted 35 minutes without breaks. The three transfer tests that were completed by all participants included a subtest from the Automated Working Memory Assessment: “Odd One Out” (OOO), a computerized version of a task that was based on a previously used analog task by Gathercole, Durling, Evans, Jeffcock, and Stone (2008) called “Following Instructions” (FI), as well as a timed arithmetic test that was developed by Cogmed (Bergman-Nutley & Klingberg, 2014). All of the tasks were completed on the computer either at school (control group) or at home or the clinic (training group).

Data from the two groups were analyzed using a univariate general linear model of latest outcome using group as a fixed factor and age, and gender and baseline performance as covariates (Bergman-Nutley & Klingberg, 2014).

After the first round of testing, significant performance differences were found between the groups for the OOO and FI (both $p<0.001$) but not in that math test (Bergman-Nutley & Klingberg, 2014). A significant difference was found in frequency of
males and females (Pearson Chi square, \( p=0.001 \)) but not in age (Bergman-Nutley & Klingberg, 2014). In the FI test, the results from the control group were linear and with minimal test-retest effect (Bergman-Nutley & Klingberg, 2014). Test two and three showed test-retest effects in the OOO and math scores but evened out. A general linear model assessed the main effect of WM training using the last testing scores as the dependent variable (Bergman-Nutley & Klingberg, 2014). The independent variables used included group, age, sex, and performance at the first set of testing scores. The group variable was significant for all three transfer tasks (all \( p<.0001 \)) (Bergman-Nutley & Klingberg, 2014). This suggests that the training group made the most improvement between the five weeks on all tasks. An analysis was completed to address connections between training improvements and transfer improvements within the training group. Improvements on two of the trained Cogmed tasks showed a significant correlation with improvement in the OOO test \((r=0.20)\) and FI \((r=0.23)\) while improvements in FI were also correlated with improvements in the arithmetic questions \((r=0.36)\) (Bergman-Nutley & Klingberg, 2014). The effect size (Cohen’s \( d \)) were calculated and found a strong effect size for FI \((d=0.90)\), medium to strong for OOO \((d=0.67)\), and a small effect size for the arithmetic questions \((d=0.20)\) (Bergman-Nutley & Klingberg, 2014). These scores were age dependent so a recalculation for the arithmetic questions was redone using age-normalized scores resulted in a small to medium \( d \) value of 0.39 (Bergman-Nutley & Klingberg, 2014). A power analysis was conducted to compare the control group and training group data using a test-retest difference in the arithmetic questions from each participant. This was done using 1,000 random samplings from each same size (Bergman-Nutley & Klingberg, 2014). For each
sample size, a $t$ test was executed and significant differences were plotted and compared to the sample size (Bergman-Nutley & Klingberg, 2014). This suggested that a power of 80% requires a sample size of approximately 75 participants in each group using this measure (Bergman-Nutley & Klingberg, 2014).

The results from this study suggest that the WM interventions used, CWMT, improved performance, which allowed for a transfer effect to untrained tasks such as the visuospatial WM task, remembering and following instructions, and arithmetic (Bergman-Nutley & Klingberg, 2014). There were large improvements in the first two tasks with a smaller but still significant improvement in the arithmetic. This study did not contain follow-up for possible long-term sustaining of improvement. Other limitations discussed include not having a control for the effects of expectancy and that the control group was passive, not active (Bergman-Nutley & Klingberg, 2014).

This study is relevant to this paper as it explores the impact of a particular type of intervention on mathematics. Bergman-Nutley and Klingberg (2014) use the same software as Dunning et al. (2013): Cogmed. A growing body of research suggests that Cogmed is one of the more advanced and reliable computerized interventions for students with WM deficits (Bergman-Nutley & Klingberg, 2014; Dunning et al., 2013; van der Donk et al, 2013). This is a strategy that cannot be ignored in the creation of a handbook for teachers and should also be brought to the attention of school boards for possible mass purchase.

**Reframing metacognition to improve working memory.** Auin and Croizet (2012) questioned whether or not a change in metacognition towards experiencing difficulty in WMC based tasks could alter WM performance. With acknowledgement that
WM is believed to have an established capacity that does not fluctuate, Autin and Croizet believe WMC can alter with a change in perception of a situation and what it means to an individual. It was hypothesized that by guiding an individual’s perception of her/his academic difficulty (often viewed as a weakness, which leads to frustration) from negative to constructive, allows for WM abilities to function at a higher rate (Autin & Croizet, 2012). The goal of the researchers with the participants was to avoid negative self-image from occurring. The research was broken into three studies that involve manipulating metacognition (Autin & Croizet, 2012).

The first study explored reactions to stressed academic situations in three condition groups, one group with intervention ‘reframing’ and two control groups without (Autin & Croizet, 2012). It was hypothesized, that the participants in the intervention group would show higher WMC in the listening span test (Autin & Croizet, 2012). The study included 111 participants all age 11 (51 boys, 60 girls). Socioeconomic status was determined based on parental occupation (Autin & Croizet, 2012). Thirty-one percent of the participants were estimated at high SES, while 22% were designated medium, and 46% at low (Autin & Croizet, 2012). No information was provided for the remaining 2% of the participants. Participants were randomly assigned into condition groups (Autin & Croizet, 2012).

The anagram provided to the participants was given under the explanation that it was an exercise that would not affect their grade and the participants were given no indication that it was a measure of academic ability (Autin & Croizet, 2012). This test was preset to be difficult enough that all students would fail. The first group then completed the anagram task (Autin & Croizet, 2012). An interview was conducted after
completion to find out about the difficulties the participant faced (Autin & Croizet, 2012). During this interview the experimenter reminded the participants that it was normal for them to experience difficulty and that was the effect of learning (Autin & Croizet, 2012). This was designed to challenge the way the participants looked at difficulty and take away any stigma of academic inability. Afterwards, the participants completed a listening span test (Autin & Croizet, 2012). The second group of participants did not receive the psychological intervention before completing the same difficult anagram task. Once finished, the participants did the same interview but the experimenter did not make any comment on expectations of difficulty (Autin & Croizet, 2012). The experimenter stated that it was their goal to study “resolution strategies” (Autin & Croizet, 2012, p. 611). The participants then completed the same listening span test as the first group. The third group did not receive the psychological intervention, nor did they complete the anagram task (Autin & Croizet, 2012). The only task that the third group did do was the same listening span test completed by the first and second group (Autin & Croizet, 2012). The listening span task involved listening to sentences and determining whether they made sense or not as well as remembering the last word (Autin & Croizet, 2012). After a series of each sentence length, the participant was asked to repeat the last words of each sentence in chronological order (Autin & Croizet, 2012). The correct number of words recalled determined the WMC score. Standardized national testing scores for each participant were accessed through school administration (Autin & Croizet, 2012).

A mixed analysis of variance (ANOVA) was performed using a 3 (conditions) x 2 (cognitive demand of the task: low [2-3 items to remember] vs. high [4-5 items to
remember]) with the last factor as a repeated measure (Autin & Croizet, 2012). This ANOVA determined that the WM scores decreased as the cognitive demand increased ($p=.01$), and condition was also found significant ($p=.03$) (Autin & Croizet, 2012). A two orthogonal contrast was used to deconstruct the effect of the condition factor (Autin & Croizet, 2012). This found no interaction between condition and cognitive demand. These data suggest that the participants who experienced the psychological support regarding academic difficulty performed higher on the WM span task than the second group that did not receive it ($p=.01$) (Autin & Croizet, 2012). An interaction between the intervention and the demand of the tasks was found suggesting that the “reframing” became more important as the demand of task got higher ($p=.04$) (Autin & Croizet, 2012). Autin and Croizet (2012) suggest that WM can be improved with a 10-minute non-intensive intervention that targets the way an individual perceives academic difficulty and that the standardized way of assessing WMC could be miscalculating WMC based on an individual’s internal messages and stress levels.

The second study was used to determine if the perception of difficulty as a positive learning experience could improve other high WM dependent activities such as reading comprehension (Autin & Croizet, 2012). Another goal of this study was to see if success instead of failure would have an impact on reading comprehension achievement (Autin & Croizet, 2012).

A sample of 131 sixth graders was used (65 boys, 66 girls). Socioeconomic status was determined by parental occupation. Participants were randomly assigned to one of four groups: difficulty with reframing, difficulty without reframing, standard, or success (Autin & Croizet, 2012). The groups were treated the same as in the first study with the
exception of the added success group. Participants in the new “success” group were given
the anagram test at a lower level that allowed all to complete all questions (Autin &
Croizet, 2012). There was also no “reframing” intervention with this group. A national
standardized test (designed for grade 7 students) was used for the reading comprehension
measure and administered so that students had 12 minutes to read and answer questions
based on the text provided (Autin & Croizet, 2012).

Data from the second study used a 4 (difference conditions) between-participant
ANOVA (Autin & Croizet, 2012). The analysis supported the hypothesis that the
participants in the intervention/”reframing” group performed significantly better than the
other three groups on the reading comprehension task ($p=.008$) (Autin & Croizet, 2012).
There was no significant difference between the achievements of the participants in the
other three groups. These data suggest that students who learn that having difficulty is a
normal part of the learning process will be able to outperform others on WM based tasks
than, say, those with the motivation from previous success (Autin & Croizet, 2012).

The goal of the third study was to determine if this change in metacognition and
learning affected self-image (Autin & Croizet, 2012). It was hypothesized that
“reframing” difficulty in academics would lower rates of poor self-image (Autin &
Croizet, 2012). The sample consisted of 68 6th graders (38 girls, 30 boys); 32% SES was
determined high, 21% intermediate, 25% low, unavailable for the remainder 22%. The
students’ SES was determined based on parental occupation. The participants were
randomly assigned to one of two conditions: difficulty with reframing or difficulty
without reframing (Autin & Croizet, 2012). The beginning of the study was the same as
the previous two studies with the groups completing the same anagram tasks. Upon
completion, they were asked questions regarding the difficulties faced in the task, but only the first group received reframing comments from the experimenter. After the interview, all participants completed a difficult reading comprehension standardized test. The test involved having 10 minutes to read and answer questions based on the provided text (Autin & Croizet, 2012). A self-descriptive task was completed after the reading comprehension (Autin & Croizet, 2012). From a pretest involving 25 sixth graders, five positive traits of high achievers, five negative traits of low achievers, 10 control traits related to warmth, five traits related to a good friend, and five traits related to a person a child would not want to be friends with, were chosen to appear in the centre of the computer screen for 2 seconds each (Autin & Croizet, 2012). In this 2-second time frame, participants had to choose whether or not they felt the word described them by clicking a key (Autin & Croizet, 2012). The response time and chose of words were recorded for analysis.

The reading comprehension data from the third study was analyzed using a 2 (condition) between-participant ANOVA (Autin & Croizet, 2012). The participants who received the “reframing” achieved higher scores than the students who did not (p=.05) (Autin & Croizet, 2012). To assess the self-descriptive task, a 2 (condition) x2 (trait valence: positive vs. negative) mixed ANOVA with the two last factors as repeated measures was used and determined no effect of condition, alone or in interaction with other factors (Autin & Croizet, 2012). Positive traits were listed more than negative traits (p=<.001) and an interaction between trait valence and trait dimension was found (p=<.001) (Autin & Croizet, 2012). Latency of response to traits was used to focus on participant self-image. A 2(condition) x 2(trait dimension) x 2(trait valence) mixed
ANOVA was used to analyze mean response times (Autin & Croizet, 2012). This showed a main effect of valence with participants reacting faster to positive traits then negative ones (p<.001) as well as trait dimensions with warm traits being chosen faster than competence traits (p=.01) (Autin & Croizet, 2012). A two-way interaction between condition and trait dimension emerged (p=.01) and when adding the “reframing” condition, the three-way interaction became significant (p=.01) (Autin & Croizet, 2012). Participants in the “reframing” group were faster to discard negative traits on competence (p=.03) (Autin & Croizet, 2012). The participants who thought less of themselves were also the ones who performed poorly on the reading comprehension task (p=.04) (Autin & Croizet, 2012). These analyses suggest that students with higher self-esteem related to academic difficulty and ability, regardless of difficulty experienced, will have better achievement on cognitively demanding tasks such as reading comprehension. One of the suggested reasons is that when individuals begin to focus on their inability and negative self-image, important WM space is being taken up rather than being used on the academic task at hand (Autin & Croizet, 2012).

