‘Being the Best Learner You Can Be’: A randomized controlled trial of a neuroscience-based primary school program

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Glossary

Affective Neuroscience—an area of research that focusses on the neural bases of emotions, placing emotions and affects in a central position with regard to the modulation of cognition and behaviour by studying "(i) the genesis of affective consciousness; (ii) how basic emotions and feelings are organised in the brain; and (iii) how the basic emotional processing systems of the brain generate internally experienced feelings." (Almada et al., 2013, pp. 254-255).

Attention—"the mechanism by which we select objects, events or locations in the environment" (Mulckhuyse and Theeuwes, 2010, p. 300).

Attention Networks:

- Alerting (or arousal) network—referring to the state of sensitivity to incoming stimuli
- Orienting network—referring to the prioritisation of sensory input for scrutiny, see also Directed Attention
- Executive Control network—involving mechanisms for monitoring and resolving conflict among thoughts, feelings, and responses (Posner and Rothbart, 2007, p. 7).

Attention Shifting—the ability to *intentionally* change focus between objects, parts of objects, thoughts and/or feelings. This includes the concept of re-focusing attention after an interruption (Posner, 2010).

Attentional Inertia—a term recognising how effortful it is to shift away from an attentional focus (Anderson et al., 1987, Diamond et al., 2005, Hawkins, 2002, Kirkham et al., 2003, Munakata et al., 2003, Oakes et al., 2004).

Behavioural Inhibition—a subset of inhibition control defined as the ability to stop or manage response(s) in the areas of action (waiting, withholding and stopping), choice (delayed gratification) and inflexibility/compulsiveness (ability to switch or change) (Bari and Robbins, 2013).

Brain (as distinct from Mind)—an observable, tangible, measurable physiological organ in the body which enables the mind (Damasio, 1999).

Change Blindness—the inability to notice quite significant changes if they occur gradually coupled with a momentary distraction or while attention is intensively focused on another aspect of the environment (Rensink, 2000, Simons, 2005).

Change Fatigue Management—"can be defined by its synonyms: being tired of change, adaptive failure, future shock and innovation fatigue" (Dilkes et al., 2014, p. 45).

Classroom-based Research—the investigation of changes to student outcomes, including learning and behaviour, through the application of environmental variables such as teacher behaviours, physical layout, targeted interventions, and/or instructional strategies (Conroy et al., 2008).

Cognitive Control (also referred to as Executive Control)—"the ability to coordinate thought and action and direct it toward obtaining goals" (Miller and Wallis, 2009, p. 99).

Cognitive Flexibility—(1) the ability to adapt cognitive processing (i.e. thinking) strategies when encountering new and/or unexpected situations (Canas et al., 2003). (2) the ability to malleably adjust to changed demands or priorities and/or to look at the same concept/object/action in different ways or from different perspectives (as required for set shifting or task switching) (Diamond, 2013).

Cognitive Inhibition—a subset of inhibition control defined as "the stopping or overriding of a mental process, in whole or in part, with or without intention" (MacLeod, 2007, p. 5).

Collaborative Skills—"describes learning experiences where students act together to perform specific tasks" (McKinney and Denton, 2006, p. 138).

Conflict Scales—measures of ability to deal with interruptions to goal-directed behaviour due to conflicting stimuli or changes to the task (Beck et al., 2011).

Contamination (or Cross-contamination)—exists when interaction occurs between the control group and some or part of the research intervention being used with the active group. Contact between the control group and the intervention can be either active or passive and is understood to compromise internal validity of research findings (Doyle and Hickey, 2013).

Continuous Performance Test—a standard method of measuring an individual's abilities to sustain and direct attention and deal with impulsivity (Conners, 2014). (Subtests on the Connors' Continuous Performance Test, the main outcome measure for this work, are listed in alphabetical order throughout the glossary.)

Critical Thinking Skills—"reflective thinking involved in the evaluation of evidence relevant to a claim so that a sound conclusion can be drawn from the evidence" (Bensley et al., 2010, p. 91).

Delayed Gratification—the ability to postpone access to immediately available rewards to gain more desirable future rewards. This includes maintaining the choice to delay, and tolerating the frustration of this self-inflicted delay (Koepke et al., 2015, p. 1).

Delay Scales—measures of ability to delay gratification or inhibit/postpone a response (Beck et al., 2011).

Digital Divide—the gap which develops in learning and learning opportunities due to unequal ability to access digital technology, in particular, the Internet in relation to age, gender and socioeconomic status (Livingstone and Helsper, 2007).

Digital Literacy—(1) includes the ability to operate digital devices and attendant software as well as "a large variety of complex cognitive, motor, sociological, and emotional skills,

which users need in order to function effectively in digital environments" (Eshet-Alkalai, 2004, p. 93) (2) the use of technologies to find, use and disseminate information (Deakin University, 2013).

Digital Media—the use of any medium that is stored and/or retrieved via electronic digital technology, including the use of the Internet, television, mobile phones, computers, handheld tablets, and electronic gaming devices such as a Wii or digital-based entertainment such as Youtube or Facebook (Choudhury and McKinney, 2013).

Directed Attention (the orienting system)—effortfully orienting towards selected stimuli, usually goal-directed, and involving the frontal and parietal cognitive control structures of the brain (Kaplan and Berman, 2010, p. 46).

Ecological Validity—the measurement of an outcome (e.g. executive functions) within the natural environment (Goulden and Silver, 2009).

Emotional Literacy—the ability to read and understand a range of emotions in both the self and others in a healthy manner (Joseph et al., 2005).

Emotional Resilience—the existence of a number of protective factors, including temperament, intelligence, and social connectedness, that allow individuals to achieve positive outcomes despite adverse circumstances (Denny et al., 2004).

Errors of Commission—measured errors in relation to response to non-targets within the Continuous Performance Test (Conners, 2014).

Errors of Detection—measured response to all items presented within the Continuous Performance Test (Conners, 2014).

Errors of Omission—measured errors in relation to missed targets within the Continuous Performance Test (Conners, 2014).

Executive Control (also referred to as Cognitive Control)—"the ability to coordinate thought and action and direct it toward obtaining goals" (Miller and Wallis, 2009, p. 99).

Executive Functions—a set of cognitive skills that are required to set and then attain a goal including the three dimensions of inhibitory control, working memory and cognitive flexibility (Center on the Developing Child at Harvard University, 2011).

Grit—perseverance and passion for long-term goals (Duckworth et al., 2007, p. 1087).

Growth Mindset—belief that intelligence can be developed through effort and instruction in contrast with a fixed mindset which holds that intelligence is a static personal attribute (Dweck, 2010b, p. 26).

Higher Order Thinking Skills (HOTS)—skills that require high levels of cognitive processing but have more generalisable benefits including the categories of transference (making connections and applying learning to areas other than its initial context), critical thinking, and problem solving (Brookhart, 2010).

Hit Rate (HRT)—measured speed of response to targets within the Continuous Performance Test (Conners, 2014).

Hit Rate Inter-stimulus Interval (HRT ISI)—measure of fatigue management in overall performance within the Continuous Performance Test (Conners, 2014).

Hit Rate Standard Deviation (HRT SD)—measure of levels of vigilance during testing within the Continuous Performance Test (Conners, 2014).

Hit Reaction-time Standard Error Inter-stimulus Interval (HSE ISI)—measure of the ability of students to sustain attention throughout the course of testing within the Continuous Performance Test. The score is derived from an analysis of hit rate with errors of omission and commission (Conners, 2014).

Impulsivity—behaving with little or no forethought or consideration of consequences (Arce and Santisteban, 2006).

Inhibition Control—the ability to stop or manage response(s), used widely in the research literature to reference physiological, cognitive and behavioural phenomena (Bari and Robbins, 2013). See also cognitive inhibition, behavioural inhibition, response inhibition and self-regulation.

Intelligence—an individual's ability to "understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought" (Neisser, 1979, p. 1).

Interference Control—successful management of distractions and interruptions (Arce and Santisteban, 2006).

Metacognition—both an individual's store of knowledge connected to "people as cognitive creatures with their diverse cognitive tasks, goals, actions, and experiences" and "any conscious cognitive or affective experiences that accompany and pertain to any intellectual enterprise" (Flavell, 1979, p. 906).

Mind (as distinct from Brain)—the collection of mental processes that occur in the brain, including thought, affect and behaviour (Damasio, 1999).

Mind, Brain and Education (MBE)—(1) a systematic collaboration between biological and psychological sciences as well as teachers, students and researchers in order to establish the

"long-term improvement of the infrastructure for creating scientific knowledge that relates to education" (Fischer, 2009, pp. 4-5) (2) a term interchangeable with neuroeducation (Ansari et al., 2012, p. 106).

Multitasking—the ability to engage in multiple tasks requiring some level of attentional control concurrently (Hembrooke and Gay, 2003).

Negative Priming—difficulty shifting attention to something that had previously been actively ignored (Allport and Wylie, 2000, May et al., 1995, Tipper, 2001).

Neuroeducation—the linking of neuroscience and education with a view to improving learning and instruction (Ansari et al., 2012, p. 105).

Neuromyths—(1) "a misconception generated by a misunderstanding, a misreading, or a misquoting of facts scientifically established (by brain research) to make a case for use of brain research in education and other contexts" (Dekker et al., 2012, p. 1) (2) misconceptions about the mind within the context of the science of the brain due to distortions of scientific facts, persistent adherence to disproven scientific hypotheses, and/or misinterpretations of experimental results (Pasquinelli, 2012, p. 1).

Neuroplasticity—1) (generic sense) the brain's capacity to change and adapt in response to developmental forces, learning processes, injury and aging (Dana Foundation, 2016). (biological sense) "the ability of the nervous system to respond to intrinsic or extrinsic stimuli by reorganizing its structure, function and connections" (Cramer et al., 2011, p. 1591).

(Cognitive) Neuroscience—(1) a systematic study aimed at elucidation of how the brain enables the mind (Gazzaniga et al., 2002). (2) "the constraint of cognitive, psychological theories with neuroscientific data in order to shape such theories to be more biologically plausible" (Ansari et al., 2011, p. 37).

Response Inhibition—the ability to stop or moderate thoughts and behaviours and reduce impulsivity (Arce and Santisteban, 2006).

Self as a 'Lifelong Learner'—the need to continually enhance personal knowledge and skills, in order to address immediate problems and to participate in a process of continuous vocational and professional development (Sharples, 2000).

Self-efficacy—personal judgements of one's capabilities to organise and execute courses of action to attain designated goals (Zimmerman, 2000).

Self-regulation—a subset of inhibition control referring to control of one's responses (both emotional and cognitive) to environmental stimuli (Dinsmore et al., 2008).

Short-term Memory—information held in the brain for only limited periods; includes transient memory and working memory (Buchsbaum and D'Esposito, 2017).

Social Change—a phenomenon whereby the pressures exerted on the individual by the collective (society) shift significantly. Pressures can target values (thoughts and beliefs), as well as behavioural norms (actions) (Form, 2015).

Social Contagion— the dissemination of behaviours, affective states or illnesses across networks (Christakis and Fowler, 2013).

Social and Emotional Learning (SEL)—"the capacity to recognize and manage emotions, solve problems effectively, and establish positive relationships with others" (Zins et al., 2004, p. 3).

Socioeconomic Status (SES)—"…the relative position of individuals, families, or groups in stratified social systems where some societal values (e.g. occupational prestige, education, economic resources, power, information) are not uniformly distributed." (Bornstein and Bradley, 2012, p. 2).

Sustained attention—the ability to remain vigilant to but disengaged from distractions without destabilising the intended focus (Lutz et al., 2008, p. 163).

Transient Memory—information that can be recalled for a brief period (e.g. what was on the breakfast menu) (Buschkuehl, 2008, Conway et al., 2005b, Cowan, 2010).

Variability—measure of the ability to cope with changes to presentation of stimuli (i.e. changing intervals between targets and changing patterns of presentation) and to manage impulsivity within the Continuous Performance Test (Conners, 2014).

Working Memory (WM)—the ability to hold information in mind and mentally work with it where the information is usually not perceptually present (Buschkuehl, 2008, Diamond, 2013).

Abstract

The centre piece of this doctoral thesis is a randomised controlled trial of an abridged version of the *Being the Best Learner You Can Be* Program (BBL Program). The BBL Program was developed by the author between 2009-2011 based upon available cognitive neuroscience and cognitive psychology research literature. The program aims to improve teaching and learning outcomes for primary (or elementary) school children by targeted development of fundamental executive functions and by fostering each student's positive attitudes towards testing, practising and reviewing their personal development. It was designed for and has operated in four South Australian metropolitan primary schools since 2009, incorporating new research information into program implementation as it becomes available.

This project employs a randomised controlled trial methodology using a mixed methods construction to examine the effectiveness of the BBL Program in novel settings. An explanation of the BBL Program is contained in Appendix 1, as the Program, itself, is not part of this assessment process. The educational neuroscience research background for the project up to and including all work available at 2011 can be found in Chapter 2. This chapter also provides detailed discussion of executive functioning along with more individualised treatment of key aspects of executive skills. Literature available post 2011 is also reviewed in Chapter 2 within a separate section. A presentation of the randomised controlled trial methodology is presented in Chapter 3 followed by research results in Chapter 4. Chapter 5 offers the discussion and conclusions from this project.

This work was carried out in real classrooms/schools rather than within a constructed laboratory setting. Seven research questions were addressed. The primary question— How and to what extent is the BBL Program more effective in increasing the specific executive functions of working memory, attention (both directed and sustained) and self-regulation (especially impulsivity) as compared to a control group receiving usual classes?—focused on

testing the effect of the program on Year 4/5 students' (children aged between 9-11 years) executive functioning (especially working memory, attention and self-regulation) through the administration of a weekly, abridged form of the BBL Program in the novel school settings of the study. The Program ran for 20 consecutive school weeks (two South Australian school terms). The computerised Conners' Continuous Performance Test was selected as the primary outcome measure. Working memory was assessed through the computer-based spatial short-term memory subtest of the Working Memory Test Battery. Computer-based tests were specifically selected for this research to provide as much test standardisation as possible and to decrease the risk of administrator differences across the variety of school-based test settings using several test administrators.

Six secondary questions were identified for this project. These examined aspects of student motivation and attitudes towards learning, sleep habits in relation to student executive functions, and the impact of socioeconomic status (SES) through program delivery to schools across the socioeconomic spectrum. Secondary questions were:

- How and to what extent does student attitude towards school and learning reflect executive function levels as measured by the test battery?
- How and to what extent does an individual student's sleep profile influence levels of executive function?
- How and to what extent do student mindset (i.e. perception about his/herself as a learner--see glossary) and teacher/parent views of student ability align with objective executive function performance, especially in relation to SES?
- How and to what extent do study outcome measures relate to socioeconomic status (SES) as defined by a school's Index of Educational Disadvantage rating?
- How and to what extent were SES levels reflected in student improvement data?

- How and to what extent did the BBL Program demonstrate positive outcomes (i.e. feasibility in delivery and acceptability to teachers and/or students) for the study population?

To address the questions relating to motivation, engagement and SES, data were collected from students using the Motivation and Engagement Scale, the Modified Child Nutrition Questionnaire and Physical Activity Questionnaire for Older Children. The ACES Sleep Program 7-day sleep diary was used to answer sleep related question in the active condition only.

Subjective data from teachers, using the Student Behaviour Rating Scale, and parents, using the Behaviour Rating Inventory of Executive Function of student skills in relation to computer-based student performance outcomes were examined. At the end of the intervention period, teachers and randomly selected students within the active condition were interviewed to answer the question of portability.

Key findings confirmed the BBL Program's effectiveness in supporting executive functioning in participating students when compared to the control group. While positive, results showed mitigation against performance decline rather than skills improvement. Contrary to current research, greater improvement was found in the higher SES group as opposed to the lower SES group. Additionally, students in this study appeared to be better judges of their executive functioning abilities than either their parents or teachers. The Program proved to be portable and valued from both teacher and student perspectives.

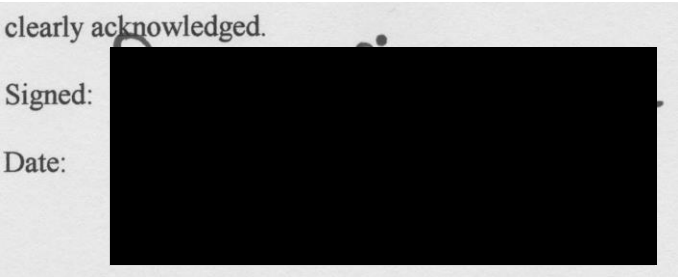
This research has confirmed the value for and feasibility of targeting improvements to executive functioning within classroom settings. This work demonstrates that noticeable improvements to student behaviour and performance can be seen within 20 weeks. Both students and teachers found the BBL Program's approach and lessons engaging. The program

was accessible to all students across all levels of SES and with a range of learning challenges. However, data indicate that more intensive focus is required for students with poorer initial skills sets. Finally, this program provides a relatively inexpensive approach (i.e. it does not require rigid implementation regimes nor costly materials) to engaging students and staff in attaining better learning outcomes by targeting development of executive functions, the skills that underpin academic learning.

Declaration

I declare that:

this thesis presents work carried out by myself and does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; to the best of my knowledge it does not contain any materials previously published or written by another person except where due reference is made in the text; and all substantive contributions by others to the work presented, including jointly authored publications, is



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I give heartfelt thanks to all participating classroom teachers who distributed and collected the various questionnaires and tolerated the stream of students leaving and entering their classrooms during the pre- and post-testing process. It was a pleasure to work with each of you. I also am deeply indebted to all student participants for their enthusiasm and interest in the BBL Program.

Finally, I wish to express my gratitude to my family, especially to John Cole, my partner, for his tolerance of my often-distracted state of mind during the research and writing phases of this thesis.

Chapter 1 Introduction

Human brains are naturally designed to make meaning from differing environments (Blakemore and Frith, 2005, Shonkoff and Phillips, 2000, Sousa, 2005, The Royal Society, 2011). Being intimately involved in moment-by-moment learning—sensing, processing, and incorporating (Buchsbaum and D'Esposito, 2017)—makes it difficult to realise the enormous dexterity and complexity of brain function. However, teachers do notice when students fail to learn. One often held belief in education is that failure to learn is directly related to poor student motivation (Alkaabi and Vyver, 2017, Hung et al., 2012) or low cognitive capacity (Chiesi et al., 2011, Graf et al., 2009). However, motivation and cognitive capacity alone do not provide a full overview. There are many underlying skills required for learning that directly influence a learner's motivation and success, including a range of executive functions (Diamond, 2013). Executive functions encompass everything that is required to set and then attain a goal—including the ability to remember, pay attention and self-regulate thinking, behaviour and/or emotion (Dawson and Guare, 2004).

Executive functions can be conceptualised as cognitive tools that make most learning possible (Diamond, 2013). Research literature on executive functioning has emerged from both cognitive neuroscience (Alvarez and Emory, 2006, Ardila, 2008, Cartwright, 2012) and cognitive psychology (Anderson, 2002, Anderson and Reidy, 2012, Anderson et al., 2001, Diamond, 2013, Friese and Hofmann, 2009, Hofmann et al., 2012). These two disciplines generally examine the process of executive functioning from differing perspectives; neuroscience with a brain/biology lens and psychology with a behavioural lens. However, there are many points of agreement between the fields that have relevance for educators.

In Australia, the development of student executive functions as part of school curriculum had not been widely embraced throughout the early 2000s, with interest ignited only within the

last seven to ten years. For example, in 2011, Westwell and Panizzon, two researchers from Flinders University, were commissioned by the Australian Government to report on the implications from cognitive neuroscience on career development strategies and possible interventions. A major section of this report was given over to defining core executive functions and explaining their importance in relation to student development. Further, the report strongly recommended that a more strategic approach to developing executive functions in students be adopted by all Australian schools (Westwell and Panizzon, 2011). Two years later, in support of this recommendation, Westwell and Panizzon produced an online guide to executive functions to provide easy access to both executive function concepts and a rationale for educational interest (Westwell and Panizzon, 2014). In 2013, this author was invited to present at the national Australian Council for Educational Research (ACER) conference, *How the Brain Learns: What lessons are there for teaching?* as the national steering committee was unaware of anyone else in the country working with executive function development in school classrooms (personal communication from ACER conference convener). The inaugural Australian Mind, Brain and Education conference was held in Melbourne in 2015. Broadmeadows Primary School was (not entirely correctly) introduced as the first school in the country to directly foster development of executive functions with school-based conference delegates being urged to follow this lead. Since 2014, other school-based projects have been initiated, largely through the Science of Learning Centre at the University of Queensland Brain Institute, Science of Learning Research Centre, University of Melbourne, and projects financially supported by Pearson Academy. The Being the Best Learner You Can Be Program in South Australia has also continued to operate. Clearly, however, there is still a distance to travel to fulfil the recommendation made in 2011 by Westwell and Panizzon for a national strategic approach. In addition, international research such as the work by Howard-Jones in the United Kingdom (Howard-Jones, 2014)

and Gilmore and Cragg (Gilmore and Cragg, 2014) in the United States would indicate that the understanding and use of executive functions as foundational learning tools is not fully and accurately integrated into educational practice beyond Australian borders.

Executive functions are not fully established in the brain at birth. Rather, they are a product of neuroplasticity. That is, executive functions develop over time *and* with the right stimuli. (Center on the Developing Child at Harvard University, 2011). In addition, one's general world view or perceptual filters (e.g. culture and languages spoken), play a large part in determining *where* attention is directed, *if* attention is directed and therefore what is or is not remembered or learned (Boroditsky, 2011, Huang and Liao, 2005, Mangels et al., 2006, Markson et al., 2008). This insight into cognition provides a means for willing educators to both improve their own practice as well as many outcomes for their students. The current work provides an examination of one approach to marrying educational practice with the burgeoning cognitive research literature on the 'learning brain' from both neuroscience and psychology using a mixed methods enquiry.

1.1 Significance of Study

The focus of this work is a classroom program entitled Being the Best Learner You Can Be Program (BBL Program). This program is a unique South Australian attempt to embed current cognitive neuroscience and psychology into existing schools, classrooms and mandated curricula. This program was purpose-designed for four specific South Australian primary schools over a three-year period. Therefore, its capacity to be effective in school environments beyond the four developmental school populations was unknown. Furthermore, aspects of its delivery, composition of student populations of these original four schools, as well as methods for embedding the concepts into school ethos have varied across sites, making direct cross-school outcome comparisons difficult. This study was designed as a phase one study (i.e. an evaluation of program effectiveness, feasibility and portability

initially using a small population (National Health and Medical Research Council, 2015)) to formally evaluate a shortened, core version of the BBL Program within novel classroom environments This work is divorced from efforts to change the wider school culture—a feature of the full BBL Program.

The principal significance of this work is the ecological translation of neuroscience research into a classroom environment – implementing a program and evaluating it in the real-world pressures of schools as opposed to constructed, laboratory environments. Key factors in the evaluation were individual student change in relation to specific executive functions as well as portability and perceived value of the program. Portability was determined by feasibility of program delivery in a range of sites and acceptability, by both students and staff. A primary aspect of the study design was to compile quantitative data to support program effectiveness across differing school settings. A randomised controlled trial (RTC) was adopted here. The use of RTCs in educational research is not universally embraced. Research design for this project was informed by work from both Morrison (Morrison, 2001) and Durlak and Du Pre (Durlak and DuPre, 2008), while post intervention analysis relied on later work by Lemons and colleagues (2014) (Lemons et al., 2014). In addition, a qualitative component was included to capture information not readily accessible through an RTC methodology.

Outcomes of this study hold significance for the educational field on three levels. Firstly, the BBL Program is inexpensive to implement within a classroom as lessons use materials that are readily available in schools, easily acquired online, or inexpensively purchased from supermarkets and discount stores. Secondly, the program focusses on the processes of learning (e.g. perception, attending, remembering and practise) using existent curricula so that no further pressure is placed on curriculum content. Thirdly, this work specifically examines the impact of socioeconomic status (SES) in relation to a neuroeducational intervention to examine whether students in lower SES conditions can close the academic gap

with targeted skills intervention and if there is a ceiling effect on executive function development in students with more highly developed skills levels at baseline.

1.2 Research Aims and Questions

The aim of this work was to examine the effectiveness and portability of the BBL Program across a range of socioeconomically distinct school settings. Based on the available literature, research questions were proposed in relation to improving executive function and student motivation/attitude by fostering each student's positive attitudes towards testing, practising and reviewing their personal development. Sleep, SES, and program portability were also research focal points. Although physical activity and diet were clear factors in the literature, these elements do not feature prominently in the BBL Program intervention as South Australian schools currently have a plethora of targeted physical activity and dietary programs. Therefore, no specific research questions have been generated here. However, data from dietary and physical activity measures are factored into the study analysis. The research base on access to digital media and brain development is enticing but beyond the scope of the present work.

Research questions for this study are:

(Executive Function)

1. How and to what extent is the BBL Program more effective in increasing the specific executive functions of working memory, attention (both directed and sustained) and self-regulation (especially impulsivity) as compared to a control group receiving usual classes?

(Motivation and Attitude)

- How and to what extent does student attitude towards school and learning reflect executive function levels as measured by the test battery?

(Physical Aspects--Sleep)

- How and to what extent does an individual student's sleep profile influence levels of executive function?

(Socioeconomic Status)

- How and to what extent do student mindset (i.e. perception about his/herself as a learner--see glossary) and teacher/parent views of student ability align with objective executive function performance, especially in relation to SES?
- How and to what extent do study outcome measures relate to socioeconomic status (SES) as defined by a school's Index of Educational Disadvantage rating?
    - How and to what extent were SES levels reflected in student improvement data?

(Portability)

- How and to what extent did the BBL Program demonstrate positive outcomes (i.e. feasibility in delivery and acceptability to teachers and/or students) for the study population?

1.3 Thesis Construction

The current study focusses on assessing the effectiveness and portability of the BBL Program in novel educational settings (i.e. schools other than the four sites where the BBL Program was incubated). Information on the program is located throughout the thesis as follows:

- An explanation of the full program is provided in Appendix 1
- BBL Program Key Principles are in Appendix 2
- Information provided to parents and schools gives a summary of the Program and contains the Parent Flier which identifies Program focus areas is in Appendix 5
- An overview of the 20-week intensive program can be accessed in Table 11, p. 162.

Chapter 2 reviews the background literature which shaped development of the BBL Program between 2009-11. Since the program was created and refined, research literature in

neuroeducation has grown substantially (see Figure 8, p. 116). Thus, the literature is reviewed in two parts to clarify the influences that shaped the BBL Program's construction. Section 2.1 in Chapter 2 provides an examination of literature available for the initial creation of the BBL Program between 2009-2011. The review of literature post 2011 is then presented in Section 2.3 of the same chapter. This approach historically positions the BBL Program and provides an additional means to review the program's construction in relation to research progress. An exception to this is the information provided under the Physical Inputs section. Here, topics are reviewed to the present in the same discussion. This was done, firstly, because materials on physical inputs represent background considerations for this study. Therefore, a distinction is not required to locate the BBL Program within a specific period of research and, secondly, pertinent areas of research were generally stable within the respective fields reviewed.

Methodology for the study is detailed in Chapter 3, including the randomised controlled trial of the shortened BBL Program which was delivered across the spectrum of social advantage. The main measure for the trial is the Conners' Continuous Performance Test (CPT). This tool incorporates measures for:

- attention—"the mechanism by which we select objects, events or locations in the environment" (Mulckhuyse and Theeuwes, 2010, p. 300).
- working memory—the ability to hold information in mind and mentally work with it where the information is usually not perceptually present (Buschkuehl, 2008, Diamond, 2013).
- inhibition control— the ability to stop or manage response(s), used widely in the research literature to reference physiological, cognitive and behavioural phenomena (Bari and Robbins, 2013).

Chapter 4 provides quantitative, qualitative and integrated results from the study and examines evidence for each of the research questions. The final chapter (Chapter 5) offers discussions and conclusions drawn from study findings as these relate to more recent literature. Recommendations for future work and for educational practice are also considered.

Chapter 2 Literature Review - Neuroscience and Education

Section 2.1 of this review will consider the research that was instrumental in developing the 'Being the Best Learner You Can Be' (BBL) Program. Discussion will examine work prior to and including 2011—the period when the BBL Program was developed and refined. To provide a complete background specific to this project, the review will also include reflections on South Australian educational context, as relevant. This initial review is structured to provide a progression from general educational context to a narrower consideration of the use of a neuroeducational approach in classroom practice.

The role of education within society will first be investigated. This will be followed by an analysis of identified issues arising when education and the cognitive sciences of learning (e.g. neuroscience and psychology) are connected. In the third subsection, discussion will centre around concepts that shape neuroeducational practice with emphasis given to the Mind, Brain and Education discipline. Finally, essential elements for a classroom-based program will be examined. These elements include the understanding and development of executive functions (especially the sub-elements of inhibitory control, working memory, and cognitive flexibility), social and emotional considerations, and physical inputs that support the best student learning conditions by supporting optimal brain functioning.

Section 2.2 will examine the literature on assessment of field-based interventions current at 2012 when this project was shaped. Intervention areas include targeted approaches used to improve or measure executive functions and the physical aspects of sleep, activity, diet, socioeconomic conditions and digital media use, discussed in the section on Physical Inputs. This literature is pertinent to the design of the research project and the range of outcome measures that were selected. In the final part of this chapter, Section 2.3, research post-2011 will be examined for developments and changes.

2.1 Background Literature to BBL Program Development

The development of the BBL Program was influenced by three factors. These are general educational context, prevailing views regarding the use of neuroscience research in education and identification of essential elements required in creating a neuroeducational program.

2.1.1 General Educational Context

In many societies including Australia, formal education is required as a part of every child's life. Thus, it is a logical question to ask, 'What factors lead to educational success?' However, an even more fundamental question takes priority. That is, 'Why educate in the first place?' since the answers to this question shape the definition of what constitutes success.

In this section, the review will examine the purpose of education followed by a brief consideration of the factors which indicate success in education. This discourse sets the scene for the ensuing discussion concerning the alliance of education and neuroscience and the establishment of elements required for a neuroeducation approach such as the BBL Program.

Why educate?

Although education has always been perceived as a means to provide children with the basic skills required to operate effectively within a given society, views on what skills were *basic* have varied. For example, in 1524, Martin Luther's *An die Ratsherren aller Städte deutschen Landes, dass sie christliche Schulen aufrichten und halten sollen* (To the councilmen of all cities in Germany that they establish and maintain Christian schools) stated that the purpose of universal education was to ensure that individuals were able to read the Bible. This was important because Luther perceived faith to be the cornerstone of life and, that faith was exercised through reading the Scriptures or the Christian Bible (Faber, 2015).

Setting religious motivations aside, the role of education has been variously described as preparing the populace for the workforce (i.e. to make a living), keeping children out of the labour market, promoting positive participation in community and democracy, ensuring the experience of a good and worthwhile life, instilling care for the environment, building and maintaining positive relationships, as well as understanding and respecting diversity and differences (British Columbia Teachers' Federation, 2011). This range of individual factors can be conceptualised using the following three general drivers for education—democratic purpose, individual purpose, and economic purpose. These factors are defined by Professor Alan Reid in his 2010 position paper on South Australian educational policy as:

- Democratic purpose—schools are expected by society to produce students who are active and competent democratic citizens (public purpose)
- Individual purpose—the education process prepares the individual for a positive social and economic life (private purpose)
- Economic purpose—schools produce students who are positive economic contributors (constrained public purpose) (Reid, 2010, p.1).

A range of extrinsic and intrinsic success factors related to democratic and individual purpose will now be explored.

Extrinsic and Intrinsic Factors

There have been many entry points into the examination of student success. As Jörg and colleagues noted in their 2007 position paper, there is a "complex reality of learning" (Jörg et al., 2007, p. 147) which by definition, provides many different access points for factor analysis of what constitutes education. Looking at the factors that result in positive learning outcomes for students, Hattie (2009) delineated 138 factors that have been researched in the literature. By 2011, this number had increased to 150 (Hattie, 2011) and by 2016, to 198 (Fisher et al., 2016).

Educational literature also contains copious research on intrinsic factors (i.e. factors found within an individual) that lead to positive student learning outcomes (Wesson, 2011). Table 1 below is a brief overview of the range of extrinsic and intrinsic factors that emerged via an Internet. The table is provided to firstly, reflect the range of factors which can be found in the complex sphere of education and secondly, to give context to the shaping of a neuroeducational program discussed in Section 2.1.3.

Table 1 was constructed using the key search words: *educational success, academic success, learning factors,* and *skills for learning*. These terms were selected from the vast ranges of educational terminology as they best narrowed the search field to factors that would create the most well-rounded learners—the key focus of the BBL Program. Searches were conducted using Google Scholar and the University of South Australia's library search platform. Interrogated university databases include ERIC, A+ Education, Education Database, and Education a SAGE full-text Collection. Table 1 has been limited to sixteen items in each factor. The decision to list only sixteen factors was made based on the purpose of the table. This was to illustrate the complexity of what constitutes success in education. Additionally, in the opinion of the author, the sixteen terms used in the Table 1 exemplified the broad range of research topics currently pursued without creating too much repetition in what is a background point for the current work.

To be included in the list for Table 1, the item needed to appear from at least three key word searches, be reflected in peer-reviewed journals, and be the subject of some type of government or formal school board policy consideration. The list is not exhaustive, nor is it arranged in any order of importance, as importance is relative to the educational stance being reviewed/investigated. A range of references has been provided to indicate the spread of research directions within each topic.

Table 1 Important factors in achieving educational success

Extrinsic Factor	**Intrinsic Factors**
Socioeconomic status (education, income, occupation) (Alloway et al., 2014, Amone-P'Olak et al., 2011, Bornstein and Bradley, 2012, Brito and Noble, 2014a, Duncan and Magnuson, 2012, Hackman, 2012, Hackman et al., 2015, Jednoróg et al., 2012, Livingstone and Helsper, 2007, Meconi et al., 2016, Miller et al., 2015, Morris et al., 2010, Piotrowska et al., 2015, Shechtman et al., 2013)	Various executive functions, (including self-control/regulation—also referred to as inhibition, attending skills, memory/working memory, flexibility) (Ahmed and Stephen Miller, 2011, Barkin, 2013, Best et al., 2011, Blakemore and Choudhury, 2006, Carlson et al., 2016, Cartwright, 2012, Center on the Developing Child at Harvard University, 2011, Diamond, 2013, Hofmann et al., 2012, Martin et al., 2012a, Richland and Burchinal, 2012, Rigoli et al., 2012, Tools of the Mind, 2014, Vergara-Lopez et al., 2013, Yeager and Yeager, 2013)
Teacher estimates of achievement (combined with perceptual bias results) (Aronson, 2010, Dweck, 2008a, Good et al., 2012, Hattie, 2011, Mangels et al., 2012, Park et al., 2014)	Disposition—as a learned pattern of response (Ritchhart and Perkins, 2005, Shechtman et al., 2013, Sternberg, 2005, Zayas et al., 2014)
Family life (Bradley and Corwyn, 2002, Brannen et al., 2000, Campbell and Crawford, 2001, Diamond, 2013, Hackman, 2012, Johnson et al., 2011, Li et al., 2016, Meyer et al., 2013, Misson et al., 2011, Mittal et al., 2013, Noble et al., 2015, Prior, 2011, Zimmerman, 2008)	Sleep (Hirshkowitz et al., 2015) (Blunden and Rigney, 2015, Born, 2012, Bub et al., 2011, Falbe et al., 2015, Fatima and Mamun, 2015, Orzeł-Gryglewska, 2010, Owens et al., 2016, Sadeh et al., 2003, Turnbull et al., 2013)
School environment (ethos, organisation, physical structure, etc.) (Alekno, 2012, Ansari et al., 2017, Dinham, 2007, Hattie, 2011)	Beliefs about self, including growth/fixed mindset (combined with Self-efficacy results) (Brass, 2012, Dweck, 2010b, Mangels et al., 2012, Paunesku et al., 2015)
Social relationships, especially with teacher(s) (Alekno, 2012, Cameron et al., 2005, Clement and Lovat, 2012, Dekker et al., 2012, Dilkes et al., 2014, Dinham, 2007, Gibson et al., 2014, Gilmore and Cragg, 2014, Hargreaves, 2000, Kennedy, 2008, Kidd et al., 2015, Klem and Connell, 2004, Rivers, 2013, Schleicher et al., 2012)	Motivation (Alkaabi and Vyver, 2017, Campbell, 2011, Howard-Jones and Demetriou, 2009, Hung et al., 2012, Mega et al., 2014, Meijer and van den Wittenboer, 2004, Raghubar et al., 2010, Vergara-Lopez et al., 2013, Vohs et al., 2014, Wang and Eccles, 2013, Williams and Williams, 2011)
Vocabulary programs (Baron-Cohen et al., 2010, Clément et al., 2013, Fernald et al., 2013, Marulis and Neuman, 2013, Morris et al., 2010, Weisleder and Fernald, 2013)	Stress (Dishman et al., 2006, Hackman, 2012, Hölzel et al., 2011, Kiecolt-Glaser, 2010, Lovallo, 2013, Nicholls et al., 2016, Schwabe, 2013, Wang and Aamodt, 2012)
Self-reported grades (Adachi and Willoughby, 2013, Fisher et al., 2016, Hattie, 2011,	Creativity (Brass, 2012, Diamond and Lee, 2011, Howard-Jones, 2002, Immordino-Yang and Damasio, 2007, Shechtman et al., 2013, Smeekens and Kane, 2016)

Quiroga et al., 2013, Schwartz and Beaver, 2015)	
Targeted programs (e.g. Piagetian or creativity) (Bywater, 2012, Hoagwood et al., 2007, Hölzel et al., 2011, Jacob and Parkinson, 2015, Morrison and Chein, 2011, Pegg et al., 2005, Raver et al., 2009, Reyes, 2012)	Aspirations/Purpose (Dolan and Peasgood, 2008, Hill and Wang, 2015, Shechtman et al., 2013, Vulpe and Dafinoiu, 2012, Zyngier, 2008)
Formative assessment (Black, 2015, Panadero and Jonsson, 2013, Shute and Kim, 2014)	Confidence (Cragg and Gilmore, 2014, Dolan and Peasgood, 2008, Mega et al., 2014)
Teacher credibility (Eric et al., 2010, Mazer and Stowe, 2016, Won et al., 2017, Yeh, 2009)	Fitness/Diet (Francis and Stevenson, 2013, Gomez-Tolle, 2012)
Microteaching (Ralph, 2014)	Engagement/Interest (Bowen, 2003, Cragg and Gilmore, 2014, Deakin Crick and Goldspink, 2014, Howard-Jones and Demetriou, 2009, Klem and Connell, 2004, McMahon and Zyngier, 2009, Wang and Eccles, 2013, Zyngier, 2008)
Cognitive task analysis (Koedinger and McLaughlin, 2016)	Grit (Duckworth et al., 2007, Shechtman et al., 2013)
Classroom discussion (Applebee et al., 2003, Murphy et al., 2009, Yu et al., 2016b)	Reflective & problems solving skills (Ahmed and Stephen Miller, 2011, Alvarez and Emory, 2006, Canas et al., 2003, Canham et al., 2012, Chang et al., 2011, Cragg and Gilmore, 2014, Graham et al., 2007b, Hung et al., 2012, Lee et al., 2015, Mangels et al., 2012, Raghubar et al., 2010, Wiley and Jarosz, 2012)
Targeted interventions (Bywater, 2012, Hoagwood et al., 2007, Lin-Siegler et al., 2016, Pegg et al., 2005, Reyes, 2012, Vernon-Feagans et al., 2013)	Underpinning literacy/numeracy skills (Alptekin and Erçetin, 2009a, Bhide et al., 2013, Blair and Razza, 2007, Bodrova and Leong, 2003, Brackett, 2012, Cragg and Gilmore, 2014, Daunic et al., 2013, Dommett and Devonshire, 2010, Fisher et al., 2016, Goswami, 2008, Kuhl, 2011a, Prior, 2011, Raghubar et al., 2010, Snow et al., 2007, Voogt et al., 2013)
Reciprocal teaching (Huang and Yang, 2015, Marsh and Hattie, 2002, Reichenberg and Kent, 2014, Schünemann et al., 2013)	Temperament—as an inherent quality (Colom et al., 2007, Mittal et al., 2013, Posner and Rothbart, 2007)
Feedback (especially immediate and timely) (Botvinick, 2001, Campbell, 2011, Howard-Jones et al., 2010, Mangels et al., 2012, Shechtman et al., 2013, Tichon, 2007)	Emotional intelligence (EQ) & social skills (Brackett et al., 2011, Collaborative for Academic Social and Emotional Learning (CASEL), 2010, Diamond, 2013, Luca and Tarricone, 2001, Márquez et al., 2006, Mattson, 2014)

Into the 21st Century—Social Context as a Primary Factor for Success

Currently, the prevailing context in Australian educational literature is 21st century learning (Australian Curriculum Assessment and Reporting Authority, 2016, Australian Curriculum Assessment and Reporting Authority, 2017). By 2011, with the first decade of the new century already relegated to history, educational debate regarding the skills required for success in the 2000s still abounded. In many definitions, the largest distinguishing attribute of the 21st century was the need for digital literacy—the use of technologies to find, use and disseminate information, (Deakin University, 2013). Additionally, educators and academics (e.g. (Dede, 2010, Griffin et al., 2012, Johnson, 2009, Larson and Miller, 2011, Marzano and Heflebower, 2012, Noss, 2012, Rich, 2010, Schleicher et al., 2012, Shechtman et al., 2013, Voogt et al., 2013) pointed to collaboration, critical thinking and problem-solving as key 21st century skills. The following is a diagram produced by the Partnership for 21st Century Learning that attempts to encapsulate the ideal in modern education.

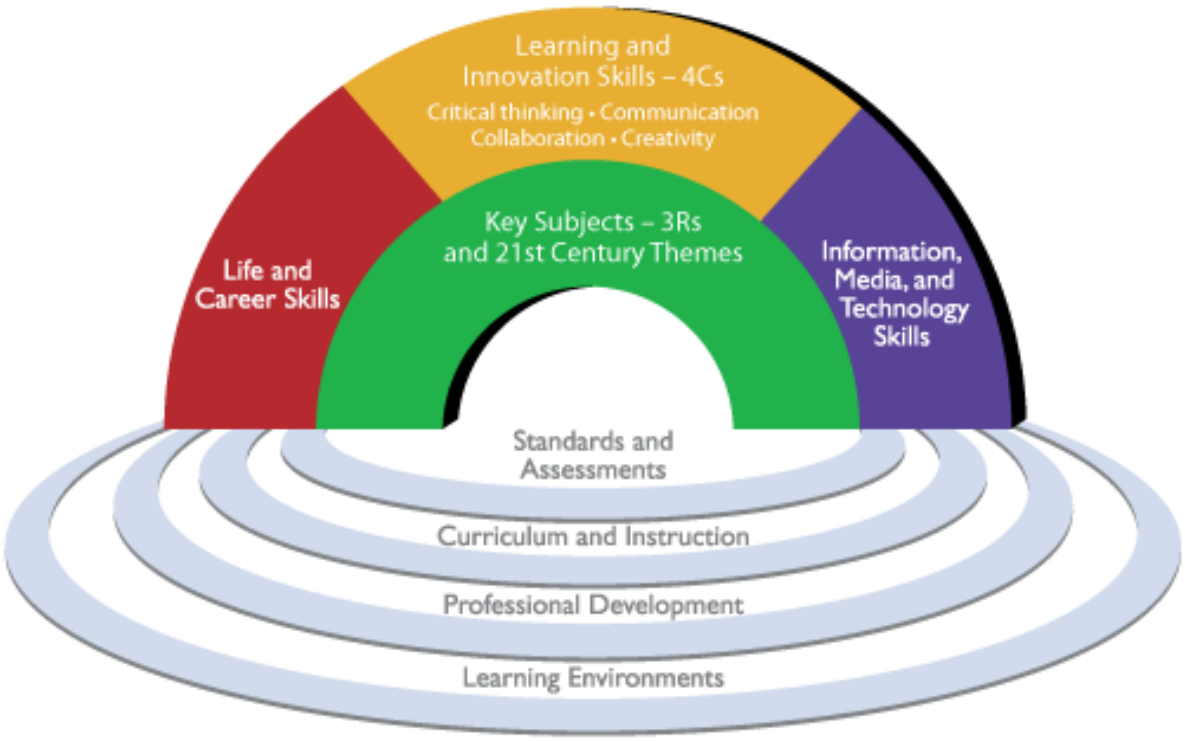


Figure 1 Partnership for 21st century learning skills
(Partnership for 21st Century Skills, 2011, p. 1)

The elements displayed are largely unchanged from those that were espoused in the early 70's when Alvin Toffler's book, *Future Shock*, was current and the author was a high school student. In the following sections, it will be asserted that the elements that make 21st century education dramatically different from the past are:

- available technology and information richness
- increased speed of social change
- new understanding of the brain and how it learns.