Autin and Croizet (2012) suggest that making alterations in the way that individuals think about difficulties they experience when learning in a positive way can reduce stress, suppress negative self-thought, increase reading comprehension, and WMC. The three studies presented in Autin and Croizet’s report support that the 10-minute psychological intervention was able to provide immediate results in increasing WMC based on the measures and analysis used. One of the limitations discussed is the lack of cross-cultural application. With learning and difficulty viewed in a variety of ways across cultures, the only cultural application this study would have would be in a
Western society, with a westernized view of academic performance (Autin & Croizet, 2012).

The findings in this report are significant to the development of a handbook for teachers in WM as this provides support for a simple and effective intervention that does not cost money, nor does it take a lot of time. If the results of this intervention can increase WMC, it would be interesting to see what other abilities related to WM are also affected.

The studies explored in this portion of the paper are essential. Programs such as CWMT, and BrainAge are becoming more common. It is also key to note that spending money and having access to a computer are not the only ways in which a teacher or even parent(s) can impact a child’s WM. Interventions such as these are effective, which is what is important for a child’s learning.

**School-Based Resources for Working Memory**

Teacher resources for assisting students with WM issues or concerns are fairly limited. Dehn (2008), Gathercole and Alloway (2007, 2008), and Alloway (2011) are the primary resources specifically addressed to aiding teachers. In these resources, research-based interventions are proposed that cover general classroom guidelines, teaching techniques, and learning strategies to reduce demands on WM for students. For the purpose of this review, commonalities between the resources will be discussed.

Gathercole and Alloway (2008) and Alloway (2011) express the importance of having an educator who can identify when a student’s WM is overloaded. Symptoms may include failing to follow instruction and task abandonment, which are key in identifying when a student may need to take a break and to evaluate how a task can be completed.
with less stress on WM. Teaching strategies and techniques provided in the resources are all associated with good teaching practices. Many require an initial investment of time at the beginning of implementation, but promise that with practice, the efforts will pay off.

The development of metacognition within the learner seems to be key in ensuring that strategies and interventions are continually used (Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2008). For a learner, knowing which strategies, as well as when and how to implement them, is crucial in ensuring that any task addressed will be successful. Ensuring that skills become automatic is also important for easing demand on WM as it increases speed and proficiency (Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2008). When a skill becomes automatic through rehearsal, it requires less thought processing, reasoning, and other cognitive skills that WM has to mediate.

Reading, writing, comprehension, and mathematics are all addressed in detail with explanations as to how WM impacts each process and what can be done to ease demands on WM. This is done to ensure that educators realize how significant WM is to the learning process and daily life. Learning aids are suggested to assist students in language and mathematics including charts, graphic organizers, pre-written instructions, visual cues, and computer programs (Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2007, 2008). Between Gathercole and Alloway (2007, 2008) and Alloway (2011) there are few references to how the interventions and suggestions provided can benefit any subject beyond Language and Mathematics. Dehn (2008) attempts to provide several examples in other subject areas, such as Science and Foreign Languages, to assist educators in seeing the potential and how the interventions can be used.

Gathercole and Alloway (2008) provide examples of student behaviour that show
symptoms of a WM deficit to assist teachers with identifying similar students in their classroom. No additional resources are provided in the chapters relating to the specific topics, but the bibliography in the back of the text is extensive for providing additional texts for specific topics. The literature and chapter reviews are short and to the point which is essential for teachers with limited time. The explanation and attention given to division of intelligence quotient (IQ) and WM is well laid out with a graphic explanation.

Alloway (2011) discusses WM as it relates to different learning disabilities and conditions including reading, mathematics, dyspraxia, ADHD and Autism. Alloway provides excellent behaviour profiles that show typical symptoms of WM deficits in students. As teachers do not implement any type of psycho-educational testing, a chapter on the different types of tests and how to diagnose WM seems irrelevant.

While Dehn’s study (2008) is extensive in literature review, research, theory, diagnosis, and intervention, it provides an overwhelming amount of information that a teacher might not have time to read thoroughly. The chapters specifically related to explaining what WM is and how it works, disorders and conditions, academic learning, and interventions provide comprehensive data and related information for teachers. Dehn goes beyond discussing how WM affects ADHD and Autism as he also includes cognitive disabilities such as schizophrenia, Down’s syndrome, acquired brain injuries, stress, and age. While Down’s syndrome and brain injuries are not often seen outside a special education classroom, it is important to educate teachers in how WM affects these students in order to understand their conditions.

Within teacher education and resources, WM and its significance to learning is severely under-acknowledged. Alloway (2011), Dehn (2008), and Gathercole and
Alloway (2008) provide much-needed information for classroom teachers. These resources are not age or grade specific and the information provided is heavily biased in United Kingdom and United States data and school systems. There is currently no evidence to suggest that a WM resource or handbook has been published or provided for Canadian teachers that is relevant to their teaching division. With cognitive processes continually advancing through a child’s age development, a detailed resource specific to the student’s age range would be appropriate for their teacher in order to provide the structured and supported learning environment required for optimal learning.

**Chapter Summary**

The content explored in this chapter is meant to provide the reader with a thorough overview of what WM is as well as current theories and research. With so specific statistics related to WM, it is hard to estimate how many children in the current Ontario and Canadian school system currently face issues with deficits. Kohen et al. (2006) as part of Statistics Canada’s Health Analysis Measurement Group do clearly state that many of the identified children with SLDs have problems accessing support of any variety within their classroom and school. This is a statistic that needs to change and it will not be solved with just money. Educating teachers on WM and how to support students with deficits will create a significant change in what happens in these classrooms. Studies indicate that children who show deficits in working memory are those with dyslexia, dyscalculia, dyspraxia, ASD, ADHD, and Williams and Down’s syndromes.

Currently the most effective way to identify and measure WM is through battery testing. The most commonly occurring batteries for WM shown in research are the WJ III
and the AWMA. These batteries assess cognitive abilities and can provide explanations as to why students have the difficulties they currently experience. These batteries are based on theories such as the CHC theory and Baddeley’s WM theory. Within CHC, WM is considered a narrow ability in Stratum III subsumed by STM in Stratum II. The CHC’s definition of WM is comparable to Baddeley’s with WM being described as “a system for holding information and allowing it to be used to perform a wide range of cognitive tasks, including transfer into, and retrieval from, LTM” (Baddeley, 2006, p. 4).

There is a growing source of academic resources that extend beyond basic information for parents and teachers. Collections of work relating to WM by specialists in the field are becoming more common. Research related to WM assessment and correlations to learning difficulties advocates that WM is a cognitive ability that needs to be more prominent in a classroom.

Connections between WM and math abilities, reading span and comprehension, behaviour related to shifting and inhibition, difficulties creating cues to search LTM for retrieval of information, and issues related to children with ADHD with less WMC, all show how relevant WM is to learning. It is important to provide teachers with support and strategies in order to help children with these kinds of issues.

In recent years there has been a rise in computer-based interventions. Cogmed’s CWMT and BrainAge are the two more common WM training based interventions on computers that have been used in research. Another program, Luminosity, a brain-training program online, is becoming easily accessible by the general public. More research needs to focus on comparing these types of programs to ensure that the cost, time and effort being put into these interventions are worth it.
There are currently no teacher-focused resources that are based in North America. All book resources disused and found online come from the U.K. with U.K.-based statistics and references. The closest resource that meets this criterion is Dehn (2008) who has created an extensive resource related to WM covering everything from inception of ideas to types of measures for WM. While the content in this reference is excellent, the process of reading it for a teacher may be overwhelming. Due to constraints on a teacher’s time, having a reference book that is to the point and only relevant to what a teacher needs would be momentous.

The data and information collected in this chapter lend support to the claim that a handbook needs to be created specifically for Junior and Intermediate teachers to help them help their students with WM deficits. This type of reference book would aggregate concise information on the subject, saving teachers time and frustration while providing their students with the skills and strategies to be successful in school as well as life.
CHAPTER THREE: METHODOLOGY

This chapter describes the methodological process that was used to create *Working Memory in the Junior/Intermediate Classroom*. Information regarding the needs assessments, school boards, teachers, and assessment of the handbook will be discussed followed by an overview of the chapter.

**Process of Development for the Handbook**

The goal of this project was to create a handbook for teachers on WM. With this in mind, an extensive review of current research relating to Baddeley’s WM theory, WM and CHC theory, assessment, correlations, interventions, and teacher resources was undertaken. Throughout the literature, growing support for students with WM deficit was discovered through suggestions for interventions and strategies for improvement. These suggestions and strategies were collected in order to provide the users of the handbook with tips that were based on current empirical research.

In order to further guide the creation of a handbook that addressed WM concerns, a needs assessment was used to collect data from Junior/Intermediate teachers. This qualitative assessment included short-answer questions in order to find out what teachers already knew and needed to know about WM. Each question focused on answering one of the following research questions: (a) What evidence do junior and intermediate teachers have of working memory deficits among their students? (b) How are they prepared to deal with these behaviours? (c) What kind of additional support and information do they need? The answers to these questions guided the handbook in order to ensure that it is appropriate for the Junior/Intermediate setting and met the concerns expressed by teachers. The researcher drafted the needs assessment and in order to ensure
that the needs assessment is reliable and valid, the Advising Faculty conducted a series of reviews. After several revisions, the Brock University Research Ethics Board reviewed the application, needs assessment, informed consent letter, and letter of invitation and clearance to proceed was granted (File 13-260 SAVAGE). Ethical clearance has also been received by two school boards in Southern Ontario.


The objectives of the handbook are:

1. Educators will identify characteristics of students struggling with WM issues.
2. Educators will identify strategies that support WM to help their students learn.
3. Educators will adapt their classroom practices in order to ease students’ WM
4. Educators will evaluate the handbook for functionality, effectiveness, and relevance to a classroom setting.

Needs for the Handbook

After reviewing the available research on WM and its impact on learning, classroom behaviours, interventions, and teaching resources, it became evident that there was something missing in today’s classrooms: real awareness of the role of WM by teachers and proactive interventions to benefit all students. While the research suggests clear connections between WM and learning, it also showed that many researchers are actively trying to find ways to accommodate for students with deficits. The question still remained: What are teachers doing about it?

During teachers’ education and professional development related to teaching children, WM and executive functioning is often the disregarded (van der Donk et al.,
2013). How do you teach about something related to learning that is difficult to identify and linked with learning disabilities? While looking for information regarding WM in the classroom and how to address it, it was discovered that there were limited resources specifically designed for teachers. The only resources available were either too large or complicated for the busy teacher lifestyle, only available overseas, or did not provide connections to the Canadian classroom due to being based in the United Kingdom. With WM being highly significant to students with LD and other cognitive disorders, it was felt that the lack of resource was unacceptable.

**Needs Assessment for the Handbook**

Before developing a handbook, a needs assessment was used to identify what kind of appropriate information should be included. The needs assessment (Appendix A) was completed by seven teachers.

**Participants of the Needs Assessment**

The sample of participants (two male and five female) was a convenience sample of the targeted population (i.e., mainstream teachers in the junior and intermediate divisions). After the school boards agreed to allow their teachers to complete the needs assessment, volunteers meeting the criteria (junior/intermediate teachers) were asked to volunteer. Volunteers were contacted via email to ensure that the criteria were met and to identify their school location in order to drop off the consent form and needs assessment. The needs assessments were returned anonymously so none of the data collected can be traced back to any specific participant.

**Description and Duration of the Needs Assessment**

The needs assessment was a questionnaire that consisted of eight questions and a
comment section. The questionnaire focused on what the participants already knew about WM, WM and their students, as well as how to help their students with WM issues. Educators in two Southern Ontario school districts completed the needs assessment. Five questions were short answer, one was a direct yes or no question, and two were yes or no questions followed by a request for additional information if applicable.

First, the participants were asked to define in their own words what WM was. They were then asked what strong WM look like in a classroom and what the differences in behaviour and academic ability would be from average WM developing students. The participants then considered the same question while thinking of a student with a WM deficit and how he or she would compare with an average WM developing student. The participants were asked to list any strategies known to them about helping students overcome WM issues. Participants then commented on whether or not they have received resources, readings, or professional development that related to WM deficits and if they knew who to turn to in their school for assistance. At the end, participants identified the type of information they would like to see in a handbook directed to teachers.

Once participants had expressed an interest in the research and provided their school location, a copy of the needs assessment, informed consent form, and a cover letter were delivered to their school. The researcher went back a week later to collect the responses and a copy of the informed consent form sealed in an envelope from the school secretary. The informed consent form and needs assessment were in separate envelopes and not opened until all required paperwork from all participants were collected. Even the researcher does not know which needs assessment belongs to a given participant.
Findings of the Needs Assessment

Below is a detailed account of the responses to the needs assessment questions by all participants. Each needs assessment was given number in order to correspond each answer from the same set of responses.