Available Technology and Information Richness

Thanks to the Internet, society is now overwhelmingly information-rich (Hardey, 1999). It is no longer necessary to go to public facilities, such as schools or libraries, or consult encyclopaedia to access knowledge. Into the 21st century, this ought to mean that the focus of formal schooling can shift from imparting knowledge, towards teaching skills that assist in critical analysis (also referred to as thinking skills/ higher order thinking skills (HOTS)/ and critical thinking skills (Forster, 2004)). That is, the main purpose of education can no longer be to deliver curriculum as one delivers a package. In the words of the National Research Council, "The meaning of 'knowing' has shifted from being able to remember and repeat information to being able to find and use it." (Simon in (Bransford et al., 2007, p. 5).

An abundance of available information (Forster, 2004, Hardey, 1999, Partnership for 21st Century Skills, 2011, Noss, 2012, Saavedra and Opfer, 2012) alters educational focus from answers to questions. However, the ability to ask the right questions as opposed to give the right answers requires a substantial pedagogical shift for classroom practice. One method used to help implement this shift is inquiry-based learning (Hwang et al., 2015) (also referred to as problem-based learning (Chin and Chia, 2004)and/or project-based learning (Hung et al., 2012)). Inquiry-based learning begins with questions/problems posed and works towards some sort of resolution through student exploration and research. This contrasts with the

traditional practice where teachers present facts/materials for student absorption ((ACARA), 2016, Chin and Chia, 2004). Inquiry-based learning underpins a constructivist philosophy towards learning where students construct their understanding through their range of experiences and make meaning through personal relevance—a view which ties into the neuroscience-based understanding of learning (Carew and Magsamen, 2010, Hmelo-Silver et al., 2007) discussion to in Section 2.1.2 on Neuroscience and Education.

Many approaches that promote critical thinking, well-researched or not, are marketed to educators. A good, evidence-based example of analytical tools comes from the Visible Thinking Team at Harvard's Graduate School of Education (Ritchhart and Perkins, 2008). However, as will be noted in Section 2.1.2 on Seeking Collaboration, not all materials available for classroom use have Harvard's strong research backing (Ritchhart and Perkins, 2008, Ritchhart and Perkins, 2005, Ritchhart et al., 2009). Hence, educators (as well as their students) require well-developed critical thinking skills.

The development of powerful, individual technologies is another aspect of the 21st century digital world that can facilitate more personalised learning programs and opportunities (Saavedra and Opfer, 2012, Schleicher et al., 2012, Voogt et al., 2013). Opportunities exist via both online and face-to-face modes. The practice of flipped classrooms—a pedagogical model in which the typical lecture and homework elements of a course are reversed (EduCause, 2012) is one such pedagogy. Digital technology is the platform for flipped classrooms. Using this mode of instruction, students access lectures and information via the worldwide web or via digital video material outside of class time with the aim of bringing thoughts and queries into class for discussion, exploration and development (Flipped Learning Network, 2014, Hamdan et al., 2013, Sams and Bergmann, 2013).

Not everyone has equal and ready access to digital media, especially, the Internet (Livingstone and Helsper, 2007). For those who cannot stay connected such as under-

resourced schools and students who do not have home Internet access, a new type of educational gap—the digital divide—has been created in the 21st century (Livingstone and Helsper, 2007). Beyond the question of digital divide, research into the effect of digital technology on learning indicates that the best schools/teachers tend to use technology to the greatest educational advantage (Davidson et al., 2010, Johnson, 2006, Kraidy, 2002, McKnight et al., 2016, Shaw, 2001b, Voogt et al., 2013, Woessmann and Fuchs, 2004). As Fuchs and Woessmann (2004) note, schools with high computer availability also tend to be those with other positive educational attributes and, taking this into account, "computer availability at school is not related to pupil performance in math and reading" (Woessmann and Fuchs, 2004, p. 13). The effects of digital technology use on brain development, and specifically attention and working memory, will be considered in Section 2.1.4 in the subsection Access to Digital Media, p. 94.

Increased Speed of Social Change

In the 21st century, society is changing at an ever-increasing rate (Productivity Commission, 2016). A report commissioned by the Australian government entitled, *Digital Disruption: What Do Governments Need to Do?*, identifies the *information age* as the third great social change period driven by technological development, following steam power and electrification (Productivity Commission, 2016). The rise of the information age has substantially disrupted society by "fundamentally changing the way the economy and society operate" (Productivity Commission, 2016, p. 14). Social change is a phenomenon whereby the pressures exerted on the individual by the collective (society) shift significantly. Pressures can target values (thoughts and beliefs), as well as behavioural norms (actions) (Form, 2015). This is especially true in relation to shifts in viable occupations (Productivity Commission, 2016).

The likelihood of several job and career changes during the course of one's working life is another 21st century change factor on the increase (Productivity Commission, 2016). Hence, today's teachers cannot claim to educate students for specific sectors of the workforce since the job market is in a constant state of flux, with many long standing occupations (e.g. production line worker and postal worker) disappearing in line with technological advances with others yet to be created (Productivity Commission, 2016). To be the most job ready, students today require a range of social and emotional skills and attitudes to augment their cognitive skills (Marzano and Heflebower, 2012, Noss, 2012, Partnership for 21st Century Skills, 2011, Saavedra and Opfer, 2012, Voogt et al., 2013). In educational literature, those frequently suggested include the acquisition of:

- a growth mindset – (concept established by Carol Dweck and popularised in her book *Mindset: The new psychology of success* (2006)) defined as a belief that intelligence can be developed through effort and instruction and contrasted with a 'fixed' mindset where the belief is that intelligence is a static attribute (Dweck, 2010b, p. 26).
- grit – perseverance and passion for long-term goals (Duckworth et al., 2007, p. 1087).
- emotional resilience – the existence of a number of protective factors, including temperament, intelligence, and social connectedness, that allow individuals to achieve positive outcomes despite adverse circumstances (Denny et al., 2004).
- collaborative skills – —"describes learning experiences where students act together to perform specific tasks" (McKinney and Denton, 2006, p. 138).
- change fatigue management – "can be defined by its synonyms: being tired of change, adaptive failure, future shock and innovation fatigue" (Dilkes et al., 2014, p. 45).
- critical thinking skills – "reflective thinking involved in the evaluation of evidence relevant to a claim so that a sound conclusion can be drawn from the evidence" (Bensley et al., 2010, p. 91).
- a sense of self as a 'lifelong learner' – the need to continually enhance personal knowledge and skills, in order to address immediate problems and to participate in a process of continuous vocational and professional development as it is no longer feasible to equip learners at school, college or university with all the knowledge and skills they need to prosper throughout their lifetimes (Sharples, 2000, p. 178).

This begs the question, 'Is there a common denominator underpinning what prepares students to strive, thrive and connive (seize opportunities)?' The answer to this question may come from new understandings of how the brain learns, through the growth of the Mind, Brain and Education discipline (Carew and Magsamen, 2010, Ferrari and McBride, 2011, Fischer, 2009, Fischer et al., 2007, Tokuhama-Espinosa, 2011).

New Understanding Regarding the Brain and Learning

During the 1990s, neuroscience research experienced an unprecedented expansion (Center on the Developing Child at Harvard University, 2011). This was made possible by advances in investigative technology such as functional magnetic resonance imaging (*f*MRI) or the positron emission tomography (PET) scan as well as funding inputs from large government initiatives (e.g. the US 'Decade of the Brain between 1990 and 1999). As a result, knowledge about the brain and how it learns grew enormously (see Figure 8, p. 103). Long held academic learning theories were now able to be proved (or disproved) by neuroimaging techniques available to the investigative sciences (Alvarez and Emory, 2006, Blumenfeld, 2007, Casey et al., 2005, Posner, 2010). As a result of neuroimaging, it is possible to detect when a brain is paying attention e.g. (Fan et al., 2005, Posner, 2010, Posner and Rothbart, 2005), recalling a memory e.g. (Maguire et al., 2006, Polyn et al., 2005) or making a decision e.g. (Bechara, 2005, McClure et al., 2004, Sanfey et al., 2003). Given this, logically the focus of education, along with all the elements in the 21st Century learning diagram above, should include the understanding of the potential inherent in the human brain's attention, memory and emotional systems. That is, the basis of educational pedagogy should be a focus on the learning brain, specifically, on developing executive functioning as the skills/abilities that underpin any directed learning.

2.1.2 Neuroscience and Education

> Education is about enhancing learning, and neuroscience is about understanding the mental processes involved in learning (The Royal Society, 2011, p. iii).

Every individual is unique, however, people are broadly united by human biology (Gazzaniga et al., 2002, Gazzaniga, 2014). Following the 'Decade of the Brain', the field of education has experienced a growing call from world bodies such as the Organisation for Economic Co-operation and Development (OECD, 2002b, OECD, 2007, OECD, 2002c, Society for Neuroscience, 2009), national research bodies (The Royal Society, 2011), academics and educators (Campbell, 2011, Carew and Magsamen, 2010, Ferrari, 2011, Fischer, 2009, Geake and Cooper, 2003, Goswami, 2004, Howard-Jones, 2008b, Howard-Jones, 2007, Muller, 2011, Pickering and Howard-Jones, 2007, Shonkoff, 2007a, Shonkoff and Levitt, 2010, Shonkoff and Phillips, 2000) and educators for quality use of neuroscience research in classroom practice .

As this section's introductory quote indicates, the core business of both education and neuroscience is learning, albeit viewed from divergent perspectives (Howard-Jones, 2011b, The Royal Society, 2011). During the 1990s-2000s, differing professional opinions produced a long running debate regarding not just *how much*, but *if*, neuroscience research had any application to a classroom. As Geake and Cooper, editors of *Westminster Studies in Education*, noted in 2003:

> We are aware that many of our [journal] readers have already joined one of two diametrically opposed camps: that neuroscience should keep its nose well out of educational affairs, or, that an even stronger case should be made for a future reliance of education on neuroscience than the

> current assortment of initial misguided enthusiasms such as left and right-brain thinking (Geake and Cooper, 2003, p. 7).

John T. Bruer rallied the negative camp with his 1997 article, Education and the Brain: A Bridge Too Far (Bruer, 1997). In this work, Bruer expressed the belief that the case for neuroscience interacting with education was at least, premature and at most, a research and paradigm gulf too large to bridge. Bruer (1997) expressed the view, as neuroscience primarily studied neurons and educators primarily dealt with schools and children, teachers would be better served by looking towards cognitive psychology to "…solve educational problems and design better instructional tools" (Bruer, 1997, p. 15).

In 2001, while participating in an international forum convened by the Centre for Educational Research and Innovation (CERI) under the Organisation for Economic Cooperation and Development (OECD), Bruer maintained his view that the present drive to re-shape education through neuroscience research was flawed at a basic level and that many policymakers and educators had "vastly overestimated what brain science can tell us about learning and education at this point" (OECD and CERI, 2001, p. 4). In 2007, as a signatory to *The Santiago Declaration*, Bruer (along with 144 other developmental research scientists) again issued a caution regarding the influence of neuroscience in the field of education. The following quote from this document outlines this view:

> The principles enunciated above [regarding child development and learning] are based primarily on findings from social and behavioral research, not brain research. Neuroscientific research, at this stage in its development, does not offer scientific guidelines for policy, practice, or parenting.

> Current brain research offers a promissory note, however, for the future. Developmental models and our understanding of learning will be aided by studies that reveal the effects of experience on brain systems working in concert. This work is likely to enhance our understanding of the mechanisms underlying learning. (James S McDonald Founcation, 2007)

In contrast, the arguments for collaboration between neuroscientists and educators extended beyond the science of early brain development. Many researchers active in the area were convinced that the knowledge from the field of neuroscience was, in the early 2000's, already sufficient to legitimately influence educational theory and practice (Campbell, 2011, Howard-Jones, 2011b). Concisely, the pro collaborative argument stated that the advances in understanding how the brain learns, facilitated by the new technology, provided fresh, compelling evidence regarding human memory and attention systems and the influence of emotion on learning and behaviour (Carew and Magsamen, 2010, Fischer et al., 2007, Geake and Cooper, 2003, Goswami, 2006, Goswami, 2004, Howard-Jones, 2007, OECD, 2002b).

To provide one example, neuroscience research had demonstrated that the long held psychological notion of critical periods of brain development—where there is a distinct window for specific skills development such as animal imprinting (Lorenz, 1937) or visual perception (Hubel and Wiesel, 1962), is a less useful concept in education than sensitive periods for learning (OECD, 2002b). That is, in most respects the brain continues to be adaptable but is more responsive (sensitive) to different types of learning at specific stages as a child matures. Language development is frequently cited to illustrate this concept. The brain is highly receptive, or sensitive, to language acquisition in the early years of life. However, languages can still be acquired well into one's senior years but with more concerted effort required from the learner.

The pro neuroeducation stance also emphasised the need for educators to gain a firm understanding of neuroscience research to avoid promulgation of neuromyths (i.e. the over-extrapolation of research findings such as the view that humans only use ten percent of their brain). Such an understanding would discourage the purchase of products marketed as brain-based but lacking underpinning science (Geake, 2008, Goswami, 2006, Howard-Jones, 2008a).

In its 2002 report, OPEC's Center for Educational Research and Innovation (CERI) set out a collaborative agenda for neuroscience and education regarding different forms of learning, emotional development and regulation, how content (i.e. materials and environment) shapes learning and how the brain learns language and mathematics (OECD, 2002b). However, by 2008 the connecting neuroscience and education debate was still in evidence and encapsulated in a review by Varma and colleagues who distilled the argument into the two main arenas of scientific (philosophic perspective, theory, method, data) and pragmatic (costs, timing, locus of control and return on effort) difference that hindered full collaboration (Varma et al., 2008). These factors were then expressed as both concerns and opportunities. (See Table 2 following.)

Table 2 Summary of concerns and opportunities (Varma et al, 2008, p. 141)

Aspect	Concern	Opportunity
1. methods	Neuroscience methods do not provide access to important educational considerations such as context	Innovative designs can allow neuroscience to study the effects of variables of interest to education, such as context
2. data	Localising different aspects of cognition to different brain networks does not inform educational practice	Neuroscience data suggest different analyses of cognition and may therefore imply new kinds of instructional theories
3. theories	Reductionism is inappropriate	Reductionism is appropriate if it is not eliminative
4. philosophy	Education and neuroscience are incommensurable	Neuroscience may help to resolve some of the incommensurables within education
5. costs	Neuroscience methods are too expensive to apply to education research questions	Educationally relevant neuroscience might attract additional research funding to education
6. timing	We do not currently know enough about the brain for neuroscience to inform education	There are already signs of success
7. control	If education cedes control to neuroscience, it will never regain its independence	Ask not what neuroscience can do for education, but what education can do for neuroscience
8. payoffs	Too often in the past, neuroscience findings have turned into neuromyths	People like to think in terms of brains, and responsible reporting of cumulative results can help them
NOTE: Shading indicates scientific aspect, no shading indicates pragmatic aspect		

From a personal viewpoint, the framing of neuroscience research versus educational application tensions in the argument by Varma and colleagues underscores the differences between the real world educational environment – the school classroom, and the luxury of controlled, laboratory conditions. Additionally, it could be argued that neuromyths do not arise from good scientific practice but, rather from misunderstandings and partial representations of data. Thus, this argument against neuroscience and educational collaboration is actually an argument for why it is imperative that a collaboration is established.

For cognitive neuroscience research to gain real traction in education, it is important for proponents of neuroeducation to follow the lead of Varma and colleagues (2008) and reframe issues as opportunities. Further, it is this author's personal experience that the most crucial point for many educational academics delineated here is the concern regarding control (see Table 2 above - author highlight). Even within the last four years, internationally renowned educational academics have stated categorically in large South Australian educational

conferences that educators should dismiss any claims by neuroscientists regarding learning and curriculum as, '…most of their work involves rats and sea slugs' (Dylan William, 2012, at DECD Northern Regional Leaders Conference). In addition, the concern that neuroscience finding often lead to neuromyths presupposes that the combination of neuroscience research and education generates the neuromyths rather than bad science (e.g. misunderstanding of the data) or poor use of the science (e.g. the presentation of partial truths from research literature). Yet, collaboration is a desirable goal if educators truly wish to ground their practice in evidence and improve student learning outcomes. Fortunately, efforts by both selected educators and researchers continued.

Seeking Collaboration

In both the United States and the United Kingdom as well as Europe and Japan, many organised groups were formed which began to focus on providing educators with access to quality neuroscience and cognitive psychology research relevant to educational policy and practice. These organisations included the Society for Neuroscience (founded 1969), the European Association for Research on Instruction and Learning (EARLI) (founded in 1985), the Dana Foundation—named after the founder, Charles A. Dana (emphasis on neuroscience formally commencing in 1992), the Japan Science and Technology Agency (founded in 1996), the Oxford Cognitive Neuroscience-Education Forum (founded in 2001), the International Mind, Brain and Education Society (founded in 2004), and the NeuroEducational Network (NEnet) (founded in 2010)—now known as the network for Mind and Brain in Education and Social Contexts. Internationally, efforts to consider neuroeducational issues, lobby for change and publish articles, approaches and programs also became available through various sources including:

- journals (e.g. *Mind, Brain and Education* commencing in 2007 and *Science of Learning* – commencing in 2015)

- governmental policy reports/submissions (e.g. internationally, the OECD's *Understanding the Brain: The birth of a learning science* (2002, 2007). In the USA, *From Neurons to Neighborhoods* (2002), in Britain, the Royal Society Brain Waves modules—in particular, *Module 2: Neuroscience: implications for education and lifelong learning* in 2011, and in Australian, the Prime Minister's Science, Engineering and Innovation Council (2009) *Transforming Learning and the Transmission of Knowledge*)
- downloadable resources providing information (e.g. Neuroscience: The Science of the Brain and Brain Facts from the Society for Neuroscience website), conference proceedings (e.g. Neuroeducation: Learning, Arts and the Brain), and essential neuroscience or neuroeducation principles (Neuroscience Core Concepts: The Essential Principles of Neuroscience)
- higher educational opportunities (e.g. the Mind, Brain and Education Program through Harvard University

In Australia, despite work by the Prime Minister's Science, Engineering and Innovation Council (PMSEIC) in 2009 and eminent thinkers connected to the South Australian *Thinkers in Residence* program, dialogue between neuroscience researchers and educators, with few exceptions, was still in its infancy prior to 2011. Courses on learning through a neuroscience lens, particularly for educators, were almost non-existent. One notable exception occurred in South Australian between 2006 and 2010 where the State's three major universities banded together to provide a one year graduate certificate course entitled, *Neuroscience (Learning)*. Primarily for educators, this course aimed to provide its students with background knowledge and skills sufficient to critically appraise the copious brain-based learning' people, programs and products beginning to arrive on antipodean shores. While ground breaking, this course provided theoretical information in a university format where educators were the student-

recipients in the tertiary teacher/student relationship. Despite providing partial scholarships for this course, the South Australian Department of Education and Child Development had no overarching planned coordination for students to implement their new learning upon graduation. Teachers were not seen as potential 'researchers' or 'research partners' and were unable to join the South Australian Neuroscience Institute (SANI) or influence research or policy directions from the classroom in any substantial, organised fashion. It should be noted that since 2011, work by the University of Queensland's Brain Institute Science of Learning Research Centre is making inroads into the education and training of educators in Australia, with major initiatives made possible in 2013 by $16 million research grant.

Constructive two-way interface between researchers and educators was problematic for many reasons. For, while neuroscience was unpacking various aspects of human brain function and learning at a rapid rate, the practical application by school-based educators was impeded due to:

- The overwhelming speed of conceptual change occurring in neuroscience, including the development of new disciplines such as 'affective neuroscience'—the study of the neural mechanisms of emotion (Goswami, 2006, Goswami, 2004, Howard-Jones, 2007, The Royal Society, 2011)
- The technical nature of reported findings coupled with professional discipline barriers arising from perceptual paradigms and discipline-specific language (jargon) that create a lack of access to useful information for educators (Carew and Magsamen, 2010, Varma et al., 2008)
- The proliferation and confusion caused by 'neuromyths' based on an over extrapolation of research findings but used to direct classroom practice (Carew and Magsamen, 2010, Geake and Cooper, 2003, Geake, 2008, Goswami, 2006, Howard-Jones, 2007, The Royal Society, 2011)

- A burgeoning array of commercial ‘brain-based education’ packages that often reflect popular neuromyths and were spruiked without enough strong research evidence to underpin them (Howard-Jones, 2007, Society for Neuroscience, 2009, The Royal Society, 2011). Often, these were highly attractive in presentation and marketing, and thus served to reinforce popular misconceptions and poor classroom practice (e.g. Brain Gym ™).
- Lack of appropriate, easily accessible training for teachers to allow them to cope with the points above (Howard-Jones, 2009, Howard-Jones, 2008b, Howard-Jones, 2008a, Society for Neuroscience, 2009, The Royal Society, 2011).
- Curriculum, attitudinal, financial and time pressures on classroom teachers which inhibited new learning, deep reflection and/or changes to pedagogy, as well as dominant political mandates impacting the educational landscape (Dilkes et al., 2014).

The reader is directed to Appendix 3 Educational Uses for Neuroscience Research for a more detailed examination of each point.

Seeking Collaborative Consensus

Research in the field of neuroscience is broad and ranges from the study of genetic matter within individual genes through to more social-based conceptual research involving the study of an ‘ethical’ brain (Gazzaniga, 2005), how humans make decisions (Isen, 2001, Vohs et al., 2008, Wittmann and Paulus, 2008), or even consciousness itself (Almada et al., 2013, Campbell, 2011, Panksepp, 2005). Several important key aspects of neuroscience research are relevant to educators and form the basis of many introductory courses on neuroeducation (e.g. the MBE course offered at Harvard and the research program at the University of Queensland Brain Institute). Based on the growing understanding of brain plasticity, key concepts focus on:

- general brain development including neural pathways, neural networks, neural systems and the interactions between neural systems
- metacognition, including both conceptual and interpersonal relationships and executive functioning
- memory systems
- attention systems
- emotional systems
- providing evidence for theories of learning and behaviour.

However, as Varma and colleagues identified in 2008, there are different motivational aims in how researchers and educators conceptually weave research information within the teaching/learning processes. In reviewing the literature available current at 2011, this author concluded that the synthesis of neuroscience research and education *from a classroom practitioner's vantage point,* could be viewed from the following three foci (see Appendix 3 *Educational Uses for Neuroscience Research - Examples and Citations* for more detail relevant to classroom practice):

1. Providing increased curriculum-related knowledge
2. Providing increased direction for educators through enhanced diagnostic and supportive capacity
3. Improving general education policy and practice (pedagogy).

Within this third point, the literature could be further divided to include research from the 'outside'—academics in various fields looking to test and apply findings within the education paradigm and from the 'inside'—educators looking at the growing body of research to discover what may be of practical use in the formation of policy, curriculum, pedagogy and

school environments. A parallel can be drawn here to the way that neuroscience research on persuasion and advertising have melded (Cacioppo et al., 2016).

Conceptualising Neuroeducation –the Rise of Mind, Brain and Education (MBE)

During the 2000's, a unifying force in the neuroeducation debate evolved with the development of a new academic discipline - Mind, Brain and Education (MBE) Science. The International Mind, Brain and Education Society was formed in 2004 as a result of a number of collaborations in a variety of countries (Ferrari and McBride, 2011). The underlying reasoning for such a coalition was to promote an integrated or transdisciplinary approach to research and practice concerning human learning and development. As key MBE players stated in their article, *Why Mind, Brain, and Education? Why Now?*

> The discovery of powerful brain-imaging tools; the remarkable, burgeoning discoveries that are transforming genetics; and the growing power of methods for assessing cognition, emotion, and learning make possible an alliance that can illuminate human learning and development. As hidden processes in the brain and body become visible, researchers and educators can begin to observe the biological effects of educational interventions and relate them to outcomes in learning and development. This new approach can simultaneously inform effective practice and build fundamental knowledge about the ways that children and adults learn and develop (Fischer et al., 2007, p. 1).

Learning is about making connections, physiologically at a neural level and conceptually at cognitive, affective, and across cognitive-affective levels. The 'new science' of mind, brain and education focusses on breaking down academic silos to consider the fullness of human

cognition and embraces an 'evolutionary' approach to educational practice in much the same way as the Baldwin Effect (the capability of an organism to be flexible and creative in adapting its behaviour to a changing environment (Psychology Dictionary, 2016a)) is understood in evolutionary psychology. Work by Tokuhama-Espinosa (2011) graphically illustrates and succinctly summarises much of the verbal explanation and debate in the literature as shown in the following figure.

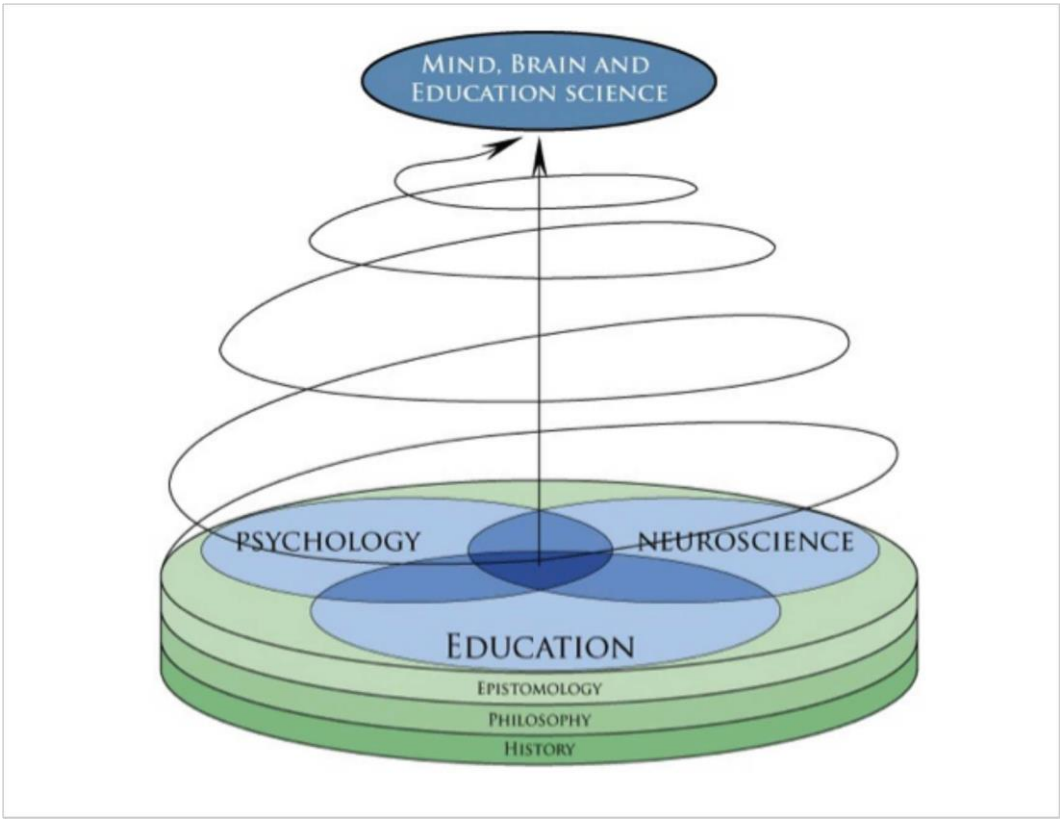


Figure 2 Evolution of the Mind, Brain and Education discipline
(used with permission-all rights reserved)

Historically, one could argue that MBE science is a newborn discipline, given its relatively recent creation in the mid 2000s. Alternatively, one could view MBE as a natural culmination of modern scientific thought growing out of an underpinning understanding of the fundamental links between human sensing, knowing and conceptualising—a construct proffered by Hippocrates as early as 380 BEC (Ferrari and McBride, 2011, p. 86).

The website of the International Mind, Brain and Education Society states that the mission of the society is to '…facilitate cross-cultural collaboration in biology, education and the cognitive and developmental sciences' with expressed objectives to:

- 'Improve the state of knowledge in and dialogue between education, biology, and the developmental and cognitive sciences;
- Create and develop resources for scientists, practitioners, public policy makers, and the public; and
- Create and identify useful information, research directions, and promising educational practices.' (International Mind Brain and Education Society, 2016)

These stated objectives are quite broad overarching statements. In her 2011 article, Tokuhama-Espinosa, offered a more incisive explanation of MBE parameters. Reflecting the reality of a transdisciplinary approach, Tokuhama-Espinosa states that MBE practitioners are educators, neuroscientists, and psychologists who:

- Are willing to share knowledge outside of their discipline
- Recognise the need to adapt language and context to the audience
- Embrace the belief that connecting information across fields is advantageous for all
- Expect to operate as peers with other neuroscientists, psychologists and educators (Tokuhama-Espinosa, 2011, p. 6).

Further, if MBE practitioners are faithful to these ideals, and critically reflective enough to select only the best information from their respective fields, the new science of teaching and learning that ensues will create complex, evidence-based solutions for the complex problems facing education (Tokuhama-Espinosa, 2011, pp. 3-5).

The new neuroeducational learning science, or MBE, created through the cross fertilisation of several research fields, aims to share and/or challenge entrenched disciplinary perspectives. This practice allows researchers and educators to better dispel bias and to approach the

'Truth' by carefully mapping more of the terrain. The following diagram clarifies the relationships of key disciplines that contribute to MBE construction. It is important to note that the field of neuroeducation, as alleged by some academics, does not attempt to assimilate any of the parent fields. Rather, neuroeducation is made both possible and necessary by the independent existence of every other discipline as demonstrated by the following diagram.

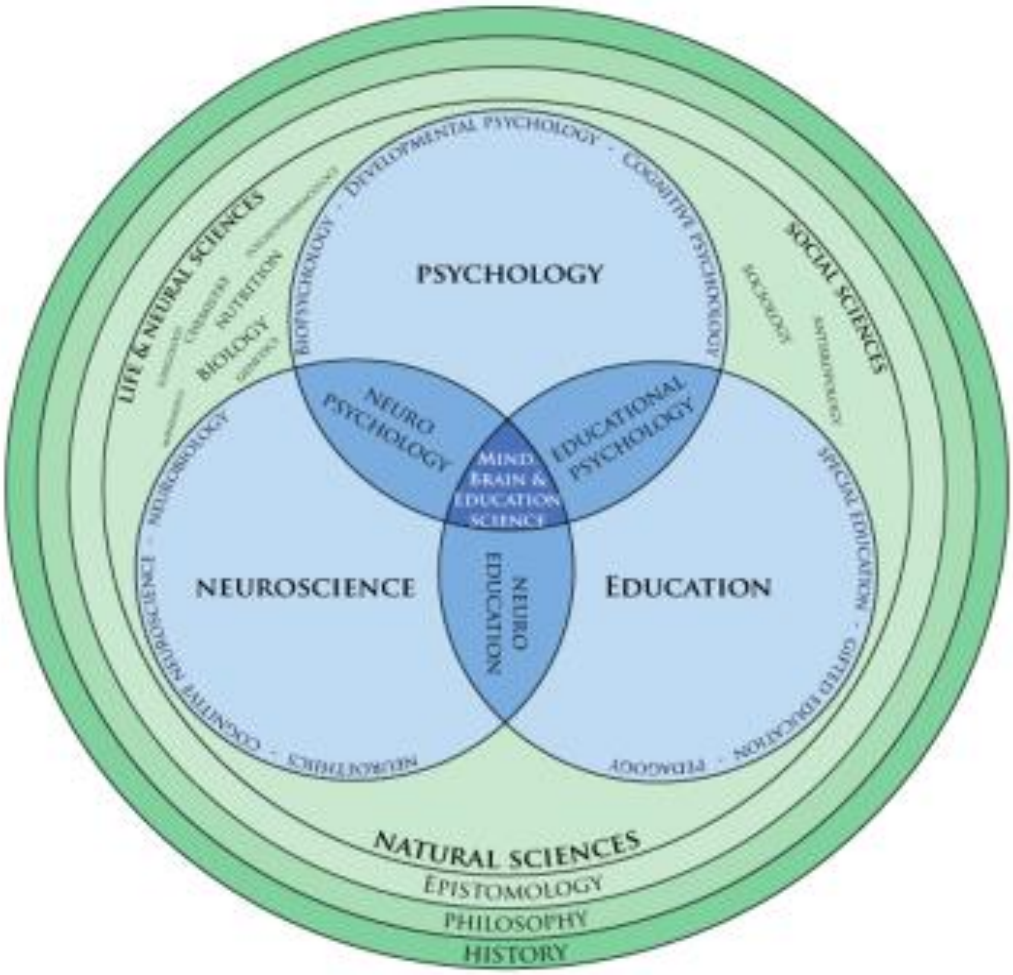


Figure 3 Tokuhama-Espinosa's model of the origins of Mind, Brain and Education science
(used with permission-all rights reserved)

2.1.3 Shaping a Neuroeducation Program: Distilling the Essential Elements

> By identifying and understanding the limits [brain capacity] places on learning, we can tailor more effective learning environments (PMSEIC, 2009, p. 11).

Having established a clear sense of the background educational literature, this review now considers the essential characteristics and skills a student should possess for optimal learning as these emerge from the cognitive sciences literature. Basic to this discussion are the *biological* concepts of neuroplasticity—"the ability of the nervous system to respond to intrinsic or extrinsic stimuli by reorganizing its structure, function and connections" (Cramer et al., 2011), p1591) and the brain as a pattern-seeking/pattern-making mechanism. The latter concept leads to consideration of the impact of perceptual bias and the development of dispositions through pattern repetition and executive functioning.

Neuroplasticity

> Everything having to do with human training and education has to be re-examined in the light of neuroplasticity. (Doidge, 2007)

In the past twenty-five years, research in the discipline of neuroscience has enormously expanded understanding of human brain function and development (Yeung et al., 2017). Some researchers posit that human brains have two significant neuronal growth periods during the early years and in adolescence during which a surge in neural growth and pruning takes place (Blakemore and Choudhury, 2006, Gogtay et al., 2004, Paus, 2005). It is thought that pruning is a necessary process in normal brain development which allows for the formation and/or refinement to major neural networks responsible for aspects of perception, emotional response and cognition (Gogtay et al., 2004, Paus, 2005, Sowell et al., 2003).

Each person's brain is unique due to both his/her genetics and individual personal experiences (Blakemore and Frith, 2005, Giedd et al., 1999, Gogtay et al., 2004, Jernigan et al., 1991, Mustard, 2007, Shonkoff and Phillips, 2000, Sowell et al., 2003, Sowell et al., 2004, Sowell et al., 1999). While the neural development that takes place during the early years and adolescence is foundational, the learning that takes place in between these two periods is also important since all brains respond to new learning and experience with structural change to neural networks (Bavelier et al., 2010, Cotman and Berchtold, 2002, Dishman et al., 2006, Kramer and Erickson, 2007, Mechelli et al., 2004). This phenomenon is commonly referred to as neuroplasticity (Shaw, 2001a) and is validation for a model of synaptic function proposed originally by Donald Hebb over fifty years ago.

The concept of neuroplasticity (or brain plasticity) is both good news and bad, in that individuals are born with a 'blueprint' for how their brains could and should develop, but require the necessary inputs to stimulate the brain to develop according to the template (Center on the Developing Child at Harvard University, 2011). When that input is not provided, an individual's brain will not realise its potential or worse, a variety of emotional, behavioural, perceptual and learning difficulties may occur (Center on the Developing Child at Harvard University, 2011) . To illustrate, according to Patricia Kuhl, Director of the LIFE Center (Learning in Informal and Formal Environments) at the University of Washington, USA:

> Evidence relating socioeconomic status (SES) to brain function for language suggests that SES should be considered a **proxy** for the opportunity to learn and that the complexity of language input is a significant factor in developing brain areas related to language. The data indicate that the opportunity to learn from complex stimuli and events

> are vital early in life, and that success in school begins in infancy (Kuhl, 2011a, p. 128).

Explorations of neuroplasticity have altered some fundamental beliefs about brain development (Blakemore and Bunge, 2012). For example, it was previously thought that the first five years of life absolutely cemented brain construction in an individual. However, it is now known that any learning at any stage of life physically alters the structure and/or function of the brain (Bavelier et al., 2010, Cramer et al., 2011, Kuboshima-Amemori and Sawaguchi, 2007, Shaw, 2001a). As Cramer and colleagues explain, "Neuroplasticity occurs with many variations, in many forms, and in many contexts. Common themes in plasticity that emerge across diverse central nervous system conditions include experience dependence, time sensitivity and the importance of motivation and attention." (Cramer et al., 2011, p. 1592).

A better understanding of neuroplasticity has given impetus to the importance of nurturing executive function development in schools (Blakemore and Choudhury, 2006). For example, investigations into the relationship of executive functioning and academic performance (Best et al., 2011), including the development reading (Alptekin and Erçetin, 2009a, Best et al., 2011, Cartwright, 2012, Hruby and Goswami, 2011), and mathematics (De Smedt et al., 2010, Kaufmann, 2008, Raghubar et al., 2010). For, although the brain is set to develop along predictable lines, personal experience and learned patterns of response fundamentally affect the process (Center on the Developing Child at Harvard University, 2011, Fox et al., 2010, Posner and Rothbart, 2005). Furthermore, the brain is frugal. As part of the learning process the brain also discards or prunes neural connections that are not reinforced through repeated use (Cramer et al., 2011). In summary, brains constantly alter in response to experience, thought and action and, thus, are more or less prepared for future learning by how past development has led to the present (Draganski et al., 2006, Giedd et al., 1999, Kuboshima-

Amemori and Sawaguchi, 2007, Mechelli et al., 2004, OECD, 2002b, PMSEIC, 2009, Shonkoff and Phillips, 2000).

Importance of Patterns

> Our predictions are based on our past experiences, our brains turn these experiences into patterns that we unconsciously use to guide us. So reliant are we on these patterns that they can shape our actual experience (Brinson, 2016, p. 2).

Patterns are fundamental to organisation and learning (Bransford et al., 2007, Brinson, 2016, Squire, 2004). From a very early age, the brain begins to create meaning from experience arranged as neural patterns or 'schema' (concepts or frameworks that interpret, organise and categorise mental inputs (Psychology Dictionary, 2016b) (Bransford et al., 2007, Brinson, 2016). Learned patterns of both behaviour and perception form the basis of one's world view with the capacity to deliver positive or negative educational outcomes (Boroditsky, 2001, David and Kistner, 2000, Fatima and Mamun, 2015, Goldin, 2000, Mangels et al., 2006, Markson et al., 2008). A range of studies have shown changes in brain development, structure and/or density as a result of life experiences (Giedd, 2012, Giedd, 2008, Gogtay et al., 2004). People who are bilingual (Mechelli et al., 2004), musicians (Gaser and Schlaug, 2003), or even London taxi drivers (Maguire et al., 2006) will display measurable differences in brain structure from mono-linguists, non-musicians and any other driver respectively. Similarly, the consequences connected to an impoverished background such as malnutrition (Hackman and Farah, 2009), suffering neglect in one's early years (Dawson et al., 2000, Downey, 2007, Hackman, 2012) or experiencing a significant traumatising incident such as bullying (Elliott, 2003, Giedd, 2008, Greenwood, 2002, Hazler et al., 2006, Perry et al., 1995) with also leave detectable, physical changes in the brain expressed as strongly embedded patterns of thought, emotion and behaviour.

As mentioned above, there are two important, major periods of brain development that have attracted the most research to date. These occur in the first years of life and again during adolescence when major patterns of cognition and affect are established (Giedd et al., 1999, Gogtay et al., 2004, Shonkoff and Levitt, 2010, Shonkoff and Phillips, 2000). These developmental periods can be likened to the construction of a house, in that they lay the foundation for an individual's subsequent life interactions. As it is possible to extend the dimensions of a house after construction, so too, can the brain develop and change at fundamental levels. However, like a house extension, this requires much more effort, planning and structural change than laying a larger foundation initially. Hence, the patterns of thought, emotion and action that are laid down in both childhood and adolescence are key factors in educational and lifelong success and in building cognitive reserve (the ability to optimise normal performance) (Stern, 2002).

In the human brain, well-constructed patterns of cognition and affect can be identified within the paradigm of executive functioning (Ahmed and Stephen Miller, 2011, Alvarez and Emory, 2006, Anderson et al., 2001, Ardila, 2008{Zelazo, 2011 #297)}, including what captures attention (Diamond, 2013, Fan et al., 2005), is retained in memory (Diamond, 2013, Engle, 2002, Zelazo and Müller, 2011) or is inhibited from expression (Cartwright, 2012, Davidson et al., 2006, Diamond, 2013, Garon et al., 2008, Hofmann et al., 2012). Of principle importance is the role that patterns play in thinking (e.g. mindsets and critical analysis), feeling (e.g. belief frameworks) and acting (behavioural habits) as well as the role that practice plays in strengthening these patterns (Meltzoff et al., 2009, OECD, 2002b, OECD, 2002a, OECD and CERI, 2001).

Learned Patterns Create Perceptual Bias

> Because learning involves transfer from previous experiences, one's existing knowledge can also make it difficult to learn new information (Blunden and Rigney, 2015, p. 70).

In an effort to understand and improve the process of teaching and learning, a number of different learning models have been proposed (Beatty, 2008, Woolfolk Hoy et al., 2013). These include a range of theories such as information processing theory (Simon, 1978), Skinner's reinforcement theory (Skinner, 1984), Gardner's Theory of Multiple Intelligences (Gardner, 2011), and Kolb's four-stage experiential learning theory (Kolb et al., 2001)—to name but a few. Briefly, what the plethora of models indicates is that learning is a complex and multifaceted process that is dependent upon both an individual's internal and external environments at any given point (Woolfolk Hoy et al., 2013).

Over the years, learning theories have become so numerous (according to Atherton, 2005, there are more than 50) that academics can use four broad categories to encompass the behavioural, cognitive, constructivist and sociocultural paradigms (Woolfolk Hoy et al., 2013). Alternatively, the general learning process can be viewed from a biological or brain function lens where learning takes place in relation to perception, attention, memory, and behaviour and where learning is enhanced or extinguished due to the strength, duration and repetition of memory, emotional context, and brain health (Gazzaniga, 2014, Gazzaniga et al., 2002). Thus, it could be said that what an individual brings to current learning opportunities and subsequent behaviour is highly dependent upon the relationship of perceptual outlook or world view (cognitive filters) (Siddiqui, 2008, Ziaei et al., 2014) coupled with attention and memory skills in a constantly revolving cycle as represented by the following diagram (see Figure 4). Information in (what claims one's attention) is perceptually filtered (Siddiqui,

2008). Storage (memory making) is dependent upon attentional focus (Ansari et al., 2012, Conway et al., 2005b, Cowan, 2011, Diamond, 2013), and outcome (behaviour-including thoughts and feelings) (Dickson and Burton, 2011, Geake and Cooper, 2003, Greenwood, 2002, Kirkcaldy et al., 2002, LeDoux, 1993, Miller, 2000) is derived as a consequence.