Question 1. The first question asked participants to “Please describe in your own words what working memory is.”

There was a variety of understanding from participants. Participant 1 gave a broad and basic example of how WM could be used (performing regular tasks), but did not specify beyond that. While WM is used to learn how to do regular task, the automatic act of the task does not belong in WM (Dehn, 2008).

All other participants identified that WM has something to do with holding information, manipulating it and applying it, either through tasks such as mathematics, or recalling facts. Some key phrases from the responses include: active memory, perform cognitive tasks, where information is stored, memory and attention ability mixed together, and filing cabinet for visual and verbal information. Participants 2 and 5 specifically related it to STM and also mentioned cognitive and executive functioning. Participants 7, 6, 4, and 2 commented on how WM dealt with current and immediate information.

Question 2. The second question asked participants to answer the following queries: “How would a student with strong working memory capacity present in the classroom? How would the student’s behaviour and academic performance differ from students with average working memory capacity?”

All participants were able to accurately describe a student with a high WMC.
Behaviours identified included: following instructions accurately; juggle demands of a classroom without frustration; better comprehension of language, math, and science; work independently; does not disrupt others; finish work faster; quickly summarize information; and retrieve information easily with a higher rate and quality of recall.

Based on these responses the participants are able to identify students with normal to high WMC. While some of these characteristics such as following instructions, working independently, and not disrupting others may be applicable to normally developing students, the others are adequate descriptions of a higher functioning WM child.

**Question 3.** The third question asked participants, “How would students with working memory deficits present in the classroom? How would the student’s behaviour and academic performance different from students with average working memory capacity?”

All participants had an accurate understanding of how a WM deficit student would behave in a classroom. The following descriptions were used: problems remembering facts; acting out; frustrated; asking questions to previously answered questions; less able to pay attention; day dreamer; engage in more off-task behaviour; experience road blocks and clunk moments; difficulty completing assignments; slower to make connections with prior learning; struggles with organization and prioritizing; and avoids tasks.

Participants 2, 4, and 6 commented on being distracted. Participants 4, 6, and 7 expressed having low WM students experiencing frustration. Participants 3, 4, 5, and 7 identified struggles with initiating and completing tasks.

**Question 4.** The fourth question asked, “Are you aware of any strategies that can be used to help students with working memory deficits? If so, what strategies are you aware of?”
Participant 7 noted that they did not know any specific strategies related to WM, but they did teach using mnemonics, which they thought might help. Participant 1 only listed memorizing facts and seemed unconfident with that strategy as it concluded with a question mark. Participants 3, 4, 5, and 6 identified the strategy of chunking. Participants 2, 5, and 6 recommended giving instructions in a variety of ways/multimodal processing (visually, orally, etc.). Participants 2, 4, and 6 suggested using checklists or step-by-step instructions. Other strategies mentioned by participants included note-taking, highlighting important information, and manipulations to help with retrieval.

**Question 5.** The fifth question asked participants, “Have you received any readings or classroom resources on working memory or working memory deficits? Yes/No. If yes, please describe what type of resources.”

Five participants (1, 2, 3, 4, and 6) said no to being provided with readings or classroom resources. Participant 7 identified not being given anything specific to WM, but had been given vague ideas from an educational psychologist consultant. Participant 5 said that they were given articles that outlined classroom interventions for students with this profile.

**Question 6.** The sixth question asked, “Have you received any professional development (PD) to help you prepare and work with students with working memory deficits? Yes/No. If yes, please describe what type of PD.”

Six participants (1, 2, 3, 4, 6, and 7) identified not having received professional development related to WM. Participant 5 identified yes and commented that this was done through their Additional Qualification courses in Special Education Part 1, 2, and 3, which were all completed with the participants own financial resources.
**Question 7.** The seventh question asked participants, “Are you aware of a colleague at your location that could assist you with any student working memory issues or concerns? Yes/No.”

Two participants (1 and 4) identified that they would not know who to ask for help with students with WM concerns. Two participants (2 and 5) answered yes. Participants 3 and 6 answered yes with identifying that they believed that a SERT (Special Education Resource Teacher) would have resources. Participant 6 also identified Learning For All Coaches and Special Education Consultant. Participant 7 answered yes identifying that they would use a SERT as well but believed their knowledge would be vague and would not help in the classroom.

**Question 8.** The eighth question asked, “What would you appreciate being included in a written resource for teachers in relation to students’ working memory?”

All participants except for Participant 4 gave suggestions. Participant 1 asked for how to use it for academic purposes. A summary and research about WM was asked for from Participant 2. Participants 2, 3, 6, and 7 asked for clear, practical, and effective suggestions/strategies for the classroom. Reproducible forms and organizers were important for Participant 2. A checklist for characteristics, quick screening tools, and diagnostic assessments were identified by Participant 6. Participant 5 asked for typical profile characteristics and how to link classroom support with home guidance for parents. Participant 7 wants strategies that are useful in small groups in order to teach more than one child at a time.

**Comments**

Participants were then asked to provide any additional comments or suggestions.
regarding students’ working memory. Four participants (1, 3, 5, and 6) did not leave any comments. Participant 2 commented on wanting to know more about the correlation between WM deficits and attention deficits. Participant 7 expressed concern regarding time accommodations for these students and felt not every student needs to complete the same work. Participant 4 commented that they thought this handbook was a great idea and very much needed.

The responses provided in the needs assessments suggest that there is a diverse understanding of what WM is, how it impacts learning, and what strategies can be used to help deficit students. One participant who was confident in their knowledge about WM had completed Additional Qualification course, which they paid for. This suggests that none of the participants had been given adequate resources or information from their school board or SERT. The participants had a good understanding of how high and low WM would manifest in a student and gave 10 different strategies that they can use in a classroom. Diverse suggestions of what to include in the handbook was provided by the participants that will guide its development.

**Implementation of the Handbook**

With WM being present in all classrooms, there is no restriction to the type of classroom or kinds of students a teacher must have in order to be able to benefit from reading *Working Memory Strategies for the Junior/Intermediate Educator: A Handbook*. At the same time, administrators, parents, social workers, and any person who deals with children may find this handbook to be of use.

The handbook provides an outline of current WM theory, explains how it impacts learning, and provides suggestions and strategies for teachers to help their students with learning and everyday life.
**Educator Evaluation of the Handbook**

The same participants who completed the needs assessment were approached to review the *Working Memory in the Junior/Intermediate Classroom* handbook. This evaluation was based on accessibility, organization, quality, and usefulness of information provided in the handbook. As the responses from the needs assessment influenced the creation of the handbook, it was only appropriate to use the same participants. This ensured that the handbook met their required needs as classroom teachers in this field. The evaluation was a short questionnaire with open-ended questions to provide generalized comments. The responses are discussed in chapter 5.

**Chapter Summary**

While special education is of rising concern, inclusive classrooms where all styles, types, and methods of learning are being embraced are continuing to grow in numbers. Many teachers are not prepared, nor do they have the knowledge of how to support learners with WM deficits. While students with WM deficits are sometimes difficult to identify, due to developed coping strategies or behaviour by the child, deficits are present in all classrooms and require support. It became clear that a handbook that filled this gap in teacher professional development was necessary. A needs assessment completed by seven teachers in the junior and intermediate divisions helped to guide the requirements of the handbook and identify where teachers need assistance most. Responses from the needs assessment suggest that while some teachers seem to have a solid understanding of what a WM deficit looks, many do not know where to go to get assistance for these students, nor are they provided with any additional resources through their school board. In order to ensure that the handbook meets the criteria of teachers, the same participants will provide an evaluation of the book based on its objectives.
CHAPTER FOUR: WORKING MEMORY STRATEGIES FOR THE JUNIOR/INTERMEDIATE EDUCATOR: A HANDBOOK

This chapter presents *Working Memory Strategies for the Junior/Intermediate Educator: A Handbook*, which was created to help educators identify characteristics of students struggling with WM issues and strategies that support WM to help students learn, and to adapt their classroom practices in order to ease students’ WM. A variety of resources contributed to the creation of the handbook including empirical research, journal articles, needs assessment and feedback from junior/intermediate teachers, and resource books.

The handbook begins by explaining what WM is in an analogy and describes how the book is structured. Chapter One explores theories related to WM that include Baddeley and CHC Theory of Cognitive Ability, how WM is structured with a breakdown of each compartment’s role, and how WM relates to IQ. Chapter Two focuses on how WM looks in children through different stages of development and at different capacity levels. Chapter Three describes the identification process, provides an observation guideline for teachers to use when concerned about students, and strategies for working with students who need to reduce their WM load without specific concerns related to other conditions. Chapter Four bridges common classroom conditions with the current understanding of WM. Specific conditions that are focused on include reading, dyslexia and language impairment, dyscalculia and math impairments, dyspraxia/movement, ASD, OCD/anxiety, and ADD/ADHD. Chapter Five outlines useful resources, suggestions on how to work with parents, and different provincial and national organizations that can assist children, parents, and teachers with any conditions mentioned in the handbook.

Kathryn Haynes
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Introduction

This book was written to give guidance and support in working memory for teachers in the junior and intermediate divisions. With growing research into how working memory affects learning, it is important to ensure that we, as educators, are armed with the most current knowledge and strategies to help our students.

Through research, it has come to my attention that not all teachers are given professional development or resources related to working memory. This handbook is meant to fill the gap and ensure that one of the brain’s most vital functions related to learning is covered for Ontario teachers.

I know how easy it is for students with difficulty in working memory to be overlooked or not noticed in an inclusive classroom. These students are good at creating their own strategies to hide their difficulties. Let’s make sure that we can spot them, and help them!

Working Memory

Think of using your working memory like a juggler. Jugglers pass balls between their hands. Think of these balls as spurts of information. Novice jugglers start with one ball. As experience increases, more balls are added into the circuit. Jugglers need to focus and concentrate in order to ensure that all the balls flow from one hand to the other. When the juggler gets distracted and drops a ball, that ball is gone and cannot be picked up again, but another ball can be added into the circuit. Some jugglers will only ever be able to handle 3 or 4 balls, while some may be able to handle 7 or 8. Our working memory holds information and rehearses it to ensure that it is remembered for when we need it. In our working memory, we are typically able to hold 3-4 chunks of information. Some people can hold more and some people will hold less.

This Book

Knowing that a teacher’s spare time is often rare, I have designed this handbook to take as little of your time as possible.

Chapter 1, Theory Behind Working Memory, is meant to give you an understanding of what working memory is, how it works, and relates to learning.

Chapter 2, Working Memory in Action, is to provide you with profiles of a child with normally developing working memory, a deficit working memory, and a high capacity working memory. This will help guide you in identifying students that may need more assistance.

Chapter 3, General Classroom Strategies, will provide general suggestions to implement in your classroom for every student and specific strategies that will improve working memory.

Chapter 4, Working Memory & Other Common Conditions, will provide you with an understanding of how working memory issues are present in common classroom conditions such as dyslexia, dyscalculia, ASD and ADHD. Strategies and suggestions for the classroom will also be given for each condition.

Chapter 5, Working with Parents & Other Sources, is where you can find additional information about working memory and how to work with parents.
Chapter One:
The Theory Behind Working Memory
Baddeley's Working Memory
& CHC Theory of Cognitive Ability

Baddeley's Working Memory:

Baddeley and Hitch developed a theory related to how memory works. They proposed that working memory and the model outlined were responsible for immediate storage and manipulation of information in the mind. After years of being challenged and supported, it is still the most accepted and used theory related to working memory (Dehn, 2008).

The current model (recently adapted by Baddeley) consists of the central executive and two subsystems called the phonological loop and visuospatial sketchpad. The episodic buffer component works between the central executive and the subsystems as well as interacts with long-term memory (Baddeley, 2006). The current system looks like this:

CHC Theory of Cognitive Ability:

Cattell-Horn-Carrol theory of cognitive ability, otherwise known as CHC, is a cognitive hierarchal framework that separates general intelligence, broad abilities such as short-term memory, and narrow abilities such as working memory (Dehn, 2008; Proctor, 2012).

General intelligence sits at the top of the framework in what is called Stratum I. In the middle, called Stratum II, there are 10 broad abilities that include crystallized intelligence, fluid intelligence, quantitative reasoning, reading and writing ability, short-term memory, long-term memory, long-term storage and retrieval, visual processing, auditory processing, processing speed, and decision/reaction time (Proctor, 2012). Within each of these broad abilities lie subcomponents, which are called narrow abilities (Dehn, 2008; Proctor, 2012). The difference between the two is that broad abilities are general while narrow abilities develop more specifically to personal experiences and learning. There are currently 70 recognized narrow abilities (Proctor, 2012).