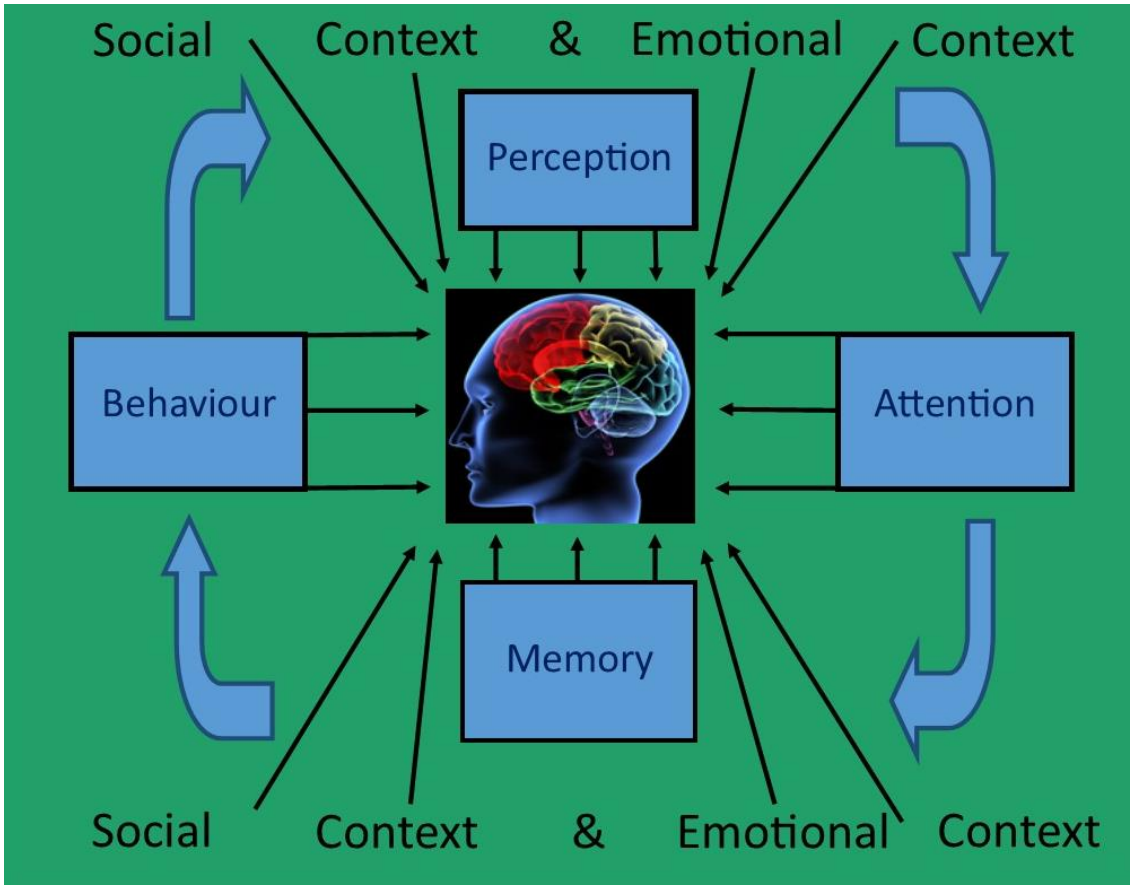


Figure 4 Perceptual information processing model
Conceptual representation by author

However, human brains do not process all incoming information (Fan et al., 2005, Posner, 2012, Posner, 2010). Instead, individuals develop learned patterns of response or filters to manage where attention is directed (Fan et al., 2005, Posner, 2012). Personal filters develop through a number of processes including culture (Boroditsky, 2001, Kuipers and Thierry, 2015), personal beliefs (Alekno, 2012, Blair and Razza, 2007, Cacioppo et al., 2016), personal relevance (salience) (Belopolsky and Theeuwes, 2010), health (Diamond, 2013,

Hackman, 2012, Oakes et al., 2004), prior experience (Belopolsky and Theeuwes, 2010), social interactions, mood (Algoe and Fredrickson, 2011, Bodrova and Leong, 2003, Brackett, 2012, Bradley and Corwyn, 2002, Goswami, 2004, Greenberg and Kusché, 2006), and situational context (Palmer et al., 2011, Posner and Rothbart, 2005, Posner and Rothbart, 2007). These filters bias learning by influencing how attentional resources are spent (Bransford et al., 2007).

Perceptual filters are not always constant or consciously acknowledged (see Project Implicit). For example, an unconscious bias towards members of a particular cultural group may result in more (or less) critical behaviour during interactions without any active intention (Goldin, 2000). Specific use of vocabulary also shapes attention and thinking (Boroditsky, 2001, Low and Simpson, 2012, Markson et al., 2008). This propensity for bias means that individual expectations influence personal perceptions, and by extension, discipline-specific theories/paradigms influence research aims, study designs and research findings. One could argue that, for this reason, all scientific research will be fundamentally flawed without structures such as peer review and independent replication of results. This same dynamic applies to theories of learning and, again by extension, to the selection of classroom pedagogy—'the method and practice of teaching, especially as an academic subject or theoretical concept' (Oxford Dictionaries Online, 2016).

From Patterns to Disposition

Over time, continued use of specific biological filtering leads to the development of dispositions or mindsets which, in turn, direct and limit the construction of an individual's internal reality (Brinson, 2016, Cohen, 1994, Fredrickson, 2004, Moore and Malinowski, 2009, Tang et al., 2007). Entrenched patterns of thinking and feeling (one's disposition) arise from a combination of genetics and life experience (Brinson, 2016). One of the strongest perceptual filters relative to learning is the sense of self as a learner (Dweck, 2008, Dweck,

2010b, Mangels et al., 2012). The beliefs held by individuals about their basic abilities and role(s) in the learning process can expand or limit learning outcomes (Good et al., 2012, Mangels et al., 2006, Rattan et al., 2012).

Since the 1970's, with Alfred Bandura's ground-breaking research into self-efficacy—personal judgements of one's capabilities to organise and execute courses of action to attain designated goals (Zimmerman, 2000, p. 83), educators have broadly considered student attitudes in relation to teaching practice but have tended to see student ability as a fixed commodity. Over the last several years, psychologist Carol Dweck has explored how personal performance is impacted by views regarding intelligence—an individual's ability to "understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought" (Neisser, 1979, p. 1). According to Dweck and her associates, individuals who believe that intelligence is a fixed quality were more inclined to focus on maintaining an aura of intelligence (i.e. not doing anything to look dumb) than individuals who believed that intelligence can be enhanced by effort (malleability). Individuals who took a 'malleable' mindset to intelligence conceptualised mistakes as part of the learning process, focused more on their learning than on intellectual status, and actively placed themselves in environments that challenged current skills levels (Dweck, 2008b, Dweck, 2010a, Dweck, 2008a, Mangels et al., 2006). Of particular note for classroom teachers, Dweck's work also examines the role of praise in relation to self-belief. One key finding suggests that high praise for low achievers can actually de-motivate rather than motivate these students (Dweck, 2008b, Mueller and Dweck, 1998, Wood, 2000). Thus, helping students to notice and actively seek out intrinsic reward would appear to be a key educational deliverable.

In this section, it has been demonstrated that neuroplasticity, the brain's reliance on patterns, and disposition are important educational considerations. In the following section, attention

will turn to an examination of executive functioning as the core underlying skills sets required to actively engage in learning.

Executive Functions

Collectively, all skills required to set and then attain a (usually medium to long term) goal are referred to as executive functions (Dawson and Guare, 2004). The precise definition of which individual skills constitute executive functioning is problematic. As reported by Zelazo and Müller (2011), "(e)xecutive function (EF) is an ill-defined but important construct that refers generally to the psychological processes involved in the conscious control of thought and action" (p. 574). In 2009 (the formative stage of the BBL Program), executive functioning was represented in the literature through a range of different research lines of inquiry which will be described below. The development of executive functions and programs created to support this development will also be discussed.

Jurado and Rosselli (2007) published a summary of research on executive function which demonstrated the wide range of conceptual frameworks in use. In a table entitled, *Concepts and components of executive function*, Jurado and Rosselli listed eleven different approaches to the field by author, each with a different set of elements thought to comprise executive functioning. This information is reconfigured by concept below for ease of discussion (see Table 3).

As well as the eleven models mentioned in Jurado and Rosselli (2007), other models were being actively promulgated during the 2000s. McCloskey (2004) and Anderson (2002) developed and spruiked their concepts of Holoarchical Developmental Model of Executive Function Capacities and Model of Executive Function respectively. Juxtaposed, these models underscore the range of elements considered for the suite of executive functions, and the diversity of conceptual thought. (See Table 4)

Table 3 Jurado & Rosselli - concepts and components of executive function restructured

Concepts/Components	Research
Planning/Organisation/Sequencing	Lezak (1983), Delis et al. (2001), Hobson & Leeds (2001), Elliot (2003), Banich (2004)
Concurrent manipulation of information/Problem solving	Lafleche & Albert (1995), Borkowsky & Burke (1996), Anderson et al. (2001), Delis et al. (2001), Hobson & Leeds (2001), Piguet et al. (2002), Elliot (2003), Banich (2004)
Purposeful control	Lezak (1983), attention; strategy; Borkowsky & Burke (1996), Anderson et al. (2001), impulse; Delis et al. (2001), behaviour; Elliot (2003), behaviour; Banich (2004)
Aspects of attention [specified as part of attention network(s)]	Baddeley & Hitch (1974), Norman & Shallice (1986). Anderson et al. (2001), Delis et al. (2001), Hobson & Leeds (2001),
Goal setting	Lezak (1983), Lafleche & Albert (1995), Anderson et al. (2001), Banich (2004)
Thinking (including reflection, creativity, analysis)	Lafleche & Albert (1995), Borkowsky & Burke (1996), Delis et al. (2001), Piguet et al. (2002), Elliot (2003), Banich (2004)

(Jurado and Rosselli, 2007) p. 214)

Table 4 Comparison of executive function conceptual models by McCluskey (2004) and Anderson (2002)

Concepts/Components	Research
Self Control: Self Activation (awake, attend) **Self Control: Self Regulation** **Self Control: Self Realisation & Self Determination** (contains the elements of EF except goal generation, long-term planning and what others call metacognition) **Self Generation** (Mind-Body Integration) **Trans-self Integration** (Cosmic consciousness)	McCloskey (2004)
Attentional Control (selective attention, self-regulation, self-monitoring, inhibition) **Cognitive Flexibility** (divided attention, working memory, conceptual transfer, feedback utilisation) **Goal Setting** (initiative, conceptual reasoning, planning, strategic organisation) **Information Processing** (efficiency, fluency, speed of processing)	Anderson (2002)

(McCloskey, 2008) slide 21 and (Anderson, 2002, p. 73)

In this same time period, Hughes and Graham (2002) stated that executive functions come into play whenever individuals are faced with novel (to them) situations that necessitate choice and the execution of actions requiring conscious reflection—the features that distinguish controlled versus automatic actions (Hughes and Graham, 2002, p. 131). Hughes, in an online resource article for Cambridge University Press, further indicated that executive function "…sub-divides in children and adults in similar ways" as inhibitory control, attentional flexibility, and working memory/planning (Hughes, undated, p. 314). By 2011, Diamond was disputing the role of planning as an executive function. Instead categorising the ability to plan as a consequence of a well-developed executive function system (Diamond and Lee, 2011). The three key features of inhibitory control, attentional flexibility and working memory eventually began to dominate the research landscape on executive functioning.

In terms of education, discussion of executive function has long been part of the special education paradigm, especially within the area of autism spectrum disorders (Cumine et al., 1998, Frith, 2003, Ozonoff et al., 1991, Pennington and Ozonoff, 1996, Perner and Lang, 2000). By the mid 2000s, the importance of executive function was becoming prominent in general educational literature as the field became interested in 'brain-based learning'. Within the state of South Australia, works by Meltzer (*Executive function in education: from theory to practice (Meltzer, 2007)*) and Dawson and Guare (*Executive skills in children and adolescents: a practical guide to assessment and intervention (Dawson and Guare, 2004)*) were beginning to affect educational thinking. In addition, work presented in a format readily accessible for educators, such as that of Renate and Geoffrey Caine (Caine and Caine, 2006, Caine, 2008, Caine and Caine, 2004, Caine and Caine, 2000) or David Sousa (Sousa, 2005, Sousa, 2007b, Sousa, 2007a, Sousa and Tomlinson, 2011) and visits from The Institute for the Future of the Mind in Oxford staff (i.e. Baroness Professor Susan Greenfield, Professor

Martin Westwell and Dr Jonathan Sharples), in particular, were shaping the viewpoints of government ministers and State education leaders.

By 2011, the literature on executive function was beginning to coalesce. In a key paper by Harvard's Center on the Developing Child entitled, *Building the Brain's "Air Traffic Control" System: How Early Experiences Shape the Development of Executive Function*, the definition of executive functions was proffered in terms of three 'dimensions' rather than as individual skills. These dimensions were defined as inhibitory control, working memory, and cognitive or mental flexibility (Center on the Developing Child at Harvard University, 2011, p. 2). As dimensions of executive function, the paper acknowledged that, "In most real-life situations, these three functions are not entirely distinct, but, rather, they work together to produce competent executive functioning" (Center on the Developing Child at Harvard University, 2011, p. 2). Thus, all lines of inquiry could be accommodated under a triad of focal points.

Development of Executive Functions

Executive functions (EF) develop over time, with practice and are particularly vulnerable to developmental disturbances, such as trauma (Center on the Developing Child at Harvard University, 2011). EF provide the foundation or common denominator for learning and social development (Center on the Developing Child at Harvard University, 2011, p. 5). As well as life experience, the development of EF skills is tied to maturation of the prefrontal cortex (Giedd et al., 1999, Gogtay et al., 2004, Hughes, 2011). Hence, this suite of skills is still under construction into early adulthood.

According to Adele Diamond, a prominent EF researcher from the University of British Columbia and Children's Hospital, skills levels of executive function are key predictors of both school readiness and long-term academic success. Levels of health and happiness are

also tied to strongly developed EF skills, especially those of self-regulation (Diamond and Lee, 2011). It should be noted that Diamond is not one research voice in the wilderness. Harvard's Center on the Developing Child concluded that, based on emerging evidence, "…the most effective early education programs of the future are likely to teach preschool curriculum content (e.g. early literacy, math, social skills) in a way that optimizes the scaffolding and practice of executive function skills" (Center on the Developing Child at Harvard University, 2011, p. 12). Best and colleagues argue that consideration of executive function development is relevant throughout the lifespan and particularly relevant to school performance in children over the age of five (Best et al., 2011).

The following graph demonstrates the typical development of EF skills, highlighting the largest period of growth in the first six years of age and with rapid development peaking around age 25. It should be noted, however, that executive function skills are never really mastered. Given appropriate stimuli and use, executive function skills are continually refined throughout life (Diamond, 2013).

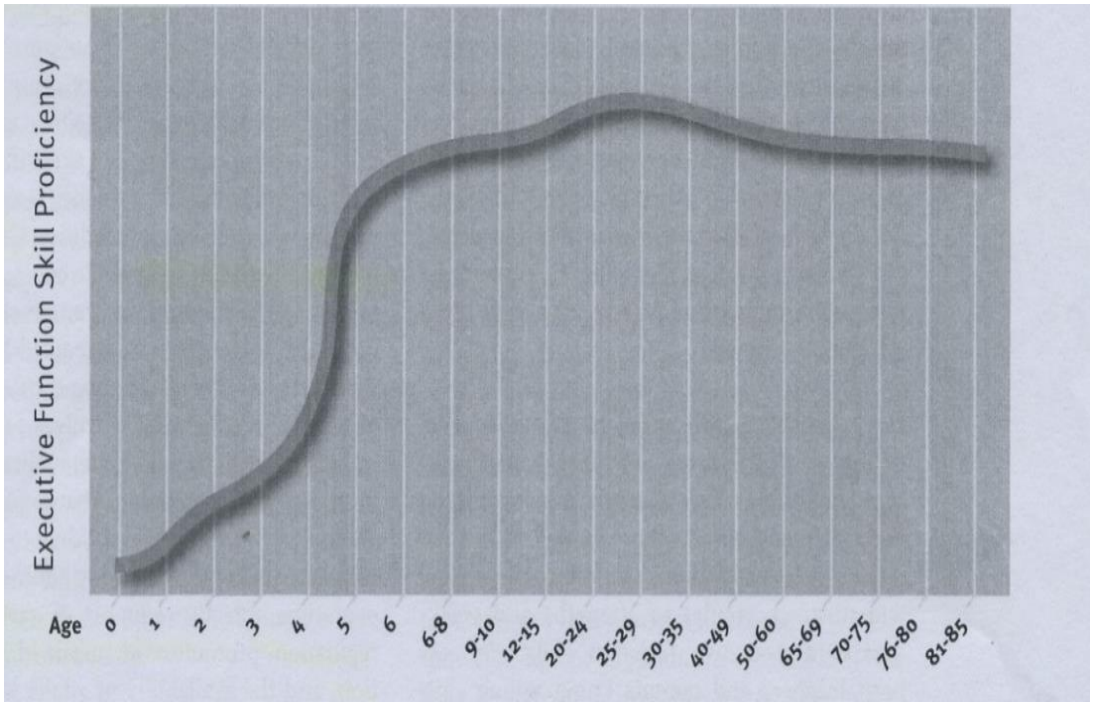


Figure 5 Development of executive function skills
(Center on the Developing Child at Harvard University, 2011, p. 5)

Although the general trajectory is the same, not all executive functions develop at the same rate, with attentional control improving *most rapidly* between the ages of 2-5 years; information processing between the ages of 5-8 years; cognitive flexibility between the ages of 6-9 years; and goal setting between the ages of 7-12 years (Anderson et al., 2001).

Programs to Improve Executive Functioning

> Thus are your pupils to be saved: first, by the stock of ideas with which you furnish them; second, by the amount of voluntary attention that they can exert in holding to the right ones, however, unpalatable; and, third, by the several habits of acting definitely on these latter to which they have been successfully trained (James, 1899, p. 188).

Given that EF are developmental in nature but need to be adequately nurtured to mature throughout the lifespan, is it possible to enhance individual skills and thereby, positive academic outcomes? As the quote above indicates, the concept of training attention and inhibition is not novel to the 21st century. However, it could be argued that both the expected and interrupted development (e.g. due to neglect, abuse or brain injury) of these and other executive functions are now better understood.

There is growing evidence from the study of targeted brain training programs that interventions can both improve EF skills in individuals and also improve performance on general tests of intelligence (Center on the Developing Child at Harvard University, 2011, p. 8). Because of some ground-breaking work by researchers such as Michael Merzenich, Michael Posner, Torkel Klingberg and Adele Diamond, executive skills are now viewed as trainable. This perceptual change has given rise to many commercial products which claim to improve various aspects of cognition including; attention, memory, reasoning, inhibition,

and/or processing speed. The following table gives an overview of general brain training programs that were available by 2011.

Table 5 Technology-based commercial online brain training programs

Programs & start date	Targeted Skill(s)	Cost (USD to AUD conversions Aug 2016	Research Base
Lumosity (2005)	an online program consisting of games targeting improvements in memory, attention, flexibility, speed of processing, and problem solving	Some games offered free. Subscriptions: $19.52 AUD/month, $9.07AUD/month for full year, $6.51AUD/month over two years, lifetime membership $391.55AUD	(supportive) https://www.lumosity.com/hcp/research/completed Hardy JL, Drescher D, Sarkar K, Kellett G, & Scanlon M. (2011). Enhancing visual attention and working memory with a web-based cognitive training program. Mensa Research Journal, 42(2), 13–20. (unsupportive) (Melby-Lervåg et al., 2013)
Cogmed (2001)	working memory and attention training program	In Australia, upon application	(supportive) http://www.cogmed.com/wp-content/uploads/CogmedClaimsEvidence.pdf; (Diamond and Lee, 2011) (unsupportive) (www.sciencedirect.com/science/article/pii/S2211368112000629, 2012)
Brain HQ (Posit Science) (2002)	BrainHQ built by Posit Science &features 29 exercises that work out attention, memory, brain speed, intelligence, navigation, and people skills.	Some games offered free. Subscriptions: $17.00AUD/month $120.00AUD/year	http://www.brainhq.com/world-class-science/information-researchers (pro) (unsupportive) (Melby-Lervåg et al., 2013, Shipstead et al., 2012)
Fit Brains (2007)	a mobile/online platform focused on the area of brain fitness through exercises	Free version with reduced range. Subscriptions: $39.15AUD/3 months $$65.26AUD/year $261.06AUD lifetime	(supportive) http://www.fitbrains.com/brain-fitness/ (unsupportive) (Melby-Lervåg et al., 2013)
CognitFit (1999)	Claims to measure and train an individual's cognitive skills by identifying cognitive alterations and deficiencies, and creating a personalized brain training program	Initial testing free. Subscriptions: $26.04AUD/month $130.47 AUD/6 months $234.90AUD/year	(supportive) https://www.cognifit.com/neuroscience (unsupportive) (Melby-Lervåg et al., 2013)
NeuroNation (2011)	Aims to improve memory, focus and intelligence	Basic package is free with option to purchase additional games	(supportive) http://www.neuronation.com/science/behind-neuronation 'The science behind NeuroNation was established with the help of researchers at the FU Berlin. (unsupportive) (Melby-Lervåg et al., 2013)
Happy Neuron (2007)	For all ages, designed to maximise learning capacity—adapt to new information, sharpen brain & minimise effects of aging	Free subscription	(supportive) http://www.happy-neuron.com/the-method/scientific-validation (unsupportive) (Melby-Lervåg et al., 2013)
ABC Active Memory (2013) Outside 2011 parameter but included as local content.	memory, flexibility (problem solving and reasoning), attention and knowledge	Free service from 17 May 2016	(supportive) Active Memory has been developed in partnership with the University of Sydney, the University of Melbourne and the Florey Institute of Neuroscience and Mental Health. Uses breakthrough statistical model to customise training & measures change in cognition. Participation in Active Memory contributes to one of the largest studies of its kind into brain training and its potential health benefits. https://www.activememory.com/help (unsupportive) (Melby-Lervåg et al., 2013)

Supporting Research

As expected, each program listed in the table above offers scientific evidence for its construction and operation. However, the general (non-commercially aligned) literature is not so unified. In 2011, much research added support to the notion that executive functioning could improve with training in much the same way that physical skills are improved through skills analysis and focussed practice (Diamond and Lee, 2011, Kilgard and Merzenich, 2001, Klingberg, 2010, Posner, 2010, Posner and Rothbart, 2005). As different types of physical training (e.g. endurance, cross-, and strength training) will variously sculpt the body in a task-specific fashion, researchers have identified brain training approaches that target specific EF components.

Most brain training literature focusses on working memory and/or attention. Few studies examine other aspects of executive function such as inhibition or behaviour control. The studies that do exist tended to report findings in conjunction with attention and/or working memory (Diamond et al., 2005, Hölzel et al., 2011, Tang et al., 2007).

In relation to working memory, Morrison and Chein (2011) have delineated *strategy training* for working memory (where domain-specific strategies to retain more information are taught and practised) and *core training* (where repetition of demanding working memory tasks assist in the development of domain-general mechanisms) as distinct brain training regimes (Morrison and Chein, 2011). These researchers make the following two observations. Firstly, the collective research body on working memory training supports the approach as a useful method for improving working memory capacity as well as general cognition. Secondly, the use of a core training approach appears to deliver "more far-reaching transfer effects" (Morrison and Chein, 2011, p. 46).

According to Diamond and Lee (2011), children with the least developed executive functions (i.e. those with ADHD, lower working memory, and from low SES backgrounds) generally

benefit the most from any EF development program, although this result may reflect a ceiling effect for those with well-developed skills. Targeted, computer-based training has also been shown to improve both working memory and reasoning (Diamond and Lee, 2011, p. 6). Klingberg (2010) states that training working memory not only improves capacity within the training tasks but also for other tasks with similar working memory and attentional requirements (Klingberg, 2010). Further, it appears that improving working memory capacity can produce some flow-on effects for general cognitive flexibility skills as well as attention (Klingberg, 2010, Klingberg, 2006, Olesen et al., 2004, Westerberg and Klingberg, 2007). It should be noted here that in more recent years, some of findings regarding generalisation are in dispute. This contention will be dealt with further in Section 2.3 on Developments in Research Post 2011, p. 114.

It is important to note that programs to improve executive functioning are not confined to digital technology. In their comprehensive review of approaches to improved executive functioning, Diamond and Lee (2011) identify six categories of program delivery which have been shown to improve EFs in children. These are:

- Computerised training
- Non-computerised games
- Hybrids of computerised training and non-computerised games
- Aerobic exercise and sports
- Martial arts & Mindfulness practices
- School curricula (Diamond and Lee, 2011)

The following table details several curriculum-based intervention programs which combine a brain training approach with curriculum content to improving academic performance. This table is included to give background to the state of the research literature at 2011. The ongoing examination of brain training programs will be dealt with in Chapter 5 as part of the post 2011 literature review.

Table 6 Technology-based curriculum-related brain training programs

Targeted Programs	Targeted Skill(s)	Cost	Research Base by Independent Bodies and/or Program Developers (as noted)
The Listening Program (delivered through technology)	Children learning and attention difficulties, Auditory Processing problems, sensory processing difficulties, dyslexia, Autism/Aspergers, ADD / ADHD, reading and spelling difficulties	Price on application in Australia	INDEPENDENT UNIVERSITY RESEARCH VERDICT: NOT RECOMMENDED see https://www.suttonspeech.com.au/wp-content/uploads/2016/03/The-Listening-Program.pdf https://www.mq.edu.au/__data/assets/pdf_file/0016/171106/musec_briefing_23_the_listening_programtm.pdf
Jungle Memory (delivered through technology)	Jungle Memory is designed for children aged 7-16 years. The program aims to boost learning outcomes for students with learning difficulties, including Dyslexia and Autistic Spectrum Disorder	8-week subscription = US $49.99	INDEPENDENT UNIVERSITY RESEARCH VERDICT: RECOMMENDED see http://junglememory.com/pages/general_content_area?content_area_id=23 cites research with various student populations in several countries
Fast ForWord (delivered through technology)	Fast ForWord is a suite of computer-based language intervention programs designed to improve children's reading and oral language skills. The programs are based on the hypothesis that oral language difficulties often arise from a rapid auditory temporal processing deficit that compromises the development of phonological representations. (Strong et al. 2011)	Home program 3-month subscription between A$900-A$1260 depending upon level of personal support	INDEPENDENT UNIVERSITY RESEARCH VERDICT: NOT RECOMMENDED see (Rouse and Krueger, 2004) (Strong et al., 2011) http://www.mq.edu.au/research/research-centres-groups-and-facilities/healthy-people/centres/macquarie-university-special-education-centre-musec/community-outreach-overview/musec-briefings
Number Race (delivered through technology)	Primarily designed for children aged 4 to 8 who are making their first steps with numbers to learn the basic concepts of number and arithmetic; older children to build fluency number sense; and students with mathematical learning disabilities (dyscalculia)	Free download at http://www.thenumberrace.com/nr/home.php	RESEARCH BY DEVELOPERS & ASSOCIATES see (Wilson et al., 2006)
Reading Doctor® (delivered through technology)	Software/apps designed to teach students to read and spell using synthetic phonics to strengthen skills that reading scientists have identified as crucial to literacy learning.	A$199 for CD-ROM & materials A$189 for online/downloadable copy	RESEARCH BY DEVELOPERS & ASSOCIATES see http://www.readingdoctor.com.au/research-on-reading
QuickSmart Literacy (face-to-face delivery)	https://simerr.une.edu.au/quicksmart/pages/qsreading-intervention.php Automaticity of basic literacy skills (e.g. phonics, non-phonemic sight words)	https://simerr.une.edu.au/quicksmart/pages/pricing.php School licence: schools <100 = A$7700 schools >100 = A$11,550	RESEARCH BY DEVELOPERS & ASSOCIATES see https://simerr.une.edu.au/quicksmart/pages/qsresearchoverview.php; (Graham and Bellert, 2005, Graham and Bellert, 2007, Graham et al., 2007b)
QuickSmart Maths (face-to-face delivery)	https://simerr.une.edu.au/quicksmart/pages/qsmathematics-intervention.php Automaticity of basic number facts	https://simerr.une.edu.au/quicksmart/pages/pricing.php as per QuickSmart Literacy. Both programs together require one licence fee.	RESEARCH BY DEVELOPERS & ASSOCIATES see https://simerr.une.edu.au/quicksmart/pages/qsresearchoverv

			ew.php; (Bellert, 2009, Graham et al., 2007a, Graham et al., 2007b, Pegg et al., 2005)
Mangahigh (delivered through technology)	Games-based maths resource for use in schools. 18 original maths games and more than 60,000 maths questions, full reporting and analytics	Up to 30 students = $16.50@; up to 250 students $11.98@ https://www.mangahigh.com/en-au/	RESEARCH BY DEVELOPERS & ASSOCIATES see https://www.mangahigh.com
RAVE-O (face-to-face delivery)	http://www.voyagersopris.com/curriculum/subject/literacy/rave-o/overview RAVE-O is the first comprehensive research and evidence-based approach to reading fluency in the literature	http://store.voyagersopris.com/rave-o/	RESEARCH BY DEVELOPERS & ASSOCIATES see https://ase.tufts.edu/crlr/RAVE-O/research.htm; (Wolf et al., 2009)
PATHS (Promoting Alternative THinking Strategies) (Greenberg et al, 1995) (face-to-face delivery)	The PATHS curriculum focuses on promoting children's emotional development, self-regulation, and social problem–solving skills. Has been researched in special education settings as well. http://www.blueprintsprograms.com/factsheet/promoting-alternative-thinking-strategies-paths	http://www.blueprintsprograms.com/program-costs/promoting-alternative-thinking-strategies-paths Start-up =US$4,000 + trainer travel costs for initial two-day teacher training for up to 40 teachers. Another day for training set up & meeting with the school administration at $2,000. Materials $350-$600 per class	RESEARCH BY DEVELOPERS & ASSOCIATES see (Domitrovich et al., 2007, Kam et al., 2004, Riggs et al., 2006, Senn et al., 2004) See http://www.pathstraining.com/main/research/
Tools of the Mind (Bodrova and Leong, 2001) (face-to-face delivery)	Development of executive functions skills in preschoolers and kindergarten http://toolsofthemind.org/	Currently not available outside of Canada & the US. Costs for materials range between US$600-$1100. Materials are linked to literacy & numeracy development. Professional training is additional.	INDEPENDENT UNIVERSITY RESEARCH VERDICT: RECOMMENDED see http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2174918/; (Diamond and Lee, 2011)
Chicago School Readiness Program (face-to-face delivery)	Intended to improve low-income preschool children's school readiness, by increasing their emotional and behavioural adjustment	?	RESEARCH BY DEVELOPERS & ASSOCIATES see Statistically significant positive impacts on children's externalizing and internalizing behaviours-(Raver et al., 2009) Statistically significant positive impacts on children's self-regulation (executive functioning and attention/impulsivity) and pre-academic (vocabulary, letter naming, and early math) skills-(Raver et al., 2011)
NOTE: Primary INDEPENDENT RESEARCH reference: http://www.mq.edu.au/research/research-centres-groups-and-facilities/healthy-people/centres/macquarie-university-special-education-centre-musec/community-outreach-overview/musec-briefings			

Portability

The concept of portability of skills and skill sets is a key research concern as *performance* on a single task does not necessarily represent an *ability* that will be generalised to all life situations. Morrison and Chein (2011) noted that not everyone benefits from the same training regimes in the same ways or to the same degrees due to a range of individual characteristics (e.g. disability, age or current skills levels) (Morrison and Chein, 2011). Similarly, Jaeggi and colleagues concluded that future research should focus on which training regimes deliver the best outcomes in relation to specific populations, rather than revisiting the general question of overall effectiveness (Jaeggi et al., 2011). Section 2.1.4 will further analyse current research on executive functioning and neurobiological development as these relate to classroom-based neuroeducational practice.

2.1.4 Essential Elements for a Neuroeducational Program

> Imaging studies have revealed common networks underlying many important tasks undertaken at school, such as reading and number skills, and we are beginning to learn how genes and experience work together to shape the development of these networks (Posner and Rothbart, 2005, p. 99).

This section will examine three main facets of a neuroeducational program as dictated by current research literature. The three dimensions of executive function, as delineated by the Center on the Developing Child (Harvard University), are examined first. Following this, key aspects of the social-emotional brain which impact learning and learning outcomes are discussed. Finally, the neurobiological or physical aspects that impact learning by their direct influence on optimum brain functioning are considered.

The Three Dimensions of Executive Functioning

> To be successful takes creativity, flexibility, self-control, and discipline. Central to all those are 'executive functions,' including mentally playing with ideas, giving a considered rather than an impulsive response, and staying focused (Diamond and Lee, 2011, p.1).

Executive functions underpin all directed learning activity. Executive function competency in preschoolers is predictive of both school readiness (Blair and Razza, 2007, Morrison et al., 2010) and overall school success (Gathercole et al. 2004 Borella et al 2010, (Duncan et al., 2007). Generally, primary classroom teachers are focused on improving literacy and numeracy skills, with the expectation that foundational learning tools or executive functions (e.g. directed attention and memory skills) are in place. There is also a tendency to assume that some students are inherently just not proficient at managing their attention and/or remembering key information or processes but, *more importantly*, to believe that these are *fixed* attributes—a belief, that as mentioned above, is proving incorrect (Dweck, 2010a, Klingberg, 2010, Olesen et al., 2004). As demonstrated in the discussion regarding definitions of EFs, there are many ways to organise the various executive elements in relation to each other. The selection of key executive function areas discussed here parallels the working definition used in the BBL Program (see page 24). Literature on executive function reviewed here will be constrained by relevance to an educational (school) environment.

Inhibition, working memory and cognitive flexibility were identified as core dimensions of executive functioning (Center on the Developing Child at Harvard University, 2011). However, to be immediately useful to teachers and students in a classroom environment, these dimensions require more detailed consideration. The next sections will expand these elements. As will be seen, inhibition has multiple, important facets including self-regulation, delayed gratification and attentional control. Working memory will be considered as part of a

suite of memory capacities under the broader heading of *Memory*. The discussion about cognitive flexibility will include research pertinent to metacognition.

Dimension 1: Inhibition (Self-regulation, Delayed Gratification and Attentional Control)

Inhibition can be considered from several perspectives, including biological (cellular) (Bari and Robbins, 2013), motor (Hammond et al., 2011), behavioural (Arce and Santisteban, 2006, Hofmann et al., 2012), and cognitive (Arce and Santisteban, 2006, Diamond, 2013). In the context of this study, the concept of inhibition control has two aspects—response inhibition (the ability to stop or moderate thoughts and behaviours and reduce impulsivity) and interference control (managing distractions and interruptions) (Arce and Santisteban, 2006). Inhibition, as defined by Dawson and Guare (2004), encompasses cognitive self-regulation, delayed gratification and interference control. Once again, however, the use of multiple and overlapping definitions of executive function, inhibition, and self-regulation have rendered a concise literature review challenging. For the purposes of this review, cognitive, behavioural and motor inhibition will be discussed as a single entity, as exact demarcation remains unclear (Anderson and Levy, 2009).

Self-regulation

Self-regulation is defined in a variety of ways in relation to self-control, executive functioning and metacognition as follows:

- synonymous with self-control (Baumeister and Exline, 2000, Fujita et al., 2006, Vohs and Baumeister, 2011)
- a concept that overarches self-control (Morrison et al., 2010)
- different from self-control (Vohs and Baumeister, 2011)
- conceptually including emotional and behavioural regulation (Bodrova and Leong, 2003, Bodrova and Leong, 2005, Eisenberg and Spinrad, 2004)
- synonymous with executive function (Bodrova and Leong, 2008)

- contained within the suite of executive functions (Dawson and Guare, 2004)
- standing apart from executive functioning (Morrison et al., 2010, Singer and Bashir, 1999)
- as an element within metacognition or vice versa (Veenman et al., 2006)
- interchangeably with metacognition (Dinsmore et al., 2008).

However specific research groups choose to parcel up the territory, all see that self-regulation is closely interconnected with aspects of cognition (i.e. working memory, attention, impulsivity control, higher order thinking). Self-regulation is also stimulus-dependent for full and proper development (Bodrova and Leong, 2005, Dinsmore et al., 2008, Hölzel et al., 2011, Isen, 2000, Shonkoff and Phillips, 2000, Vohs and Baumeister, 2011).

In relation to brain development and academic proficiency, self-regulation is seen as vital (Diamond and Lee, 2011). Zimmermann and colleagues (2000) refer to self-regulation as the most important human quality in that the ability to manage thought, emotion and behaviour is what makes humans highly adaptive and flexible (Zimmerman et al., 2000). In the classroom, an example of self-regulation would be the student who is desperate to contribute to a discussion but is still able to listen to the opinions of others and manage the desire to blurt out a thought in favour of waiting for a turn to speak. Many studies identify the ability to self-regulate as positively correlated to academic outcomes (Dinsmore et al., 2008, Garner, 2009, Hornbeck et al., 2008, Houghton et al., 2011, Matthews et al., 2009, Morrison et al., 2010, Raver et al., 2011, Singer and Bashir, 1999, Vohs and Baumeister, 2011). Self-regulation requires effort and is, therefore, subject to fatigue (Strayhorn, 2002, Vohs and Baumeister, 2011) meaning that even students (or teachers) who have good self-regulation skills can fail to exhibit them at times. Most importantly, self-regulation skills can be taught and improved by targeted practice (Bodrova and Leong, 2005, Bodrova and Leong, 2008, Dinsmore et al., 2008, Garner, 2009, Hölzel et al., 2011, Hornbeck et al., 2008).

Based on the bulk of literature, this work draws a distinction between self-regulation and self-control as outlined by Vohs and Baumeister (2011). Self-control sits within the broader concept of self-regulation and is defined as the act of overriding one tendency in order to attain a goal (e.g. not grabbing a toy in order to maintain a friendship) (Vohs and Baumeister, 2011). Whereas self-regulation refers to a wider category of behaviours including a number of "purposeful processes" to self-correct (with corrective behaviours originating from within the individual) and stay on track to achieve a specific goal (e.g. choosing not to take a chocolate from the teacher's table or finishing the boring history assignment (Vohs and Baumeister, 2011, p. 1).

Delayed Gratification

Another facet of inhibition is delayed gratification—the ability to wait for something that is highly valued rather than seek immediate satisfaction. Delaying gratification requires memory capacity that allows for holding the goal in mind (Jurado and Rosselli, 2007), sufficient self-regulatory skills (Arce and Santisteban, 2006, Bodrova and Leong, 2005, Bodrova and Leong, 2003) and a sense of time, including an understanding of present and future, to assist in the wait (Logue, 1998, Logue, 1992, Takahashi, 2005, Wittmann and Paulus, 2008).

The Marshmallow Experiment is an example of delaying gratification. This experiment was developed by psychologists, Walter Mischel and Ebbe B. Ebbesen in the 1960's and reported in their 1970 paper entitled, *Attention in delay of gratification* (Mischel and Ebbesen, 1970). Briefly, this experiment placed four-year old children individually in a room with a marshmallow and no direct adult supervision. Children were told that they would receive two marshmallows if they were prepared to wait for an adult to return before eating the first marshmallow. The most important part of this work was the follow-up as the children grew into adulthood. Results showed that those individuals who at four years of age could delay

gratification, consistently succeeded at whatever test measure was employed at every stage of re-testing. Further, individuals who waited for their second marshmallow as a child were happier and healthier than their less patient peers (Mischel et al., 1988)—a result that has been replicated elsewhere (Diamond and Lee, 2011, Moffitt et al., 2011).

Within the school context, students with poor delayed gratification skills are less autonomous learners. They display higher levels of off-task behaviour when teachers are not structuring the environment, such as during group work or while doing individual tasks. Furthermore, how teachers structure classrooms for students with poor delayed gratification skills directly impacts learning improvement (Cameron et al., 2005). Higher levels of self-regulation at school-entry are predictive of school success and higher teacher assessments at the end of one year of schooling (Rimm-Kaufman et al., 2009). Conversely, inability to delay gratification has been associated with a number of health and psychosocial issues including increased risk of drug and alcohol abuse (Petry, 2001, Romer et al., 2010), obesity (Moffitt et al., 2011, Nederkoorn et al., 2006), aggression (Arce and Santisteban, 2006, Wilkowski et al., 2010), delinquency (Moffitt et al., 2011) and friendship issues (Lawhon, 1997, Moffitt et al., 2011).

Attention (An Aspect of Inhibitory Control)

> Attention research investigates how voluntary control and subjective experience arise from and regulate our behavior (Posner and Rothbart, 2007, p. 1).

Attention is not a single construct or neural system. There are various types of attention which are supported by different neural networks. In the past fifteen to twenty years, attention research has focussed on three notable networks that appear to be functionally independently (Fan et al., 2005, McConnell and Shore, 2011). These are the:

- Alerting (or arousal) network—referring to the state of sensitivity to incoming stimuli

- Orienting network—referring to the prioritisation of sensory input for scrutiny
- Executive Control network—involving mechanisms for monitoring and resolving conflict among thoughts, feelings, and responses (Posner and Rothbart, 2007, p. 7).

The executive control network within the realm of attention is not synonymous with the broader concept of executive functioning or executive functions. Attentional executive control deals with sustaining attention and managing elements that compete for attention (Posner and Rothbart, 2007). This network allocates attention based on both stimulus-driven events and the goals or expectations a person may have (Ptak, 2012). As has been demonstrated above, while attention is one component of executive functioning, there are numerous other aspect involved including working memory and self-regulation.

Executive functions (including effortful attending) must be developed through personal experience and use (Fan et al., 2005). As mentioned, a person's general world view or perceptual filters play a large part in determining *where* to direct attention, *if* attention is directed and therefore, what is or is not remembered or learned.

Broadly speaking, the act of attending can be viewed as either a bottom-up or top-down process. These terms distinguish attention that occurs automatically or reactively in response to sensory input (bottom-up) from that which is to some extent under cognitive control (top-down) (Casey et al., 2005, Kane et al., 2006, Leber and Egeth, 2006, Pessoa et al., 2003b). A primary function of the brain is to ensure that the organism remains safe. Bottom-up or reactive attention is the underlying mechanism that allows for continual monitoring of the environment for potential threats (Casey et al., 2005, Kane et al., 2006, Leber and Egeth, 2006, Pessoa et al., 2003a, Rossi, 2009).

The concept of top-down attention includes the abilities to direct, sustain and shift attention (Casey et al., 2005, Leber and Egeth, 2006, Pessoa et al., 2003b, Rossi, 2009, Sarter et al., 2006). These are defined as:

- Directed attention (the orienting system)—the ability to distinguish the most salient features and then focus exclusively on those features while ignoring/neglecting other pieces of information
- Sustained attention—the ability to maintain an exclusive focus, once directed
- Attention shifting—the ability to *intentionally* change focus between objects, parts of objects, thoughts and/or feelings. This includes the concept of re-focusing attention after an interruption. Factors that come into play here include *attentional inertia*—the ability to shift away from an attentional focus (Anderson et al., 1987, Diamond et al., 2005, Hawkins, 2002, Kirkham et al., 2003, Munakata et al., 2003, Oakes et al., 2004), *change blindness*—the inability to notice quite significant changes if they occur gradually (Rensink, 2000, Simons, 2005), coupled with a momentary distraction or while attention is intensively focused on another aspect of the environment and *negative priming*—the difficulty related to the need to shift attention to something that previously had been actively ignored (Allport and Wylie, 2000, May et al., 1995, Tipper, 2001).

Top-down attention, in all its various forms, improves with age and practice (Casey et al., 2005, Kane et al., 2006, Leber and Egeth, 2006, Pessoa et al., 2003a, Sarter et al., 2006). More importantly, it is the top-down attention that teachers largely require from their students in the classroom (Leber and Egeth, 2006, Sarter et al., 2006). As previously mentioned, the human brain filters rather than records incoming information such that, learning is governed by where and how well individuals focus attention, and not just through contact with a

learning environment or piece of information (Boroditsky, 2011, Downey, 2007, Shonkoff and Levitt, 2010, Wolfe, 2006).