When our students undergo battery testing for learning disabilities, most of the common tests are based on CHC (Flanagan et al., 2013). They take into consideration how all of these abilities function through the different tasks. Many of these abilities have been connected with learning, but the one that has shown the most general significance is working memory (Dehn, 2008)
## Components of Working Memory

<table>
<thead>
<tr>
<th><strong>Central Executive</strong></th>
<th><strong>Episodic Buffer</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The central executive deals with mental activities and cognitive functioning (Baddeley, 2006). It is used when data is being processed, stored and retrieved. It is believed that the main functions include: focusing attention, which allows focus on the relevant information and ignoring disruptions; dividing attention, which allows coordination or multiple activities in a single timeframe; decision and implementation of plans; moving attention between tasks, and linking the current coded information within WM with the coded information in long-term memory (Baddeley, 2006). With the central executive doing all of this, it is common for it to become stressed and overloaded (Dehn, 2008). This is when you find distractions harder to ignore.</td>
<td>The episodic buffer is used as a go-between for the central executive, visuospatial sketchpad, phonological loop, and long-term memory (Baddeley, 2006). Any access the buffer has to the subsystems goes through the central executive. Information can be quickly lost from the buffer if it becomes distracted (Baddeley, 2006). It is believed to be the basis of conscious awareness as it combines current information and prior knowledge into the present (Dehn, 2008).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Visuospatial Sketchpad</strong></th>
<th><strong>Phonological Loop</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The visuospatial sketchpad is responsible for storing images, pictures, and information about locations and is commonly used for math skills, learning language, and remembering events and patterns (Baddeley, 2006). It is temporary storage and it actively rehearses information to prevent decay (Dehn, 2008). If the information is not rehearsed it can decay within seconds. The visual component is responsible for static information such as objects, shapes and colours, whereas the spatial storage focuses on motion and directions (Dehn, 2008). It is believed to have connections with motor function. The sketchpad and central executive work together to produce and manipulate mental images (Dehn, 2008). The phonological loop is important to the sketchpad, as verbal coding of visual objects is needed in order to rehearse and retain information as cognitive development increases (Baddeley, 2006).</td>
<td>The phonological loop rehearses and stores information related to spoken language including numbers, words, and sentences, and remembers instructions (Baddeley, 2006). It is divided into two mini loops; a temporary, passive storage compartment and a sub-vocal, articulatory rehearsal loop. Items being rehearsed can be easily forgotten within two seconds, regardless of age (Dehn, 2008). The loop contributes to other skill acquisition such as reading, text comprehension, and grammar (Dehn, 2008). Information that is put into the system and gets coded and matched with meaning representations in long-term memory (Baddeley, 2006). Putting words together to create a sentence and have meaning is the responsibility of the central executive (Dehn, 2008).</td>
</tr>
</tbody>
</table>
Working Memory Vs. IQ

Intelligence testing is based on prior knowledge that can be influenced by many factors in an individual’s life including socio-economic status (Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2008). Many measures of IQ combine scores related to a variety of abilities and relate them to other age-specific groups, but does not specifically measure abilities related to memory (Dehn, 2008). Intelligence testing in schools has declined due to the inconsistency of predicting academic success of students (Alloway, 2011; Gathercole & Alloway, 2008).

This is where working memory comes in. Working memory specifically measures capacity and abilities related to the memory systems and are a reliable predictor of learning potential. Working memory tests provide all the necessary information to complete the tasks, and the answers are based on the individual’s ability to manipulate that information (Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2008). This means that any age and background of student can complete the testing without being disadvantaged beyond their own abilities.

There are some connections between IQ score and working memory ability, as often a low score will reflect in low ability and vice versa (Dehn, 2008). This connection is not always the case as many individuals can have an average IQ and still have difficulties with academics. Some intelligence testing is starting to incorporate working memory measures into their tests in order to provide a more comprehensive assessment of abilities (Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2008; Flanagan et al., 2013).
Chapter Two: Working Memory in Action
Typical Working Memory Development

Each person's working memory develops at a different rate. Within one classroom it is possible for there to a 6-year range of working memory abilities (Alloway, 2011). For that reason, the main developments are outlined based on ages that are outside the Junior and Intermediate divisions to help you identify where some of your students might be (Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2008).

<table>
<thead>
<tr>
<th>Age/ Range</th>
<th>Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preschool On</td>
<td>Short-term memory span and working memory development are interrelated and a heavy dependance on the phonological loop for memory.</td>
</tr>
<tr>
<td>3</td>
<td>The phonological loop memory is established.</td>
</tr>
<tr>
<td>4</td>
<td>All working memory components are in place, remembering 2-3 words in a sequence, typical number recall in order is 3 digits, and backwards recall in sequence is 2 digits.</td>
</tr>
<tr>
<td>5</td>
<td>Beginning to store information visually, can recall 1 item (such as an instruction), and can repeat 3 words in sequence.</td>
</tr>
<tr>
<td>5-11</td>
<td>Has a visuospatial capacity of 4-6 ‘pictures’.</td>
</tr>
<tr>
<td>6-8</td>
<td>Uses verbal short-term memory to remember visuospatial information as visuospatial encoding begins.</td>
</tr>
<tr>
<td>7</td>
<td>Can recall 2 items (such as instructions) and a conscious application of remembering strategies begins to develop.</td>
</tr>
<tr>
<td>7-8</td>
<td>Spontaneous rehearsal begins.</td>
</tr>
<tr>
<td>9</td>
<td>Can repeat up to 4 words in a sequence and will have issues inhibiting irrelevant data from interrupting rehearsal.</td>
</tr>
<tr>
<td>10</td>
<td>Can recall up to 3 items (such as instructions), consistently uses verbal rehearsal, information is stored verbally rather than visually, visuospatial rehearsal is done through verbal rehearsal, speech rate is 3 words/second, and is able to recall 4 words heard in a second.</td>
</tr>
<tr>
<td>11</td>
<td>Can repeat up to 5 words in sequence.</td>
</tr>
<tr>
<td>12</td>
<td>Number of recall digits increases to 6.</td>
</tr>
<tr>
<td>14</td>
<td>Can recall 4 items (such as instructions) and should be better at disregarding irrelevant disruptions.</td>
</tr>
<tr>
<td>14-15</td>
<td>Processing reaches adult levels.</td>
</tr>
<tr>
<td>15</td>
<td>Backwards digit recall is between 4 and 5.</td>
</tr>
<tr>
<td>15-16</td>
<td>Adult levels of working memory are reached.</td>
</tr>
<tr>
<td>16</td>
<td>Digit recall stops at 7 or 8.</td>
</tr>
</tbody>
</table>

High Capacity Working Memory

Students who have higher than average working memory capacities are the ones who complete tasks quickly, do not need reminders, attain skills with ease, and retain knowledge easily. These students are often deemed as gifted. Do not let this fool you though as it is possible to have a gifted student who does get off task and appears to have attention issues that are not ADD or ADHD related (Dehn, 2008)
Deficit Working Memory

For the purpose of this handbook, a deficit in working memory will refer to drastically lower than average working memory capability compared to normal development in similar age groups. It is possible to have a working memory weakness where lower capacities are present but still comparable to age-similar peers (Alloway, 2011; Gathercole & Alloway, 2008). There are two ways that a deficit in working memory may be present; cognitive processing and capacity (Dehn, 2008). Capacity is limited but can be stretched over time. Working memory is closely related to attention, phonological processing, executive functioning, fluid reasoning and processing speed (Flanagan et al., 2013). Having a deficit in working memory may affect these cognitive functions (Flanagan et al., 2010). At the same time, if someone has strong cognitive functions, support can be given to working memory and hide symptoms of issues.

Skills that depend on working memory and will suffer when there are delays include reading decoding, reading comprehension, written expression, and mathematics (Alloway, 2011; Baddeley, 2006; Dehn, 2008; Gathercole & Alloway, 2008). Listening to a teacher talk and writing notes at the same time will be extremely difficult, as well as writing sentences from memory and mental arithmetic. The information gets lost very quickly in the mind from either distractions (such as the next sentence heard) or not enough rehearsal in the mind. Once the information is gone, it cannot be recalled (Dehn, 2008).

A deficit or weakness in working memory will be in combination with other learning disabilities (Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2008). It is rarely on its own. It can also be the difference between a slow learner and a learning disabled child. Children with working memory issues are often mislabeled in schools as having 'ADD-type tendencies'. This is when the working memory will have a hard time inhibiting irrelevant stimuli (Gathercole & Alloway, 2008). A child may forget what to do next and instead of asking a teacher or peer, they get distracted by another task such as a game, something in their desk, or what someone else is doing. Many teachers find this frustrating as some off-task behaviour is difficult to spot in a room of 30 other children and then the missed work needs to be completed at home or during recess.

In a child with a deficit in working memory, you will see delayed development when compared to the outline provided on the previous page. It is believed that these children will never be able to ‘catch up’ to normally developing children at any point in their maturity (Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2008). If they are two years behind at the age of 6, they will continue to be behind by two years at the age of 12. This does not mean that interventions and strategies will not help. Strategies and interventions will ease the load on working memory and allow for easier recall of information.

Four common signs of a working memory overload is a person’s inability to remember instructions, follow instructions without forgetting, remember what instructions they have completed or not, and stay on task. Keep an eye out for these signs with your students on a regular basis. When a student forgets something and does not know what to do, it often results in frustration and task abandonment.
Chapter Three:
Identification, Suggestions, & Strategies
Identification

So you have read through Chapters 1 & 2 and believe that you may have a child in your classroom that has issues with working memory? If your student has already been identified, ask for documentation from your Special Education Resource Teacher (SERT) or Learning Resource Teacher (LRT) to see if working memory was assessed. If it was, you already know what the child’s scores are like and if they are low or below average, we can now work on finding strategies to help them. Find your student’s strengths and weaknesses and use them when planning exercises and activities.

The three most common assessment batteries for WM are the Wechsler Intelligence Scale for Children (WISC), Woodcock Johnson Cognitive Ability Test (WJ Cog), and the Automated Working Memory Assessment (AWMA) (Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2008). The results from the assessments used should outline the student’s scores and percentiles as well as their strengths and weaknesses. If you have any questions while reading through the psychologist report, consult with your school’s SERT or LRT for further clarification.

If you are thinking of a child that has not been identified yet, then we need to look for some signs. Refer to the Working Memory Deficit outline on page 10 for an overview.

To guide you in your observations, the following are two identification charts that you can photocopy and use for different children. These charts go through the main characteristics of a working memory deficiency. When complete, take this information to your school’s SERT or LRT to discuss with the school team, and talk to the parents about what you have noticed. For more recommendations when working with parents, see Chapter 5.

Make sure you look at all aspects of the student’s academics. If you do not teach all subjects, talk to the other teachers. Share the checklist. Remember that if a student is having issues with their working memory, they are most likely having issues in areas such as reading, comprehension, language, and mathematics. How are they doing compared to typically developing students at the same age?

If having an official student assessment is not an option, there are programs and assessments that have been developed that allow teachers to complete them without the aid of a professional. One of these assessment tools is the AWMA. It is a computer program that can be purchased and runs automatically. Some schools have purchased this program and use it in early screening for at-risk students. This program does come with a price tag but can be easily purchased through Pearson.
**Academic Related Characteristics**

Make your observations during challenging activities for the student. If you have difficulty rating the student, compare them to a typical student in the same grade.

Does the student:

<table>
<thead>
<tr>
<th>Question</th>
<th>Never (0)</th>
<th>Rarely (1)</th>
<th>Sometimes (2)</th>
<th>Often (3)</th>
<th>Always (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take a long time to recall information</td>
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<td>Have issues expressing idea either orally or written</td>
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<td>Have issues elaborating responses when asked to</td>
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<td>Have issues completing mental tasks (spelling/ math)</td>
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<td>Use fingers for counting</td>
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<tr>
<td>Make poor academic progress compared to others</td>
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<td></td>
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<tr>
<td>Fail to monitor own work (spelling, poor organization etc)</td>
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<tr>
<td>Lack creativity in problem solving</td>
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<td>Have issues memorizing facts</td>
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<tr>
<td>Make basic counting errors</td>
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<tr>
<td>Have issues noticing the different between symbols during equations (ex:</td>
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<td>+ - x /)</td>
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<td>Have issues using strategies spontaneously and consistently (ex: whispering, think a loud, grouping, clustering, etc.)</td>
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<tr>
<td>Prefer simple solutions to issues</td>
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<td>Have difficulty rephrasing content</td>
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<tr>
<td>Require rereading of text for comprehension</td>
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<tr>
<td>Loose place when reading</td>
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<tr>
<td>Find learning a second language difficult</td>
<td></td>
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</tbody>
</table>

**Total marks = ___________ (A)**

*Disclaimer* This chart is not an officially recognized reference tool for diagnosing WM issues. Please consult with a professional for an official diagnosis.
Behaviour Related Characteristics

Make your observations during challenging activities for the student. If you have difficulty rating the student, compare them to a typical student in the same grade.

Does the student:

<table>
<thead>
<tr>
<th>Question</th>
<th>Never (0)</th>
<th>Rarely (1)</th>
<th>Sometimes (2)</th>
<th>Often (3)</th>
<th>Always (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have general memory issues</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Ask for repeat of instructions</td>
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</tr>
<tr>
<td>Have issues following instructions</td>
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<tr>
<td>Often loose their place in instructions</td>
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<tr>
<td>Need reminders</td>
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</tr>
<tr>
<td>Have issues following group discussions</td>
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</tr>
<tr>
<td>Shy away in large groups but not small</td>
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<td></td>
</tr>
<tr>
<td>Not remember what to say when called on</td>
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<tr>
<td>Give off topic answers to oral questions</td>
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<td></td>
<td></td>
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<tr>
<td>Get easily distracted</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Have issues multitasking (example: listening and taking notes)</td>
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<td></td>
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</tr>
<tr>
<td>Have self esteem issues</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Have motivation issues</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have issues fully completing tasks</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Get frustrated with complex tasks</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Have issues connecting current situations with the past</td>
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</tr>
</tbody>
</table>

Total marks = __________ (B)

& B: ______________

0-82 = No current concern present

83-98 = Some issues are present and student needs to be placed on a list for identification.

99+ = significant issues are present and identification should happen as soon as possible. Consult with parents, school team, and psychologist

Combine Marks A

Combine Marks A & B: ____________________
Suggestions & Strategies

General Classroom Strategies to Reduce Working Memory Load

The first thing you need to be able to do is to recognize the signs of an overloaded working memory. This is when student behaviour and academics begin to suffer more noticeably. The suggestions below are based on your teaching strategies, expectations, and the environment of your classroom. When putting these suggestions into place, you will be helping all students regardless of ability. As with any change, it takes time to adjust so do not except changes right away. Just because the aids are closer to the student, does not mean that they will automatically think to pick them up and use them.

Things to Consider:

Know the signs of overloading working memory

<table>
<thead>
<tr>
<th>Classroom</th>
<th>1. Structure is key – ensure classroom rules are enforced fairly.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Provide a personal schedule located near the student.</td>
</tr>
<tr>
<td></td>
<td>3. Ensure class timetable is within view and clear. If the schedule changed for the day, make sure it is written somewhere.</td>
</tr>
<tr>
<td></td>
<td>4. Colour code subjects and keep consistent between schedules and notebooks.</td>
</tr>
<tr>
<td></td>
<td>5. Students will respond to stimuli differently so take physical comfort, lighting, sound and heat into consideration for each student individually. This may over load their senses and encourage distraction.</td>
</tr>
<tr>
<td></td>
<td>6. Limit florescent lighting and classroom noise. Use ear buds if needed.</td>
</tr>
<tr>
<td></td>
<td>7. Limit visual clutter around the room. Less clutter means less distractions.</td>
</tr>
<tr>
<td></td>
<td>8. Have alternate learning spaces around the room where students can go to complete their work.</td>
</tr>
<tr>
<td></td>
<td>9. Use a privacy screening around desk to discourage distraction.</td>
</tr>
<tr>
<td></td>
<td>10. Have a clear transitioning process between subjects.</td>
</tr>
<tr>
<td></td>
<td>11. Have pictures of what a clean desk and locker look like. Students will use this as a guide when cleaning and organizing.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>1. Allow additional time as needed.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Ensure students have enough time to learn, process, and use information.</td>
</tr>
<tr>
<td></td>
<td>3. Allow breaks often, especially when high concentration is needed.</td>
</tr>
<tr>
<td></td>
<td>4. Use a visual timer on a projector.</td>
</tr>
<tr>
<td></td>
<td>5. If time is a trigger, avoid timed tests.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Presentation of Information</th>
<th>1. Only teach one task/skill at a time.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Break tasks down into small chunks.</td>
</tr>
<tr>
<td></td>
<td>3. Avoid multitasking.</td>
</tr>
<tr>
<td></td>
<td>4. Present information vertically, not horizontally.</td>
</tr>
<tr>
<td></td>
<td>5. Remove clutter from worksheets/pages. Only essential information.</td>
</tr>
<tr>
<td></td>
<td>6. Use two pieces of paper to block out other questions on a page that are not being worked on.</td>
</tr>
<tr>
<td></td>
<td>7. Avoid idioms and metaphors.</td>
</tr>
<tr>
<td></td>
<td>8. Many take well to kinesthetic learning.</td>
</tr>
<tr>
<td></td>
<td>9. Write down all verbal directions.</td>
</tr>
<tr>
<td></td>
<td>10. Speak slowly and clear.</td>
</tr>
</tbody>
</table>
|                            | 11. Depending on student’s strengths, consider writing full words rather than
| Devices | 1. May find using a computer for writing tasks easier such as speech-to-text software.  
2. Use a voice recorder for recording thoughts before writing them down and conversations for assessment/evaluations.  
3. Calculators ease working memory significantly. |
|-------------------------------------------------|
| Activities/Assignments | 1. Write tasks down.  
2. These may need to be shorter than those of typical students.  
3. Ensure that activities have limited abstract concepts, debates or ethical dilemmas.  
4. Have activities related to their interests.  
5. Physical activity will improve spatial awareness, coordination, etc.  
6. Provide positive physical and social feedback and acknowledge good work and focus.  
7. Group activities should have mixed abilities and be small.  
8. New concepts/ideas or difficult material should be competed in small groups.  
9. If applicable, work with a partner for physical tasks such as putting away or collecting materials.  
10. When understanding tasks are hard, have the student watch you closely. He/She can mimic you in order to finish the activity.  
11. Have students use their strengths when completing assignments (oral/visual).  
12. Ask the students why things make sense to promote higher learning. |
| Practice/Automaticity | 1. Teach learning strategies and mnemonics.  
2. Review on a regular basis.  
3. Memory games.  
4. Check for comprehension often.  
5. Use music for helping with memorization.  
6. If memorizing, repeat it in sequence and until the student is comfortable with it. Test sporadically.  
7. Read work out loud to catch mistakes.  
8. Use a ruler or bookmark to follow along when reading.  
9. Coping strategies should be reviewed, practice and developed on a regular basis. Based on age, the student may need help deciding what strategy to try. (Refer to SERT or Anxiety/OCD specific tests for possible strategies).  
10. Verbally recall information after reading text. |
| Reading | 1. When the students are reading, have them place a dot under the words that they do not know. Then they can go back and focus on them later rather than doing it while they are reading and forgetting the connections.  
2. Use a ruler to keep track of which line they are on.  
3. Reading is best done in a silent room. |
### Mnemonics

<table>
<thead>
<tr>
<th>Aids</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.</strong></td>
<td>Ensure student knows how to use the aids around the room, otherwise they will not be used.</td>
</tr>
<tr>
<td><strong>2.</strong></td>
<td>Praise students for using aids.</td>
</tr>
<tr>
<td><strong>3.</strong></td>
<td>Keep materials and aids near student and available.</td>
</tr>
<tr>
<td><strong>4.</strong></td>
<td>Allow use of aids in class time and during assessment/ evaluations.</td>
</tr>
<tr>
<td><strong>5.</strong></td>
<td>Use as many visual aids as possible.</td>
</tr>
<tr>
<td><strong>6.</strong></td>
<td>Wall charts</td>
</tr>
<tr>
<td><strong>7.</strong></td>
<td>Key words spelt on the board</td>
</tr>
<tr>
<td><strong>8.</strong></td>
<td>Word strip</td>
</tr>
<tr>
<td><strong>9.</strong></td>
<td>Word block</td>
</tr>
<tr>
<td><strong>10.</strong></td>
<td>Personalized dictation</td>
</tr>
<tr>
<td><strong>11.</strong></td>
<td>Common word chart at desk</td>
</tr>
<tr>
<td><strong>12.</strong></td>
<td>3-D objects such as counters, beads, cubes, number lines,</td>
</tr>
<tr>
<td><strong>13.</strong></td>
<td>Memory Cards</td>
</tr>
<tr>
<td><strong>14.</strong></td>
<td>Multiplication Chart</td>
</tr>
</tbody>
</table>

### Try to Avoid

1. Off topic rants/ talking
2. Talking too fast
3. Using your hands too much when talking
4. Irrelevant/ meaningless content, verbally or written
5. Continually grouping students by achievement levels

### Student Things to Consider:

1. Have a memory buddy or have a list of people to ask questions to
2. List practiced strategies the student knows close by so they can refer to it
3. Know how to use aids
   a. Record what they want to write before they start to type/ write
4. Sometimes doodling while listening to the teacher will help with focus and attention
Specific Learning Strategies

Strategies are essential for students with a learning disability and should be incorporated in the classroom and during one on one time. The better a student knows a strategy and when to use it, the more success the student is likely to have. Automaticity of these skills is important to ensure they are used accurately. Not every strategy will work for every student. Read through the list and select 3 or 4 that you think will best suit the student and their ability. Make sure that you don’t overload your student’s working memory with a lot of strategies. Work on one strategy at a time in order to avoid confusion. Keep them simple. Practice, practice, practice! The goal is for the student to be so comfortable with the strategy that they use it automatically without reminders. Remember to be flexible when a strategy or assignment is not going as planned. The strategies collected here come from a large array of sources related to teaching, working memory, ADHD, and other conditions in order to provide you with a plethora of options.

Something To Think About - Automaticity:

Automaticity is when a skill or knowledge is so well known that we are able to complete the tasks or retract information without significant thought processes (Dehn, 2008). When we are able to achieve this, the speed and efficiency of the task is improved. For many adults, this may include driving a car, while for our students it will include writing alphabet letters, knowing the multiplication table, and being able to count by 10’s. While these skills are being learnt, working memory is one of the key players at mastering. It is only when the skills or information is mastered that the demand on working memory decreases and the resources become available for something else. One skill that never becomes automatic of written expression as we rarely write or express the same thing twice. Automaticity is important to ensuring that your students not only memorize facts, information, and skills but as well as the strategies that will help them learn. Practice, Practice, Practice!

Knowing About Themselves – Metacognition:

Teaching metacognition is very important for your student’s success in learning. Metacognition is when we consciously use our cognitive functions for a specific purpose (Alloway, 2011; Autin & Croizet, 2012; Dehn, 2008; Gathercole & Alloway, 2008). In the classroom, one of the ultimate goals of metacognition it to have your students build their metamemory. Metamemory is when the insight about ones self is applied to their memory and learning. Teach your students how memory works, to be able to identify their memory strengths and weaknesses while using this information to decide on what learning strategies are best for them, and why this is important.

Your students need to learn to identify their own skills and abilities in order to decide on what strategy or process best suits their needs, as well as the ability to monitor and control their own cognitive processes. Your students should be taking ownership over their learning, so try to have them pick their choice of strategy to use unless they are continually failing with their choices.
Building metacognition may be more difficult for some students, especially those with LDs. A process that can be used to help guide this development is to start with having your students think out loud or verbalize what they are doing. When the thought process or what is being verbalized seems appropriate, move onto having them whisper to themselves when participating in self-regulatory behaviour. Students will eventually drop the whispering and move onto internal thoughts when they are ready.

Adding to Prior Knowledge/ Long-term Memory

Retrieval Cues are used to help bring forth information from long-term memory. A cue can be any kind of word, phrase, action, or chunk of information that activates the previously learnt knowledge. This strategy works by creating a connection between the trigger and the information. For example, when learning the word for run in Spanish, ‘correr’, have your students run in their spot repeating out loud the word ‘correr’. They will use that physical action as a cue and to not only remember the word, but also what it means in English.

Elaboration is when new information connects with prior knowledge. Building on previous knowledge means that less time and resources will need to be devoted to learning the new information as there is already meaning and context for it.

To make this process easier, tap into the prior knowledge before starting your new lesson or giving new information. A common practice in classrooms is to write out what the class already knows, what they want to know, and then what they have learnt. Seeing this visually will reinforce what has already been learnt and make the connection with the new information easier and quicker.