Some aspects of attending mature more quickly than others (Anderson, 2002, Diamond et al., 2005, Kirkham et al., 2003). Directing attention requires conscious thought (Leber and Egeth, 2006). Sustaining that attention (concentration) then requires an individual to see some way to personally connect with the target of interest (Leber and Egeth, 2006, Wolfe, 2010). The brain seeks to make meaning for perceived inputs. Making meaning from perception is vital to sustaining attention as, even with the best of intentions, it is impossible to maintain focus on something that seems senseless (Wolfe, 2010).

Like self-regulation, top-down attending takes energy and effort with some types of attention requiring more effort than others (Posner, 2012, Posner, 2010). This means that fatigue is a factor in the learning process. Attending to something new and on the edge of personal competency requires more cognitive exertion than attending to something new but within a familiar, already well understood context (Sarter et al., 2006). When faced with the familiar, it is the novel which stands out. When faced with the novel, attention gravitates towards the familiar (Leber and Egeth, 2006, Pashler, 1998). Similarly, sustaining attention and consciously switching attention expend mental resources at a rapid rate, sometimes resulting in directed attention fatigue—the loss of attention due to the overuse of inhibitory attention mechanisms while dealing with distraction (Beadle, 2010). An example of attention fatigue in the classroom would be those students who cannot refocus on the lesson when interruptions have occurred due to poor behaviour choices from other students.

The ability to sustain attention appears directly related to the developmental levels of other key executive functions and to levels of fluid intelligence—the ability to solve new problems, use logic in new situations, and identify patterns (Redick and Engle, 2006, Young et al.,

2010). In addition, the ability to change subject focus develops earlier than the ability to alter beliefs and concepts or consciously directed focus (Blair and Razza, 2007). Furthermore, the human brain is not built to multitask (to *intently focus* on more than one thing at a time (Hembrooke and Gay, 2003)). When people attempt to maintain a focus on two or more objects, thoughts, or processes, the brain is actually switching attention. Any attentional switch costs energy as the attending process is serial (processes only one thing at a time in some sequence) rather than parallel (Pashler, 1998). The more attentional switching required by a student, the quicker he/she depletes his/her personal reserves (Pashler, 1998, Sarter et al., 2006). When multitasking, the time taken to complete any one task and the likelihood of mistakes are both dramatically increased (Brewer et al., 2011, Otani et al., 1997, Pashler, 1998, Payne, 2008). If a person enters the room or a teacher adds one additional comment while the students are working, the brain is required to make two attentional shifts—one away from the work and another to recommence working. Attention can be both an external and internal focus as distractions can arise from personal thoughts. This latter concept will be dealt with in the section on emotional development below.

Dimension 2: Memory

The human brain has different memory systems (Squire, 2004). Memories may be stored explicitly in a verbal manner or implicitly using non-verbal pathways (Buckner et al., 1995, LeDoux, 1993, Payne, 2008, Schacter, 1992, Schacter et al., 1989). The type of memory system(s) in play will determine ease of recall, with more connections to any given memory making it more accessible (Buckner et al., 1995, Schacter, 1992). Additionally, the act of remembering is not always a conscious, controlled activity. Some memories, particularly those stored implicitly, come unbidden as a response to some event in the environment; as in the case of post-traumatic stress disorder (Downey, 2007, Perry and Pollard, 1998, Perry et al., 1995). In a more common example, the memory of a youthful romance or a favourite

childhood activity can be triggered by hearing music that is associated with specific people and places (Sah, 2000). Similarly, rapid movements and raised voices can trigger memories of great fear and personal danger for children who have experienced trauma and abuse even when there is no real danger present (Downey, 2007, Perry and Pollard, 1998, Perry et al., 1995). Once again, it is evident that what is brought to current learning opportunities is highly dependent upon previous experience.

Without the capacity to remember over time (to make new neural connections), there is no learning (Rolls, 2012). However, like attention, memory is not a single construct and the broad, generalised use of the term can often be misleading to an educator's thinking. Figure 6 below reflects a frequently used construct of different long-term memory systems. This version is adapted from García-Lázaro et al. (2012) but the graphic representation is widely available online and in many textbooks on memory.

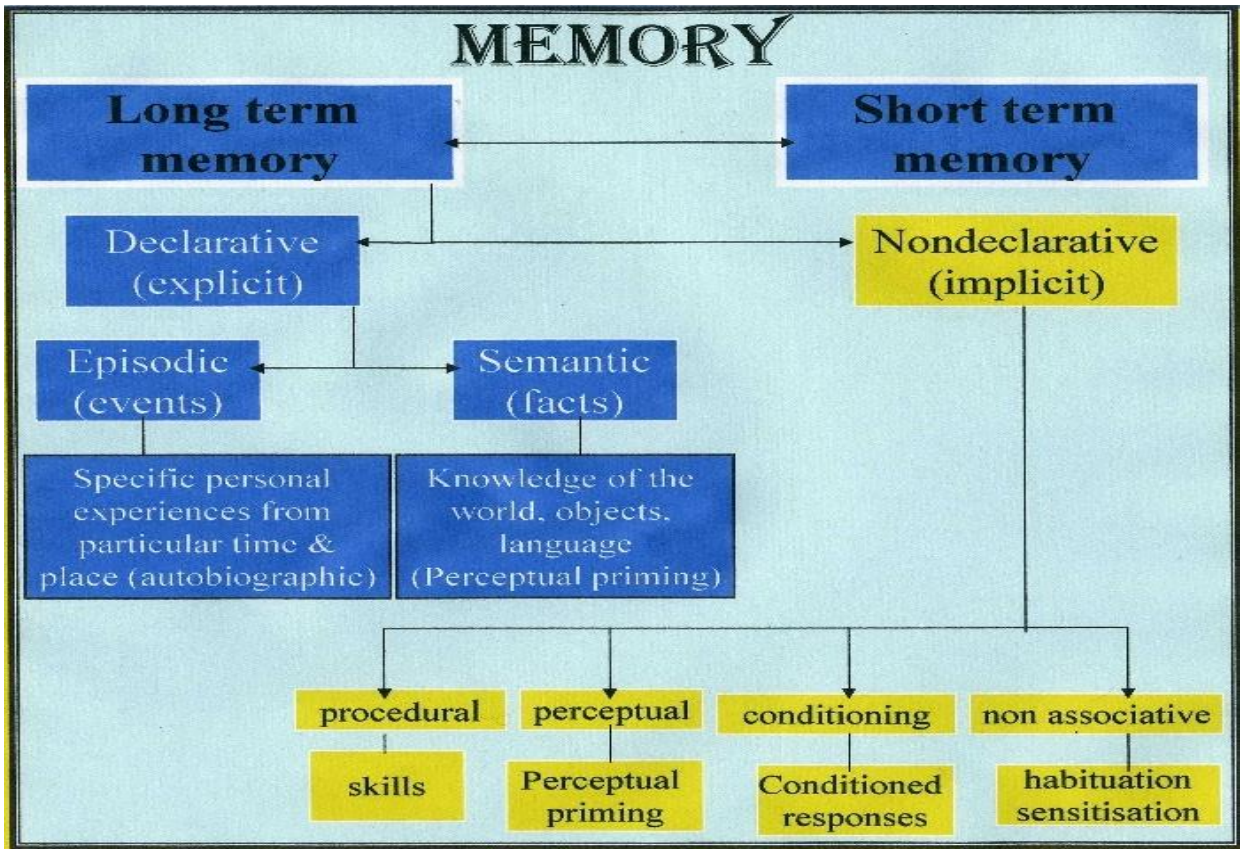


Figure 6 Model of human long-term memory
Adapted from (García-Lázaro et al., 2012, p. 614)

However, not all that is remembered, is remembered long-term. Some information is held in mind for short periods of time and is referred to as short-term memory (Purves, 2004). Aspects of short-term memory will now be discussed.

Short-term Memory

Everything that is learned is not necessarily remembered. Indeed, strategic forgetting is a part of good remembering (Purves, 2004). Short-term memory can be differentiated into transient memory and working memory. Transient memory refers to information that can be recalled for a brief period (e.g. what was on the breakfast menu) while working memory refers to the process of holding information in mind while at the same time manipulating this information (e.g. a mental maths calculation) (Buschkuehl, 2008, Conway et al., 2005b, Cowan, 2010). Working memory, as a core executive function (Center on the Developing Child at Harvard University, 2011), will now be discussed in detail.

Working Memory

Working memory(WM) is the capacity to hold information in mind while acting upon it, and develops from a very early age (Diamond, 1995). WM is tied to the developmental stage of an individual and related to the co-development of other capacities such as language (Gathercole, 1999). More complex mental abilities, for example, computation or reordering information, appear throughout childhood (Crone et al., 2006, Davidson et al., 2006).

Cowan (1999) argued for a state-based model for working memory which postulated that the allocation of attention and information held in long-term memory direct what will can held in working memory (Cowan, 1999). The relationship of working memory to attention is symbiotic. To place something in memory, there has to be some degree of conscious or unconscious attention expended. In order to pay attention, sufficient sense needs to be made of the informational input—a process reliant on prior learning, or long-term memory (Conway et al., 2005b, Cowan, 2011). According to Stedron and colleagues (2005),

developmental improvements in WM can assist in improving selective attention (Stedron et al., 2005).

Working memory is prone to a memory bottleneck. The speed and volume at which information inputs are presented represent biological limitations to what information manages to enter memory (Conway et al., 2005b, Engle and Broadway, 2011, Gathercole and Alloway, 2010, Kane and McVay, 2009, Klingberg, 2010, Lewandowsky, 2011). As well, the ability to hold information in working memory is impacted by the novelty of information being presented (McVay and Kane, 2009).

The psychological understanding of WM underwent a metamorphosis in 1974 with the introduction of the Baddeley and Hitch model of working memory (Baddeley and Hitch, 1974). The work of Baddeley and Hitch (1974) helped to re-conceptualise short-term memory from a static research realm of time and/or serial order (i.e. stimulus presentation and memory decay rates) into a field studying WM as a form of fluid cognition. (Buchsbaum and D'Esposito, 2017). This model emphasised the mechanisms rather than the storage of memory and postulated that WM has three key components. These are the central executive, phonological loop and visuospatial sketchpad (Baddeley and Hitch, 1974). The central executive was understood to be the overseer of both the phonological loop, which processes verbal input, and the visuospatial sketchpad, which processes visuospatial input (Baddeley and Hitch, 1974). In 2000, Baddeley proposed a fourth system which he called the episodic buffer (Baddeley, 2000). The episodic buffer appears to operate when language processing is the main component of input into working memory (Rudner and Rönnberg, 2008).

Prior to the 21st century, it was generally believed that the working memory capacity of an individual was a fixed component (Olesen et al., 2004). However, with the development of various brain imaging technologies and an improved understanding of brain plasticity, this

view has now shifted towards believing improvements to working memory capacity can be achieved through targeted training (Buschkuehl, 2008, Klingberg, 2010, Klingberg, 2006, Klingberg et al., 2002, Olesen et al., 2004, Posner and Rothbart, 2005, Schmiedek et al., 2010, Westerberg and Klingberg, 2007).

Dimension 3: Cognitive Flexibility (including Metacognition)

> Human intelligence, motivation, and academic self-concept are more fragile and malleable than traditionally thought. People's performance and motivation can rise and fall depending on the situations and relationships they are in, and the mindsets they adopt. Understanding this can help us nurture both the expression—and development—of intelligence. (Aronson, 2010) slide 68)

In line with The Center for the Developing Child at Harvard University (2011), this work identifies cognitive flexibility as one of three executive functioning dimensions. As a general definition, cognitive flexibility refers to the ability to adapt cognitive processing (i.e. thinking) strategies when encountering new and/or unexpected situations (Canas et al., 2003). Cognitive flexibility involves restructuring of knowledge on both conceptual and procedural levels (Spiro and Jehng, 1990). In relation to classroom demands, cognitive flexibility allows students to deal with mistakes by finding alternate ways to frame problems, to switch from one task/thought/conversation to another, to update knowledge, to re-focus when interrupted or distracted, and to interpret information from a number of different perspectives (Meltzer, 2007).

Humans are more able to think flexibly if everything changes rather than if only parts of a situation/view/design change but others remain the same (Crone et al., 2006). For example, children find it harder to successfully complete a task where the response rule changes but the materials being used do not. When asked to sort a pack of playing cards by colour and then,

using the same pack, to sort by suit children are less successful than if asked to sort cards by suit and pencils by colour.

Attentional inertia is in operation when one is unable to inhibit previous focus, such as switching focus from colour to suit in a deck of playing cards or using updated rules for familiar game (Crone et al., 2006). While typical at age three, attentional inertia can be evident in all individuals depending upon circumstances (Kloo and Perner, 2005). Further, cognitive flexibility is underpinned by metacognition (conscious self-reflection) and cognitive self-regulation of thought (remaining mentally on track and resisting intrusive or distracting memories/ideas) (Anderson and Levy, 2009). As the area of self-regulation has been addressed above in relation to *Dimension 1: Inhibition*, metacognition will now be explored.

As Veenman and colleagues (2006) note, metacognition is a term with multiple definitions which have led to a range of research approaches, for example, metacognitive awareness, the feeling of knowing and comprehension monitoring (Veenman et al., 2006). Dinsmore and colleagues, in examining the relationship of metacognition and self-regulation, concluded that the main difference between the two resides in their operational environments. Metacognition occurs within the mind of an individual in relation to thinking about thinking, behaviour and emotions whereas self-regulation is triggered by events external to the self (Dinsmore et al., 2008). Within the concept of metacognition as a type of self-reflection, two broad research parameters exist. First, scientists investigate metacognition as declarative knowledge. Second, research examines metacognition as process-related in terms of regulating thoughts, emotions and actions for problem solving and learning (Veenman et al., 2006). For the purposes of this study, the author understands metacognition to encompass both knowledge

of and contributions to self-regulation through an ability to think about thoughts, feelings and actions prior to, during and after they occur and, then to reflect on possible future changes.

The Social and Emotional Brain as Part of Executive Functioning

> …he who is unable to live in society, or has no need because he is sufficient for himself, must be either a beast or a god… A social instinct is implanted in all men by nature… (Aristotle, 2000, p. 29).

For optimum function, it is clear that the human brain requires social interaction (Adolphs, 2009, Blakemore, 2008, Cozolino, 2006, Dunbar, 2003, Hari and Kujala, 2009) and emotional connection (Ainsworth, 1968, Amminger et al., 2007, Bretherton, 1994, Chugani et al., 2001, Perry and Pollard, 1998, Siegel, 2001). These factors, therefore, cannot be ignored by modern educators. Aspects of social and emotional learning feature in current educational curricula, as the 21st century learning diagram demonstrates (see p. 9). However, there are many approaches to the development of social skills and emotional literacy—the ability to read and understand a range of emotions in both the self and others in a healthy manner (Joseph et al., 2005).

Rather than favouring the development of cognitive skills over unruly emotions, emphasis is swinging towards achieving a balance between these two important aspects of the human condition. As Immordino-Yang and Damasio (2007) note, the human emotional state is an imposing perceptual filter (Immordino-Yang and Damasio, 2007).

In the education literature, social and emotional learning (SEL) is broader than the notion of emotional literacy and can be seen to incorporate areas of executive functioning (Collaborative for Academic Social and Emotional Learning (CASEL), 2010). SEL, as defined by the Collaborative for Academic Social and Emotional Learning (CASEL), reads

as a socioemotional application of executive functioning. CASEL states that individuals need to acquire the knowledge, skills and attitudes that allow them to effectively:

- understand and manage emotions
- set and achieve positive goals
- feel and show empathy for others
- establish and maintain positive relationships
- make responsible decisions (Collaborative for Academic Social and Emotional Learning (CASEL), 2010).

As with general executive functions, social and emotional skills develop over time. For example, perspective taking (or Theory of Mind) in normally developing individuals has a period of accelerated development between ages four and eleven (Center on the Developing Child at Harvard University, 2011, Frith, 2003, Hughes and Ensor, 2007, Young et al., 2007). The social brain (the collection of "brain structures that subserve social processes" (Kennedy and Adolphs, 2012, p. 2) allows people to interact and to predict actions according to their perceived mental states (Frith, 2007). Socialisation and affect occupy much cognitive time and energy (Dunbar, 2003, Dunbar and Shultz, 2007, Sutcliffe et al., 2012) and, like many aspects of cognitive growth, are greatly influenced by interaction with the environment (Algoe and Fredrickson, 2011, Cozolino, 2006, Saarni, 2011). At birth, the brain is ready to establish a full range of emotions but without the right stimuli both emotional expression and recognition will be impaired (Anda et al., 2006, Downey, 2007, Perry and Szalavitz, 2007, Perry and Pollard, 1998, Perry et al., 1995) as was demonstrated so graphically by the children found in the Romanian orphanages in (Chugani et al., 2001).

Emotional competence, in terms of self-regulation skills, is positively correlated to academic achievement (Rhoades et al., 2011). The type and degree of emotion brought to a situation

determine both what will receive attention and how much will be accurately retained (Immordino-Yang and Damasio, 2007, Kern et al., 2005, Sah, 2000). Too little emotional investment leads to disengagement and boredom (Pekrun et al., 2010). Conversely, a flood of emotion will damp down cognitive processes and inhibit new learning (Zelazo and Müller, 2002). In short, strong emotion, where emotions are neither too elevated as to overwhelm (Downey, 2007, Greenwood, 2002, Perry et al., 1995) nor too depressed as to cause attentional disengagement (Pekrun et al., 2010), makes for strong learning (memory-making) (Sah, 2000). Given current understandings, the author believes that the memory-making process is more accurately represented by the addition of affect into the representation of memory systems presented earlier (see Figure 7) in the same way that social-emotional context underpins information processing (see Figure 4, p 40).

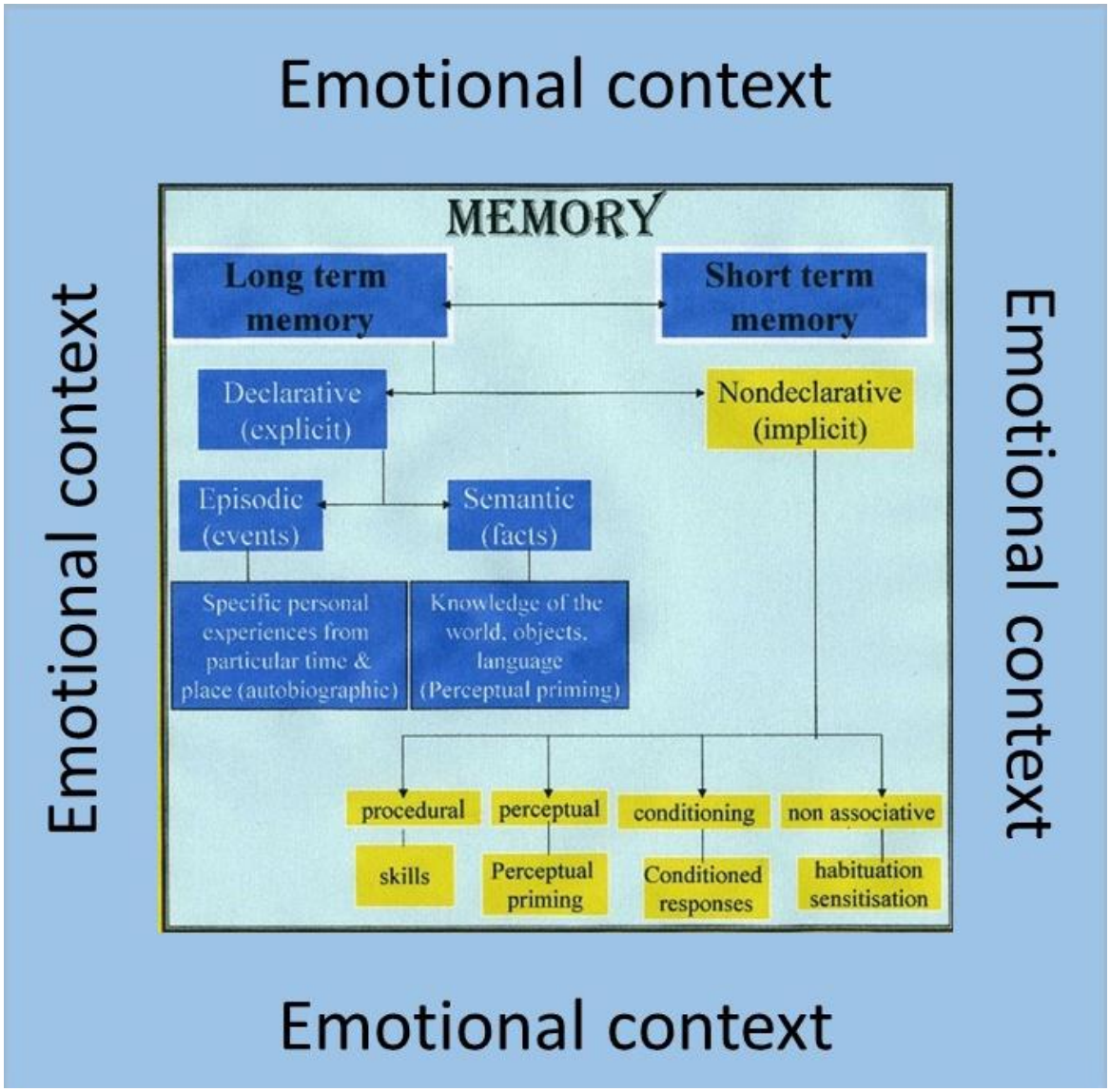


Figure 7 Memory-making includes emotional context

Adapted from (García-Lázaro et al., 2012, p. 614)

Positive and Negative Emotions

> Emotions, whether anticipated, felt in the moment, or recalled, shape our thoughts, motivations, and behaviors from morning until night, every day of our lives (Algoe and Fredrickson, 2011, p. 35).