Ways to Rehearse Information:

Verbal rehearsal is when information is repeated either out loud or in the mind. Typically developed around the age of 10, this strategy is often not developed in LD students, or is delayed. It may be necessary for you to walk your students through this process, if possible. Have the students stop and talk to themselves about what they have read. Possibly have them paraphrase, elaborate, or explain it to himself or herself or to someone else.

Semantic rehearsal is when information needing to be stored is used in creating a new context. This information needs to be repeated until remembered and can often be forgotten quite quickly if not rehearsed.

Distributed practice is when information is repeated several times in short intervals that are separated by other activities. When repeating an exercise that practices the names of different kinds of shapes, do another activity that doesn’t have to do with shapes between each repetition.

Spaced retrieval is when the time between practicing information increases after each session. This type of rehearsal strategy is good for facts where
Manipulation of information is not required. Start with leaving 2 minutes between rehearsals of information and then increase the gap time by 5 or 10 minutes. Teachers need to ensure the information being recalled is correct. Due to the gap between rehearsals, some information may be lost or transformed with another meaning accidentally.

**Ways to Help Build New Knowledge:**

**Dual encoding** is the process the mind goes through when visual and auditory information are presented at the same time. This information is more likely to be remembered as the two sub-systems in the working memory framework are being used to rehearse the same information. Try to often include this in your lessons or when you are providing examples.

**Chunking** is a common practice in memory strategies. This is when common items are grouped together and remembered in ‘chunks’. When we chunk common items, this increases our working memory capacity/ storage. Chunking is done with numbers and words.

For example, the number 384025 takes up more memory space when the numbers are remembered individually. When the numbers are combined into smaller chunks, such as 38, 40, and 25, less memory space is used.

Taking alphabet letters and combining them into words is also chunking. Reading depends on our ability to remember joined letters as specific words.

**Paraphrasing** is when we absorb information and reiterate it in our own words. This processes uses rehearsal as well as chunking. Practice paraphrasing as it is a very important life skill that will be needed. Start with short sentences and have your students paraphrase them, either written or orally. Slowly expand the length of original material into paragraphs. Ensure that the student’s paraphrasing keeps the same meaning as the original text.

**Colour coding** information or content in a text can assist the student with searching for needed information. This strategy is also helpful when handing out subject notes or documents to go home. As long as the student knows where to put the different colours of paper, the information will always be kept in the right place.

**Ways to Add Meaning to New Knowledge - Mnemonics:**

**Mnemonics** are a group of strategies that encode meaning and build connections between LTM and new information. When meaning is added, retrieval of the information is easier. This is commonly done through creating a cue or connection with a visual image, sentence or rhyme. This strategy will be very important when students have a difficult time remembering information. Some mnemonic strategies may take a while to develop and learn. To help build on meaning of the information; it can be helpful for the student to use the mnemonic strategies to create their own adaptations.
Imagery is where the student practices putting oral information into a visual image that they create either mentally or physically. This is commonly used in mental math where the information is manipulated in the mind. Ensure that it is the students that create the image. They can make the image as weird and funny as they want, this way they are more likely to remember it.

Pegwords are two words that when numbers, or similar sounding or rhyming word are used in connection with a keyword that is needing to be remembered, such as Leaping Lions, or Slick Sevens. To take this strategy farther, the two words can be visualized together to create one image in the mind. This act of creating an image where two items become associated with each other is also called chaining.

Loci is a great game for sequential information. Have your students take a look at a picture or their environment while taking a mental list of what they see. Then have them close their eyes and remember what they have seen. Students can even create imaginary spaces where they place items/ cues in it to help them remember facts or information. To assist in remembering sequential information, one space can lead to another, like rooms in a house. The students can travel through the rooms and use the cues to recall information sequentially. To reinforce their imaginary room, they can draw it out.

*Connected with Reading Comprehension:*

Self-monitoring is when the students ask themselves if what they are reading makes sense. Students will often read the wrong word and not second-guess it. This is a sign of comprehension failure. When you hear them say something wrong, ask them to take a moment and think about if what they have said aloud makes sense. Guide them to the realization that what they have read is wrong and what they can do to fix it.

A look-back is when we re-read information that does not make sense or is not comprehended. Break the information up and revisit the content in depth either individually or with a partner. This rehearsal and explanation of the information will allow for easier storage.

Visualization is when you have your students reflect on what they have read. This can be done mentally by creating an image in the mind, or physically by drawing or creating a movie. Start with small pockets of information to be visualized and slowly expand the content.

Previewing if when aspects of a text are focused on before the actual reading takes place such as looking at the title, subtitles, captions, chapter review questions, graphics and pictures. This will help the student break down how the text is organized, understand what information they are about to read will be important, and activate prior knowledge that may be helpful when the reading takes place.
Useful Aids:

Many schools will have a plethora of aids that can be used to help students with all abilities. Many of these aids will already be in your schools and many of them you will have already used in your classroom. Some aids that you may not be familiar with include computer software. There are a growing number of computer programs and software to help students with working memory issues. These programs include COGMED Working Memory Training, Lumosity, Braintrain Memory Gym Series, Shiny Learning Working Memory Training Software, & Jungle Memory. There is some contradictory evidence as to the progress and long-term benefits of these programs however this text recommends these programs based on their merits.
Chapter Four: Working Memory and Other Common Conditions
Reading, Dyslexia, & Language Impairments

Characteristics and Issues:

Students who fall under this category will have issues in storing and processing information. When planning their work, it is often done visually in the mind, which is a strength for these students, and they will prefer visual encoding of words rather than having to listen (Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2008). Writing is difficult as it requires use of a lot of working memory resources and since they are always writing something different, skills such as automaticity are not useful.
### Strategies to Consider:

| Time         | 1. Allow students to have a longer amount of time. This will encourage the students to read every word and have better comprehension.  
|              | 2. Provide breaks during extended reading time. |
| Presentation of Information | 1. Break information into smaller chunks. This will allow the student to stop and think about what they have read more often.  
|              | 2. Present information vertically when it does not have to be remembered in sequence.  
|              | 3. As the teacher, speak slowly and clearly so that the student has time to process what you are saying.  
|              | 4. Numbers are easier to follow than bullets. For younger children, try using colours. |
| Devices      | 1. For the student, recording devices can be used to track their thoughts before having to write them down. This way when they forget what they wanted to write, they can listen back. |
| Activities/Assignments | 1. Make these shorter than the typical student’s. Remember that the students this book is focused on will be working their brains a lot harder than the others. |
| Practice/Automaticity | 1. Review each of the strategies your student uses on a regular basis.  
|              | 2. If memorizing something, repeat it in sequence and until the student is comfortable with it. Test sporadically. |
| Reading      | 1. When the students are reading, have them place a dot under the words that they do not know. Then they can go back and focus on them later rather than doing it while they are reading and forgetting the connections.  
|              | 2. Use a ruler to keep track of which line they are on.  
|              | 3. Reading is best done in a silent room. |
| Mnemonics    | See page 24 |
| Aids         | 1. Ensure your student knows how to use the aids around the room, otherwise they will not be used.  
|              | 2. Allow use of aids in class time and during assessment/evaluations.  
|              | 3. Wall charts.  
|              | 4. Key words spelt on the board.  
|              | 5. Word strip.  
|              | 7. Personalized dictation.  
|              | 8. Common word chart at desk. |
Dyscalculia & Math Impairments

Characteristics and Issues:

It is estimated that around 50% of students with math impairments will also have reading issues (Alloway, 2011). Having issues in both categories can make math significantly more difficult. Working memory affects basic arithmetic calculations and problem solving (Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2008). While still learning basic arithmetic, many students will find transitioning between functions difficult and many will get them mixed up; they will add when they need to subtract, or multiply when they need to divide. Often students will have problems with complex algorithms that involve saving numbers for later use, especially when done mentally (Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2008). Mental math puts great strain on the central executive making these questions difficult. Students will often get the wrong answers unless they are able to write the question down. As students get older, their reliance for math is based on knowledge and strategies. Automaticity with numbers and basic skills will be essential to their success.
## Strategies to Consider:

<table>
<thead>
<tr>
<th>Category</th>
<th>Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time</strong></td>
<td>1. Allow students to have a longer amount of time. Due to the strain on different parts of their working memory, their processing speed and connection with their long-term memory are slower than normal.</td>
</tr>
<tr>
<td><strong>Presentation of Information</strong></td>
<td>1. Present problems vertically, not horizontally.</td>
</tr>
<tr>
<td></td>
<td>2. Depending on the student’s areas of strength, consider writing the full words rather than using number symbols (example: two &amp; 2).</td>
</tr>
<tr>
<td></td>
<td>3. Problems that include words require verbal comprehension and storage of words as well as numbers. Unrelated information should be left out of math questions in order to limit the demand on the working memory.</td>
</tr>
<tr>
<td></td>
<td>4. When explaining a procedure, speak slowly and clearly so that the student has time to process what you are saying.</td>
</tr>
<tr>
<td><strong>Devices</strong></td>
<td>1. Calculators (this will significantly ease stress on working memory).</td>
</tr>
<tr>
<td></td>
<td>2. Use a visual recording device (like a tablet or phone) to record explaining a procedure. The student can access this information on their own when they need reminding.</td>
</tr>
<tr>
<td><strong>Activities/Assignments</strong></td>
<td>1. Use group work when students are going through previously completed questions. This will allow the student to make connections and hear explanations about how the question was completed.</td>
</tr>
<tr>
<td></td>
<td>2. Allow use of aids during tests as well as regular classroom activities.</td>
</tr>
<tr>
<td><strong>Practice/Automaticity</strong></td>
<td>1. This will decrease the amount of time it takes to complete questions.</td>
</tr>
<tr>
<td><strong>Aids</strong></td>
<td>1. Make sure the students know how to use the aids that are available to them. If they are not comfortable, the aids will not get used.</td>
</tr>
<tr>
<td></td>
<td>2. 3-D objects such as counters, beads, cubes, number lines, memory cards.</td>
</tr>
<tr>
<td></td>
<td>3. Multiplication charts</td>
</tr>
</tbody>
</table>
Dyspraxia/Movement

Characteristics and Issues:

As children with movement issues or dyspraxia need to focus so much on what they are doing physically, information in their mind is often lost (Alloway, 2011; Kirby, 2002). Many will seem like they are guessing answers and have not comprehended what they have read or heard. These students are more likely to have issues with their visuospatial sketchpad (Alloway, 2011). As these students get older, they should be able to manage their motor skills but this will come with practice and consistency. It is important to ensure that enough support is being given and used by the student to ensure that as time goes on, they can become independent.
## Strategies to Consider:

<table>
<thead>
<tr>
<th>Reading</th>
<th>1. Read when room is silent.</th>
</tr>
</thead>
</table>
| Classroom | 1. Have class schedule clearly displayed near student. Use symbols and colour code all subjects with corresponding symbols and colours on notebooks and texts.  
2. Colour code ideas or concepts. |
| Time | 1. Time management is very important. Ensure that the student knows how much time there is to complete an activity. Try a visual timer on a projector.  
2. Allow additional time when physical limitations or difficulties are present. |
| Devices | 1. Use a computer or device that has a speech-to-text software. This way the focus of their work is based on their ideas, not their writing.  
2. A typing program can ease physical writing stress |
| Activities/Assignments | 1. Work with a partner for physical tasks such as putting away or collecting materials.  
2. When understanding tasks are hard, have the student watch you closely. He/She can mimic you in order to finish the activity.  
3. Have students use their strengths when completing assignments (oral/visual). |
| Practice/Automaticity | 1. Practice physical gestures, like writing or holding a pencil.  
2. To improve visual memory, have the student focus on a picture for 5 minutes. After taking the picture away, have them describe or draw what they saw with as much detail as possible. Repeat activity with less time as the student progresses.  
3. Verbal word games (Examples: Chinese Whispers and Rhyming)  
4. Verbally recall information after reading text.  
5. When memorizing something, have the student repeat the information after one minute, then again after two, and so on while completing other tasks in between. |
| Mnemonics | See page 24 |
| Aids | 1. Use as many visual aids as possible.  
2. Have aids accessible to student. |
Autism Spectrum Disorder

Characteristics and Issues:

In some of the ASD population there is a dysfunction in the frontal lobe, which is believed to cause a deficit in working memory (Dehn, 2008). Not all people with ASD have working memory issues. Research can only be conducted with higher functioning ASDs. Students you find in a classroom are more likely to have a visuospatial working memory deficit that affects language learning, and slow verbal working memory (Alloway, 2011). Many of these students will also have limited or nonexistent inner speech to guide them. While some may not have a working memory issue, they will get easily distracted with something as simple as the teacher moving while talking.

Some of this population become autistic savants, but not all savants are autistic. This is where they develop exceptional skills in one area such as mathematical calculations or music. This happens when a build up of knowledge increases the working memory performance of that subject (Alloway, 2011). This increase in capacity may not be extended to other areas of memory.
### Strategies to Consider:

#### Classroom

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1.</td>
<td>Structure is key – ensure classroom rules are enforced fairly.</td>
</tr>
<tr>
<td>2.</td>
<td>Provide a personal schedule.</td>
</tr>
<tr>
<td>3.</td>
<td>Colour code subjects and keep consistent between schedules and notebooks.</td>
</tr>
<tr>
<td>4.</td>
<td>Students will respond to stimuli differently so take physical comfort, lighting, sound and heat into consideration for each student individually. This may overload their senses and encourage distraction.</td>
</tr>
<tr>
<td>5.</td>
<td>Limit fluorescent lighting and classroom noise. Use ear buds if needed.</td>
</tr>
<tr>
<td>6.</td>
<td>Limit visual clutter around the room. Less clutter means less distractions.</td>
</tr>
<tr>
<td>7.</td>
<td>Have alternate learning spaces around the room where students can go to complete their work.</td>
</tr>
<tr>
<td>8.</td>
<td>Use a privacy screening around desk to discourage distraction.</td>
</tr>
<tr>
<td>9.</td>
<td>Have a clear transitioning process between subjects.</td>
</tr>
<tr>
<td>10.</td>
<td>Have pictures of what a clean desk and locker look like. Students will use this as a guide when cleaning and organizing.</td>
</tr>
</tbody>
</table>

#### Time

<p>| | |</p>
<table>
<thead>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>Allow breaks often, especially when high concentration is needed.</td>
</tr>
<tr>
<td>2.</td>
<td>Use a visual timer on a projector.</td>
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</tbody>
</table>

#### Presentation of Information

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>Only teach one task/skill at a time.</td>
</tr>
<tr>
<td>2.</td>
<td>Avoid multitasking.</td>
</tr>
<tr>
<td>4.</td>
<td>Use two pieces of paper to block out other questions on a page that are not being worked on.</td>
</tr>
<tr>
<td>5.</td>
<td>Avoid idioms and metaphors.</td>
</tr>
<tr>
<td>6.</td>
<td>Many take well to kinesthetic learning.</td>
</tr>
<tr>
<td>7.</td>
<td>Write down all verbal directions.</td>
</tr>
<tr>
<td>8.</td>
<td>Use lists as often as possible.</td>
</tr>
<tr>
<td>9.</td>
<td>If you are reading from a text, have the student follow along.</td>
</tr>
</tbody>
</table>

#### Devices

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>May find using a computer for writing tasks easier.</td>
</tr>
<tr>
<td>2.</td>
<td>Use a voice recorder for recording thoughts and conversations for assessment/evaluations.</td>
</tr>
</tbody>
</table>

#### Activities/Assignments

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Write tasks down.</td>
</tr>
<tr>
<td>2.</td>
<td>Ensure that activities have limited abstract concepts, debates or ethical dilemmas.</td>
</tr>
<tr>
<td>3.</td>
<td>Have activities related to their interests.</td>
</tr>
<tr>
<td>4.</td>
<td>Physical activity will improve spatial awareness, coordination, etc.</td>
</tr>
<tr>
<td>5.</td>
<td>Provide positive physical and social feedback and acknowledge good work and focus.</td>
</tr>
<tr>
<td>6.</td>
<td>Group activities should have mixed abilities and be small.</td>
</tr>
</tbody>
</table>

#### Practice/Automaticity

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Memory games.</td>
</tr>
<tr>
<td>2.</td>
<td>Check for comprehension often.</td>
</tr>
<tr>
<td>3.</td>
<td>Use music for helping with memorization.</td>
</tr>
<tr>
<td>4.</td>
<td>Read work out loud to catch mistakes.</td>
</tr>
<tr>
<td>5.</td>
<td>Use a ruler or bookmark to follow along when reading.</td>
</tr>
</tbody>
</table>

#### Mnemonics

See page 24
Obsessive Compulsive Disorder/Anxiety

Characteristics and Issues:

Anxiety and OCD in students are sometimes difficult to notice. It is easy to notice symptoms after you have been told what to look for. While OCD may have more physical symptoms, anxiety in children can often manifest on other ways such as tummy aches. Working memory has a deep connection with stress and coping (Quas & Fivush, 2009). The higher the stress levels that are experienced, the lower the working memory capacity will be.

Working Memory is important in combating what causes stress. It is our working memory that allows us to pause and reevaluate what the stressor is in order to change our opinions and perceptions (Quas & Fivush, 2009). Our working memory is what then shifts our minds to decide which coping strategies should be used. When a poor coping strategy is selected, internalizing issues may develop (Quas & Fivush, 2009). It is the working memory that focuses our thoughts and diminishes unpleasant internal speech.
## Strategies to Consider:

<table>
<thead>
<tr>
<th>Classroom</th>
<th>1. Make sure the class timetable is within view and clear. If the schedule has changed for the day, make sure it is written somewhere.</th>
</tr>
</thead>
</table>
| Time      | 1. Allow additional time when needed.  
2. If time is a trigger, avoid timed tests. |
| Presentation of Information | 1. Use numbered lists.  
2. Only give a few items at a time. |
| Activities/Assignments | 1. New concepts/idea or difficult material should be completing in small groups. |
| Practice/Automaticity | 1. Coping strategies should be reviewed, practiced and developed on a regular basis. Based on age, the student may need help deciding what strategy to try. (Refer to SERT or Anxiety/OCD specific texts for possible strategies). See reference list at the end of the chapter. |
| Mnemonics | See page 24 |
Attention Deficit Disorder/Attention Deficit Hyperactive Disorder

Characteristics and Issues:

The number of students in our classrooms with ADD and ADHD is growing. There are three types of ADHD: hyperactive/impulsive, inattentive, and a combination of hyperactive/impulsive and inattentive (Alloway, 2011; Dehn, 2008). Some executive functions are directly impacted by ADHD and are the last of the functions to fully mature, leaving the child to lag behind in typical development (Alloway, 2011). These students are unable to ignore or have great difficulty in ignoring stimuli in their environment. They have a deficit in control of their attention and attention capacity. This suggests issues with working memory as well. It is believed that with the hyperactive ADHD mind, there may not be a working memory issue, so we want to focus our efforts on the inattentive and combination conditions.

Issues within the phonological component are most commonly seen in the combined condition as well as in people with comorbid learning conditions (Dehn, 2008). Dyspraxia is another condition that may accompany this population (Alloway, 2011). Ensuring that our students have strategies to work with will reduce their symptoms and allow them to achieve more academically.
### Strategies to Consider:

| Classroom | 1. Consider using a reward system. Talk to your student about what kind of rewards they would be interested in. Some would rather have small rewards more often or save up for a larger reward.  
2. Provide a personal schedule and outline of classroom routines.  
3. Colour code subjects so that they are consistent between schedules and notebooks.  
4. Have one place where work is handed in.  
5. Colour code important handouts.  
6. Provide a personal schedule.  
7. Colour code subjects so that they are consistent between schedules and notebooks.  
8. Students will respond to stimuli differently so take physical comfort, lighting, sound and heat into consideration for each student individually. This may over load their senses and encourage distraction.  
9. Limit florescent lighting, classroom noise and have ear buds on hand in case of over stimulation.  
10. Limit visual clutter around the classroom. A clean room provides less for distractions. |
| Time | 1. Use short study/ work time to reduce working memory stress and prevent loss of information. Concentration time bursts of 5 – 10 minutes.  
2. Use a visual timer for tasks (possibly on a projector).  
3. Avoid timing tests. Give them as much time as they need (within reason). |
| Presentation of Information | 1. Use physical movement/ actions when learning. Actions and words don’t necessarily have to match and will help with remembering.  
2. Have student repeat what has been said.  
3. Keep lists of instructions short. 1-2 less items than you would give the rest of the class.  
4. Use reminders and ‘To Do’ lists. A personal white board from the dollar store is great. |
| Activities/ Assignments | 1. When providing an outline of assignments, give them two copies (one for home and one for school). Colour code them so that the student knows that all the yellow ones go home and the green one stays in their folder.  
2. Small groups. |
| Practice/ Automaticity | 1. Test knowledge regularly – everyone loves a pop quiz!  
2. Daily review of basic math (such as multiplication).  
3. Have them teach their knowledge or skill to someone else. |
| Mnemonics | See page 24 |
| Aids | 1. Use fact sheets that are easily accessible for all subjects (more important for math).  
2. Rhymes, songs, etc. are great for remembering  
3. Use cue cards where students write information and examples to refer to at a later time.  
4. Allow use in class activities and assessments/ evaluation. |
Chapter Five:
Working With Parents & Other Sources
Parents

As teachers, sometimes it is hard to provide parents with guidelines and ways to help their child. Especially when we are not sure of what to do ourselves.

If parents are asking you for advice and you do not feel confident, feel free to direct them to the resources below. Some of them are targeted to teachers as well as parents and can provide guidelines of what can be done at home in order to help working memory deficit children.

With learning disabilities and other conditions, it is often helpful to have a strong routine at home as well as at school, a healthy diet, and a lot of sleep. Making lists and visual reminders are extremely important to ensure that the student does what they need to do. Having a personal white board at home or at school for notes will make this much easier. This way the student has one place they know they can go to get the information that they need without constantly having to ask someone else for the information. There is no such thing as too much detail.

Making sure that there is good communication between you and the parents is key to ensure that work and studying gets completed at home. Using an agenda or emailing back and forth is always a good idea. Have a Ziploc bag or folder in the student’s backpack where information for home can be placed and the parents know that what they need will be there. Send home an extra outline of assignments so that parents will see it and can support their child. Even if the parents don’t use it, the student might!

Useful Resources for All

To find additional information regarding theory and components of working memory, along with working memories relationship with learning and IQ, please visit the following resources:


Organizations

Here is a list of organizations across Canada, and more specifically Ontario, that can provide support and resources for students, parents, and teachers.

_Autism Ontario_
http://www.autismontario.com
Mission: To ensure that each individual with ASD is provided the means to achieve quality of life as a respected member of society.

_Canadian Down Syndrome Society_
http://www.cdss.ca
Mission: to empower Canadians with Down syndrome and their families. Raise awareness and provide information on Down syndrome through the prenatal, early childhood, school years, adulthood, and retirement stages of life.

_Canadian Mental Health Association_
http://www.cmha.ca
Mission: facilitate access to the resources people require to maintain and improve mental health and community integration, build resilience, and support recovery from mental illness.

_CanChild: Centre for Childhood Disability Research_
http://www.canchild.ca
_CanChild_ Centre for Childhood Disability Research is a research and educational centre located at McMaster University in Hamilton, Ontario, Canada. Our research is focused on improving the lives of children and youth with disabilities and their families.

_Communication Disabilities Access Canada_
http://www.cdacanada.com
Mission: to provide information and education on human rights, access and inclusion for people who have communication disabilities.

_Council of Canadians with Disabilities_
http://www.ccdonline.ca
CCD is a national human rights organization of people with disabilities working for an inclusive and accessible Canada.

_Learning Disabilities Association of Canada_
http://www.ldac-acta.ca
_Learning Disabilities Association of Ontario_
http://www.ldao.ca
Mission: to provide leadership in learning disabilities advocacy, research, education and services and to advance the full participation of children, youth and adults with learning disabilities in today's society.
The International Dyslexia Association, Ontario Branch  
http://idaontario.com  
Purpose: to pursue and provide the most comprehensive range of information and services that address the full scope of dyslexia and related difficulties in learning to read and write.

National Educational Association of Disabled Students  
http://www.neads.ca  
Mission: to support full access to education and employment for post-secondary students and graduates with disabilities across Canada.
References


Mcgrew, K., & Wendling, B. (2010). Cattell-Horn-Carroll cognitive-achievement relations: What we have learned from the past 20 years of research. *Psychology in the Schools, 47*(7), 651-675. doi:10.1002/pits.20497


Chapter Summary

Working Memory Strategies for the Junior/Intermediate Educator: A Handbook was generated based on the feedback from a needs assessment from junior/intermediate teachers, empirical research based on WM, theoretical articles related to Baddeley’s WM and CHC Theory of Cognitive Development, and current resources.

Chapter 4 presented a copy of the educator handbook with a simple and detailed explanation of theory and practice. The content of the handbook was determined in order to provide educators with identifying characteristics of students struggling with WM issues, identify strategies that support WM to help their students learn, and to adapt their classroom practices in order to ease students’ WM.

The handbook was structured in order to provide an explanation and understanding of theory, understand how WM presents in children, identify concerns, practice strategies, identify WM issues with other common classroom conditions, and provide resources to enable educators and parents to find more help and resources if needed.
CHAPTER FIVE: SUMMARY, EVALUATION, IMPLICATIONS, AND RECOMMENDATIONS

WM has been connected with academic success (Alloway, 2011; Gathercole & Alloway, 2007, 2008). In order for students and children to make the best of the opportunities that are provided for them, they and their teachers need to be able to understand how WM affects learning and how to supplement it or ease its load when it is overwhelmed. WM is a part of the cognitive framework and develops differently in the population with learning and cognitive disabilities. The *Working Memory Strategies for the Junior/Intermediate Educator* handbook was created to ensure that teachers are able to understand and identify when students with demanding WM loads need help and to provide them with the strategies they will need in order to succeed academically and professionally in life. This chapter outlines the need for this handbook, the feedback from junior/intermediate educators who would use it, implications for practice and theory that this project has, as well as limitations, recommendations for further research, and a conclusion.

**Summary of the Project**

This project explored WM and what educators in the Junior/Intermediate divisions needed to know in order to help their students optimize learning. The purpose of this project was to create a handbook that will augment existing knowledge of educators and assist Junior/Intermediate teachers in developing strategies and interventions for students with varied WM abilities in a classroom setting. The handbook includes an outline of what WM is, why it is significant in learning, different issues students with poor WM may face, and how teachers can help these students thrive both in an academic and non-academic setting. The objectives of the handbook included having...
educators be able to identify characteristics of students struggling with WM issues, strategies that support WM to help their students learn, and be able to adapt their classroom practices in order to ease students’ WM.

The theoretical basis used for this project consisted of Baddeley and Hitch’s Working Memory Theory, more recently adapted by Baddeley (Baddeley, 2006) and CHC Theory (Dehn, 2008; Proctor, 2012). The combination of these two theories allows for a solid understanding of what working memory is, how it connects to cognitive ability, and how it impacts learning and behaviour.

The empirical evidence available suggests that providing WM-based interventions improves academics in junior and intermediate aged children. While there is no special recipe to ensure improvement, many factors need to be considered and several strategies must be attempted in order to find the right combination for any student. The data and information collected in the literature review lend support to the claim that a handbook needed to be created specifically for Junior and Intermediate teachers to ensure that they are supported in helping their students. The handbook that was developed within this project provides a comprehensive and useful resource for teachers.

**Evaluation of the Handbook**

*Working Memory Strategies for the Junior/Intermediate Educator: A Handbook* was offered for review to the same educators who volunteered to complete the initial needs assessment. Out of the seven participants who initially assisted, only three of them completed the evaluation tool for the handbook.

The evaluation tool (Appendix B) consisted of 13 qualitative and quantitative questions. Questions 1 to 10 allowed participants to rate the effectiveness of the
handbook based on specific criteria while questions 11, 12, and 13 provided participants with space for their opinions, suggestions, and comments. The evaluation tool was structured to assess if the educators understood the content and purpose of *Working Memory Strategies for the Junior/Intermediate Educator: A Handbook*. Participants were provided with the evaluation tool, the handbook, and a cover letter on May 25, 2015 by email. The cover letter explained how to complete the evaluation tool and thanked the participants for their contributions. The participants were asked to complete the evaluation tool, save their comments, and email it back to the researcher to be used to finalize the handbook. No evaluation tools were returned by June 4, 2015. It was believed that the participants may have been concerned that continuing with the research may be struck work according the union guides. The researcher sent a reminder to the participants that completing the evaluation form was not struck work. At this time in the school year, many teachers were busy compiling reports. An additional reminder was sent to participants on June 22, 2015 to request that if participants wished to withdraw from the evaluation tool that they needed to notify the researcher. At this time, three participants expressed that they would be sending their evaluation tool. Five of the other participants did not respond. When received, the evaluation tools were printed and used to make adjustments to the handbook. Anonymity was kept as there were no identification questions on the evaluation tool.

**Conclusions From the Evaluation**

The responses from the evaluation tool were compiled and a summary is provided below to each question. For questions 1 through 10, participants were asked to rate their
opinion with the statement by placing a checkmark in the appropriate column with the options of strongly agree, agree, undecided, disagree, and strongly disagree.

Question 1. The purpose of the Manual is clearly stated and understandable. Both participants indicated that they strongly agreed with this statement.

Question 2. The Manual is easy to read. Participant 1 indicated that they agreed with the statement while participant #2 indicated that they strongly agreed.

Question 3. The Manual is well organized. Participant 1 indicated that they agreed with the statement while participant #2 indicated that they strongly agreed.

Question 4. The Manual provided useful information regarding Working Memory. Both participants indicated that they strongly agreed with this statement.

Question 5. The Manual will be useful for assisting students with Working Memory issues. Both participants indicated that they strongly agreed with this statement.

Question 6. The Manual provided readily usable classroom strategies. Both participants indicated that they strongly agreed with this statement.

Question 7. The strategies suggested in the Handbook are effective for a Junior/Intermediate classroom. Both participants indicated that they strongly agreed with this statement.

Question 8. The terms used in the Handbook were clearly defined or explained. Participant 1 indicated that they agreed with the statement while Participant 2 indicated that they strongly agreed.

Question 9. I am confident in my knowledge of Working Memory after reading the Handbook. Participant 1 indicated that they agreed with the statement while Participant 2 indicated that they strongly agreed.
**Question 10. I learned new or useful information from the Handbook.**
Participant 1 indicated that they agreed with the statement while Participant 2 indicated that they strongly agreed.

**Question 11. In terms of usefulness, my overall opinion of the Handbook is** ___. Both participants thought that the handbook included useful strategies to be used with students. Participant 1 suggested that it could be of assistance when creating Individual Education Plans and that the assessment checklist could be used when the teacher is collecting evidence to take to the school team when concerned about a student. Both participants thought the information about WM and its theory would help support teachers who had limited understanding of the concept. Participant 2 specifically highlighted that the format of the handbook was clear and well organized.

**Question 12. Suggestions for improving the Handbook would be** ___. Participant 1 suggested including a student/classroom based example for each of the components of WM. The participant believed that this would help teachers related the science of WM to a particular student they are supporting. Participant 2 suggested reconsidering the checklist that was created for teachers to use with students. The participant found the organization of the questions within the chart difficult to follow visually. The participant wondered if the numbers were needed for each question and suggested aligning the text to the left rather than in the center of the column.

**Question 13. Additional comments.** Participant 1 commented on the analogy of the juggler at the beginning of the book and how it provides a great introduction for parents and teachers to working memory. Participant 2 did not provide any additional comments.
Comments and feedback from the participants on the evaluation form indicate that the handbook is clear, understandable and useful for educators working with students who have WM concerns. Formatting concerns expressed by Participant 2 were completed. The text in the observation checklist was aligned on the left and the numbers were taken away. It was decided that Participant 1’s suggestion of giving additional examples of what each component does is unnecessary. The current text provides a clear outline of what each component does and what it is responsible for. No other revisions were needed or recommended for the handbook.

**Implications for Practice**

*Working Memory Strategies for the Junior/Intermediate Educator: A Handbook* was written to provide Junior and Intermediate teachers with an understanding of how WM impacts students learning and how to help them. Educators are provided a condensed theoretical background on WM, the components, and an outline as to how it impacts learning. By specifically outlining common classroom conditions students may have and how WM is impacted, the handbook encourages educators to find strategies to work on with their students to help with learning. A list of organizations to help educators and parents is provided in case more support is required. The evaluation of the handbook suggests that this resource is valuable to Junior and Intermediate teachers as they were able to learn from the handbook.

The needs assessment based on WM suggested that a resource for teachers was necessary to fill a knowledge gap. The evaluation tool suggested that this requirement can and has been filled by the handbook that was created. The list of strategies and organizations available for assistance will be able to support educators.
Working Memory Strategies for the Junior/Intermediate Educator: A Handbook is a great starting point for many educators and even parents who are not knowledgeable about WM and how it impacts learning and behaviour. While the handbook provides a lot of suggestions and strategies, students and teachers will need to experiment using different ones and personalize each one in order to have the more impact.

Limitations of the Project

The project resulting in the creation of Working Memory Strategies for the Junior/Intermediate Educator: A Handbook has some limitations. Theory and literature relating to WM is vast and ongoing. In the handbook, specific information regarding WM was straightforward and condensed in order to ensure the reader has an understanding of the concepts discussed.

Participants were recruited through the school boards for which they work. Given more opportunity and time, the researcher would have preferred to have a larger sample from which to gather data. Including more participants would have provided a well-rounded impression of what the average teacher knew about WM before reading the handbook.

Recommendations for Further Research

Early screening and intervention are two concepts that have been loosely touched upon in research. With a strong correlation between WM and academic achievement, research should focus on how early screening and specific strategies can be implemented in the Canadian school system. A resource relating to early screening and interventions for primary level educators would be essential in ensuring that students from a young age would be able to get WM support that will help build a strong cognitive foundation.
Chapter Summary

The feedback from the evaluation form received by the participants was valuable and informative. The comments from the participants suggested that the resource created was easy to read, well-organized, understandable, and provided useful information and strategies. The participants appreciated the assessment checklist that was developed and the strategies and suggestions that were proposed in the handbook. With rising rates of students with learning disabilities, it is important for educators to know and understand how to address the demand that learning and take on a students’ WM. The creation and use of *Working Memory Strategies for the Junior/Intermediate Educator: A Handbook* will enable teachers to identify and support their students with WM deficiencies.
References


McGrew, K., & Wendling, B. (2010). Cattell-Horn-Carroll cognitive-achievement relations: What we have learned from the past 20 years of research. *Psychology in the Schools, 47*(7), 651-675. doi:10.1002/pits.20497


Appendix A

Needs Assessment

BROCK UNIVERSITY, FACULTY OF EDUCATION

Working Memory in the Junior/Intermediate Classroom (Gr. 4-8)

Teacher Questionnaire

My name is Kathryn Haynes and I am a Master of Education candidate at Brock University. My exit project, titled Working Memory in the Junior/Intermediate Classroom, involves the creation of a handbook for junior and intermediate teachers that aims to provide information about working memory and how teachers can best support students with working memory deficits to be successful learners. Input from teachers is an essential component of this project.

When responding to the questionnaire, please do not identify yourself or include information that may identify your school or the names/positions of colleagues/children. Please do not answer any questions that make you feel uncomfortable. When you have completed the questionnaire, please seal it separately from the Informed Consent Form and send it through internal mail back to the office that sent it to you. Thank you for taking the time to assist me with my project.

Date: ______________________

Professional Practice

1. Please describe in your own words what working memory is.

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

2. How would a student with strong working memory capacity present in the classroom? How would the student’s behavior and academic performance differ from students with average working memory capacity?

__________________________________________________________________
3. How would a student with working memory deficits present in the classroom? How would the student’s behavior and academic performance differ from students with average working memory capacity?

4. Are you aware of any strategies that can be used to help students with working memory deficits? If so, what strategies are you aware of?

5. Have you received any readings or classroom resources on working memory or working memory deficits? Yes/No. If Yes, please describe what type of resources:

6. Have you received any professional development (PD) to help you prepare and work with students with working memory deficits? Yes/No. If Yes, please describe what type of PD:

7. Are you aware of a colleague at your location that could assist you with any student working memory issues or concerns? Yes/No

8. What would you appreciate being included in a written resource for teachers in relation to students’ working memory?
Please provide any additional comments or suggestions regarding student’s working memory:

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

Thank you for taking the time to answer these questions.

Kathryn Haynes
Appendix B

Working Memory in the Junior/Intermediate Classroom (Gr. 4-10) Handbook

Evaluation Tool

Participation in the evaluation process and completion of this questionnaire is voluntary. You may choose to end your participation at any time. Your responses to the following questions will remain confidential – please do not put your name on the paper.

Working Memory Handbook Evaluation Survey

SA = Strongly Agree  A = Agree  U = Undecided  D = Disagree  SD = Strongly Disagree

Please use a checkmark in the appropriate column.

<table>
<thead>
<tr>
<th></th>
<th>SA</th>
<th>A</th>
<th>U</th>
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<th>SD</th>
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In terms of usefulness, my overall opinion of the Handbook is:

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Suggestions for improving the Handbook would be:

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Thank you for your willingness to read and evaluate the Handbook. Please use the attached page if you require additional space.

Additional Comments: ____________________________

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