All emotions (both negative and positive) are important to be fully responsive to one's environment. Neurobiologically, emotional states are understood to be specific reactions to stimuli which involve biochemical responses leading to an affective state (Phillips et al.,

2003, Shonkoff and Phillips, 2000). In evolutionary terms, emotions aid in an individual's survival and prosperity (Immordino-Yang and Damasio, 2007). However, positive and negative emotions affect thinking and learning in different ways (Fredrickson and Branigan, 2005). Through her Broaden and Build Theory, psychologist Barbara Fredrickson contends that the attention systems in the brain operate quite differently when an individual is in a positive emotional state as compared to either a neutral or negative state (Fredrickson, 2001, Fredrickson, 2004, Fredrickson and Branigan, 2005). Briefly, negative emotional states cause the narrowing of attentional focus while positive states allow for an expanded or broadened attentional view that more easily supports creativity, problem solving and other higher order thinking skills.

Stress, a strong emotional state, provides a good example of this. In manageable amounts, stress is a motivator for action. Additionally, not all stress is negative. *Eustress* refers to stress that produces a positive outcome and/or a positive emotional state (e.g. hope or confidence), while *distress* defines negative stress (Nelson and Cooper, 2005). Depending upon whether the threat is framed by an individual as positive or negative, the brain will create differing physiological states including receptivity to new learning or a sense of overwhelming befuddlement (Nelson and Cooper, 2005).

Negative emotional states are meant to be short-lived and brain health is compromised when a negative mindset becomes the norm (Kiecolt-Glaser, 2010, Nelson and Cooper, 2005, Sapolsky, 1996). Stress provides an excellent example of this concept. Stress occurs when there is a perceived threat or problematic situation. Under threat, the brain narrows focus to the problem at hand. All being well, the threat will be resolved and the stress will dissipate. However, if an individual is unable to successfully deal with the stressor (e.g. a child with dyslexia who cannot make sense of the written word), the stress will become a long term condition and can manifest as anxiety, health issues, mental health disorders and

memory/attentional difficulties (Anda et al., 2006, Perry and Pollard, 1998, Rodrigues et al., 2009, Sapolsky, 1996, Sapolsky, 2004). Moreover, along with loneliness and poor physical fitness, stress impairs prefrontal cortex function and development of executive functioning skills (Diamond and Lee, 2011).

The brain is also reliant upon nurture and the development of an emotional vocabulary if it is to grow towards emotional maturity. These latter two factors will now be more closely examined.

Nurture and Belonging

> Those who are nurtured best survive best. It turns out that our emotional resilience and our ability to learn are inextricably interwoven (Cozolino, 2013, p. 14).

One of the primary prerequisites for positive brain development is nurture (Anda et al., 2006, Downey, 2007, Shonkoff, 2007a, Shonkoff and Phillips, 2000). The quality of early life experiences in relation to nurture and belonging, as well as *when* experiences occur in relation to chronological maturity greatly influence how the brain is physically structured (Shonkoff, 2007b). Individuals need to feel cared about and socially connected in order for their brains to develop both a full range of emotions and the ability to modulate emotional behaviour (Shonkoff and Phillips, 2000). Living with an ever-present threat of violence promotes entrenched feelings of fear and anxiety which, in turn, affect learning and development (Downey, 2007, Shonkoff et al., 2010). Additionally, many children who encounter serious emotional neglect in their early years are reported to have lifelong difficulties in forming close, strong interpersonal relationships as well as in their abilities to concentration, and remember (Ainsworth, 1968, Bretherton, 1994, Chugani et al., 2001, Cozolino, 2006, Downey, 2007, Perry et al., 1995, Perry and Pollard, 1998).

While belonging and nurture are key to healthy brain function and development, feeling a sense of belonging to specific groups can also have a down side (Aronson, 2010, Good et al., 2008). For example, the mere knowledge of membership in a stereotyped group, such as ethnicity or gender, when brought to mind during learning or performance can greatly influence success or failure (Aronson, 2010, Good et al., 2008, Project Implicit, 2011).

Social belonging, to families and peer groups, is a key factor in building resilience (Algoe and Fredrickson, 2011, Bowes et al., 2010, Denny et al., 2004, Feragen et al., 2010, Jain et al., 2012, Rutter, 1985, Werner, 2000). Resilience underpins that ability to cope with adversity, including making mistakes—a key element in learning. Similarly, nurture has a strong impact on physical health as demonstrated by the body of trauma research now available (Anda et al., 2006, Chugani et al., 2001, Dockett and Perry, 2009, Downey, 2007, Perry et al., 1995)

Emotional Vocabulary

It can be argued that words are tools for the brain. The larger one's vocabulary, the more possible it is to think and learn. In 1992, Logue and Chavarro demonstrated that self-control is tied to language proficiency (Logue and Chavarro, 1992). In seeking to maintain a balance between cognition and affect, words provide a bridge. The words one chooses shape thought, aiding or inhibiting critical thinking and behavioural responses in both the self and others (Bargh et al., 1996, David and Kistner, 2000, Krueger and Dickson, 1994, Labroo et al., 2008, Tambiah, 1968, Wiggs and Martin, 1998).

A well-developed emotional vocabulary has been identified as underpinning effective social interactions (Baron-Cohen et al., 2010, Brackett, 2012). This is because a broad vocabulary aids metacognition and self-reflection thereby aiding self-regulation skills (Cozolino, 2006, Domitrovich et al., 2007, Greenberg and Kusché, 2006, Reyes, 2012). Further, the act of attaching a label to an emotion while highly aroused provides a means to de-escalate that

high emotional state (Domitrovich et al., 2007, Greenberg et al., 1991). Additionally, a focus on improving emotional vocabulary as part of a social and emotional learning (SEL) classroom program has been shown to positively impact academic results (Bierman et al., 2008, Brackett et al., 2011, Greenberg et al., 1995, Márquez et al., 2006).

Physical Inputs

> Diet, exercise and sleep have the potential to alter our brain health and mental function (Gomez-Pinilla in (University of California - Los Angeles, 2008, p. 1).

The physical material known as the human brain is distinct from the human mind (the collection of mental processes that occur in the brain, including thought, affect and behaviour (Damasio, 1999). Physiologically, the state of the brain (e.g. healthiness, sleepiness, or inebriation) enables full mental function of the mind (Bransford et al., 2007, Bub et al., 2011, Cotman and Berchtold, 2007, Damasio, 1999, Gazzaniga et al., 2002, Gómez-Pinilla, 2008). Patterns of sleep, exercise and diet appear to be co-dependent in both their operation and impact on brain function (Atkinson and Davenne, 2007). While proper diet (Anjos et al., 2013), exercise (Gomez-Tolle, 2012), and enough sleep aid brain functioning (Shochat et al., 2014), bodily discomfort, including pain, fatigue, hunger, thirst, and overheating/chill will deplete the amount of energy the brain can allot to cognition—the effort that can be put into attending and remembering or to maintaining emotional control (Sarter et al., 2006). Biologically, human attention will be prioritised to physical safety and well-being over the processing of cognitive information (Downey, 2007, Hascher, 2010, Immordino-Yang and Damasio, 2007, Kensinger, 2009). That is, high emotional arousal trumps clear, reflective thinking and learning. Hence, for students to reach their individual potential academically, physically, emotionally and socially, it is vitally important that they establish good life

patterns that support a healthy brain and body. Such patterns include appropriate sleep habits (Aton, 2009, Blunden and Chervin, 2010, Dewald et al., 2010, Kopasz et al., 2010), physical activity/exercise regimes (Chang et al., 2011, Cotman et al., 2007, Dishman et al., 2006) and a balanced, nutritious diet (Bellisle, 2004, Florence et al., 2008, Gómez-Pinilla, 2008).

The following sections review aspects of sleep, physical activity and diet through the lens of primary (i.e. elementary) years education. Socioeconomic status (SES) and access to digital media will also be considered as physical inputs in this section since research strongly implicates both in brain construction and health (Bornstein and Bradley, 2012, Giedd, 2012, Hackman and Farah, 2010, Johnson, 2006, Kopasz et al., 2010, Sigman, 2010). It should be noted, however, that SES is not an independent causal factor for changes to brain development. Rather, physical conditions associated with SES such as lower prenatal weight, parent-child interactions and cognitive stimulation underlie positive or negative development (Hackman and Farah, 2010). In contrast with previous sections reviewed here, research discussion regarding physical inputs will examine work current to 2017. This change in presentation structure occurs for two reasons, First, materials on physical inputs represent background considerations for this study. Therefore, a distinction is not required to locate the BBL Program within a specific period of research. Second, research topics of interest in these fields remain largely stable, with researchers working to delve more deeply into shared knowledge concerning processes and practical implications.

Sleep

Sleep Amount

There has long been the belief that students do not get enough sleep to achieve optimum cognitive, emotional or physical functioning (Blunden and Chervin, 2010, Kopasz et al., 2010, Matricciani et al., 2012, Orzeł-Gryglewska, 2010, Randazzo et al., 1998, Sadeh et al., 2003, Zimmerman, 2008). Although it is acknowledged that requirements vary depending

upon age and between individuals (Mindell et al., 2009, Smaldone et al., 2007), researchers posit that sleep quantity (Diekelmann, 2013, Paruthi et al., 2016, Strasburger, 2011), sleep quality (Dewald et al., 2010, Meijer and van den Wittenboer, 2004, Sadeh et al., 2003), and an underlying knowledge about sleep hygiene (patterns of behaviour that promote sleeping) (Blunden and Rigney, 2015, Halal and Nunes, 2014, Lemola et al., 2014) are important considerations in relation to optimising student cognition—including problem-solving, judgement and self-regulation (Orzeł-Gryglewska, 2010). Recent systematic reviews by Shochat and colleagues (2014) and Chaput and colleagues (2016), support the premise that lack of sleep impacts significantly on brain function, health and behaviour in both young children and adolescents. Reviewing the literature on adolescent sleep, Shochat and colleagues found that insufficient sleep could be associated with poor school performance and problems with physical health, psychological health and risk taking behaviours. Chaput and colleagues concluded their extensive review by stating, "longer sleep duration was associated with lower adiposity[fat] indicators, better emotional regulation, better academic achievement, and better quality of life/well-being." (Chaput et al., 2016, p. S266). Turnbull and colleagues (2013) suggested that poor sleep habits in childhood can disrupt the development of executive functions and that research into executive function development cannot overlook sleep as an important component (Turnbull et al., 2013).

In June, 2016, the American Academy of Pediatrics published guidelines updating recommended amounts of sleep for children aged between 0-18 years. For school-aged children, changes include:

- Children 3 to 5 years of age should sleep 10 to 13 hours per 24 hours (including naps) on a regular basis to promote optimal health, increased from the previous recommendation of 11 to 13 hours

- Children 6 to 12 years of age should sleep 9 to 12 hours per 24 hours on a regular basis to promote optimal health, incorporating a shift of one year from 5 to 6 years of age and an increase of two hours from the previous recommendation of 5-12 years needing 10-11 hours
- Teenagers 13 to 18 years of age should sleep 8 to 10 hours per 24 hours on a regular basis to promote optimal health, incorporating a shift from 12 to 13 years with no change to the amount of sleep from the previous recommendation of 12-18 years needing 8-10 hours (Paruthi et al., 2016).

Once again, it is important to note that guidelines are not absolutes and that individual differences occur.

Sleep Effects on Cognition and Learning

Lack of physical activity (Atkinson and Davenne, 2007, Qiu, 2005), increased access to digital media (Brown et al., 2011, Cain and Gradisar, 2010, Falbe et al., 2015, Fatima and Mamun, 2015, Hale and Guan, 2015, Sigman, 2010, Strasburger, 2011), and oppressive bedroom environments (i.e. noisy, over/under heated and too dark/light conditions) (Sadeh et al., 2003, Strasburger, 2011, Zimmerman, 2008) all negatively impact on a good night's sleep. Without the necessary amount of sleep, the brain builds up a sleep debt decreasing the ability to remember, pay attention and regulate behaviour and emotions (Bub et al., 2011, Dewald et al., 2010, Kopasz et al., 2010, McMorris et al., 2006, Meijer and van den Wittenboer, 2004, Orzeł-Gryglewska, 2010, Sadeh et al., 2003).

Lack of sleep makes it difficult to concentrate and absorb new information (Bub et al., 2011, Diekelmann, 2013, Könen et al., 2015, Meijer and Wittenboer, 2000, Meijer and van den Wittenboer, 2004, Orzeł-Gryglewska, 2010, Wilhelm et al., 2012). Information that is absorbed during the day may not be retained long-term as lack of sleep disrupts the brain's

ability to transfer learning from short-term to long-term storage during the rapid eye movement (REM) phase of the sleep cycle (Aton, 2009, Dewald et al., 2010, Geiger et al., 2010, Hetta et al., 2007, Kopasz et al., 2010, Orzeł-Gryglewska, 2010, Sadeh et al., 2003, Saletin, 2011, Stickgold, 2008, Stickgold, 2007). Regulation of emotions and emotional responses is easier when well rested (Blunden and Chervin, 2010, Dahl, 1999, Diamond, 2013, Owens et al., 2016, Walker et al., 2009). Similarly, stress reduction is positively associated with adequate sleep levels (with high levels of stress also affecting the ability to sleep well) (Capaldi et al., 2005, Diamond, 2013, Horne and McGrath, 1984, Sadeh et al., 2004, Strygin, 2011).

Physical coordination and reaction time are compromised from lack of sleep (Blunden and Chervin, 2010, Bub et al., 2011, Dewald et al., 2010) affecting performance in school-based learning tasks such as writing. The immune system becomes less robust, and, particularly pertinent for children, the energy devoted to growth and body repair may also be reduced as these processes primarily occur during sleep (Kiecolt-Glaser et al., 2011, Orzeł-Gryglewska, 2010). Additionally, insufficient sleep has been strongly linked to obesity (Qiu, 2005, Spiegel et al., 2004, Strasburger, 2011) with obesity, in turn, linked to poor cognitive performance (Hillman et al., 2008).

Research Developments in Sleep

Research changes in the sleep area since 2011 relate mostly to refinement in sleep research methodology (i.e. more reliable tools than self-reporting) (Becker et al., 2016, Czeisler, 2013, Diekelmann, 2013, Galland et al., 2012) and the development of treatment regimens or effective educational programs (Becker et al., 2016, Blunden and Rigney, 2015, Cassoff et al., 2013, Chaput et al., 2016, Meltzer, 2016). For example, various school-based sleep education programs have been implemented with the aim of improving both quality and quantity of sleep in students by improving basic sleep knowledge (Blunden and Rigney,

2015, Blunden et al., 2012b, Cassoff et al., 2013). As Howard-Jones (2014) identified, just giving students more knowledge does not usually result in long-term behavioural change. Blunden and Rigney (2015) observed that the skill of the presenter, rather than program material, may be more key to positive student outcomes from a sleep education program, with students seeming to relate more when the program was delivered by an outside expert (Blunden and Rigney, 2015).

Physical Activity

Activity, Cognition and Affect

Several lines of research indicate that, while physical activity is good for the body, it is highly beneficial for the brain as well (Berchtold et al., 2010, Chang et al., 2011, Cotman et al., 2007, Dishman et al., 2006, Drollette et al., 2014, Gomez-Tolle, 2012, Hillman et al., 2008, Lees, 2013). General levels of fitness directly affect cognitive performance in relation to both attention and memory (Chaddock et al., 2010, Labban et al., 2009, Meeusen, 2014), as well as mood and mood regulation (Dishman et al., 2006, Meeusen, 2014). Proficiency in applying executive functions is also linked to overall fitness (Chang et al., 2011, Davis et al., 2011, Dishman et al., 2006, Etnier and Chang, 2009, Hillman et al., 2008) as aspects of coordination and executive functioning appear to be neurobiologically interrelated (Diamond, 2000, Roebers and Kauer, 2009).

Since 2011, research focus in the area of exercise and cognition has shifted from studying the effects of physical activity on academic performance per se to the broader consideration of physical activity (specifically aerobic exercise) on "…brain structure and function, cognition, and scholastic performance with the goal of understanding how these health behaviors promote effective functioning within the context of learning" (Erickson et al., 2015, p. 27). Although this field is quite young, research has consistently shown that fitness in children corresponds to structural differences in the amount of white matter present in the brain

(Chaddock et al., 2010). Improvements in executive function and cognition (Hillman et al., 2014) and improvements to performance on a task of attentional and interference control (Chaddock-Heyman et al., 2013) directly correlate with aerobic exercise. Furthermore, evidence is growing that aerobic exercise can improve conscious attentional control, even after a single activity session (Drollette et al., 2014, Pontifex et al., 2013) with the most improvement evident in lower performing students (Drollette et al., 2014). Veiga and colleagues (2017) demonstrated the connection between outdoor physical play and social success in younger children. However, all brains are unique constructions and brain function responses resulting from exercise may vary between individuals due to diet and genetics (Erickson et al., 2015), although the factors involved are not well understood as yet.

Activity and Health

Physiologically, levels of exercise interact with the release of growth factors in the brain (Dishman et al., 2006, Gomez-Tolle, 2012). Additionally, regular cardiovascular exercise has been shown to reduce insulin resistance (Cotman et al., 2007), mitigate against stress (Salmon, 2001), decrease anxiety (Salmon, 2001), and reduce inflammation (Eyre and Baune, 2011, Spiegelman and Handschin, 2008). Further, exercise and the timing of exercise impacts sleep (McMorris et al., 2006).

Motor Skills and Academic Competence

The development of motor skills underpin academic competencies (Adolph, 2008, Seidler, 2010). For example, competence with learning materials (which is developed through physical practice), can either promote or inhibit learning efforts (Dewey et al., 2002). That is, when attention is occupied with trying to use the tool (e.g. coordinate the pencil), less effort can be put into the task (creating the narrative). Similarly, children who do not have a range of physical play experiences before entering school that build object control (e.g. throwing, catching, kicking, and hitting) and locomotion skills (e.g. running, jumping, climbing, and

hopping), come to school bereft of a number of basic neural networks that support academic learning in visual-spatial tasks, reasoning, social competency (Adolph, 2008, Casey et al., 2005, Dewey et al., 2002, Diamond, 2000, Etnier and Chang, 2009, Haywood and Getchell, 2009, Logan et al., 2012) and the fundamental coordination required for writing (Adolph, 2008, Grissmer et al., 2010, Logan et al., 2012).

Embodied Cognition

Another aspect of exercise in relation to neuroeducation is the concept of embodied cognition. Embodied cognition refers to the concept that all human learning is somehow grounded or related to the bodily experience of self, and that the body plays a fundamental part in all thinking processes (Howard-Jones, 2014). This area of research considers how movement aids understanding and consolidates learning rather than just tuning the brain to function optimally (Thorburn and Stolz, 2015). Embodied learning research indicts that learning that involves a whole-body experience of some sort leads to stronger memories and deeper conceptual understanding (Lindgren and Johnson-Glenberg, 2013).

Diet

Diet, Cognition and Affect

Diet is a major contributor to brain health and cognitive function in terms of both the amount and type of food consumed (Anjos et al., 2013, Bellisle, 2004, Dye, 2011, Dye and Blundell, 2002, Gómez-Pinilla, 2008). Dietary problems (including too little or too much nutritional intake) can result in permanent changes in brain structure and, therefore, cognitive functioning (Almeida et al., 2013, Anjos et al., 2013, Iannotti et al., 2016). Various researchers have found that a well-balanced diet can increase academic performance (Florence et al., 2008, Francis and Stevenson, 2013, Owen and Sunram-Lea, 2011, Taras, 2005), and support specific improvements to attention control and working memory (McNamara et al., 2010, McNamara and Carlson, 2006). Inhibition control has been

associated with a child's body mass index (BMI) such that less inhibitory control is found in children with a high BMIs, especially once the child is considered obese (Barkin, 2013). Additionally, there is a predictive quality about levels of inhibitory control and the likelihood of a child becoming obese (Barkin, 2013) since children with poorer self-control will put less restrictions on what they consume. Obesity specifically affects the executive skills of attention/mental flexibility, reward sensitivity and working memory with a consistent negative relationship between cognitive function and obesity (Barkin, 2013).

Regulation of emotion and mood (Anjos et al., 2013, Jones and Sünram-Lea, 2008, Mcmillan et al., 2011), impulsivity (Anjos et al., 2013) and aggressive behaviours (Anjos et al., 2013), as well as general mental health are aided by good dietary practice (Gómez-Pinilla, 2008, Mozurkewich et al., 2011). However, it should be noted that the research practices of assessing global cognitive performance instead of individual aspects of executive functioning (Anjos et al., 2013), lack of control around genetic heterogeneity in large epidemiological studies (Anjos et al., 2013), and lack of standard cognitive outcome measures (Barkin, 2013) provide some difficulties in interpreting and extrapolating research on nutrition, cognition and affect.

Diet and Health

Nutritional research has demonstrated that diet affects the maintenance of synaptic function and plasticity (Gómez-Pinilla, 2008), and of sleep regulation (Gómez-Pinilla, 2008). A healthy diet promotes a strong immune system with subsequent decreases in inflammation (Baune, 2011, Calder, 2009, Gören and Tewksbury, 2011), the release of growth factors (Gómez-Pinilla, 2008), and overall physical health (Gómez-Pinilla, 2008, Kopasz et al., 2010, Liang et al., 2014).

Consumption Practices

High consumption of fast foods will decrease optimal brain function (Dye, 2011). The western diet which is high in refined carbohydrates and saturated fats, has been particularly implicated in causing disrupted brain function (Francis and Stevenson, 2013). Baym and colleagues (2014) found a positive associate between relational memory and consumption of omega-3 fatty acid in children, accompanied by a negative association between memory and saturated fats consumption (Baym et al., 2014).

Consumption of breakfast, as opposed to no breakfast, supports better cognitive performance, especially memory and attention tasks (Hoyland et al., 2009). The time of meal consumption impacts cognitive performance (Hoyland et al., 2009), as does the composition of each meal (Dye, 2011, Florence et al., 2008). While breakfast tends to improve cognitive performance until late morning, lunch, particularly one high in carbohydrates, tends to slow reaction time and disrupt attention (Dye and Blundell, 2002). Hewlett et al. (2009) explored the effects of grazing—eating small but frequent meals (Hewlett et al., 2009). In this work, grazing was found to deliver better performance in verbal reasoning and working memory than eating in three main meals. It was postulated that this outcome relates to a more modulated glucose level in the blood (Hewlett et al., 2009). It should be noted that metabolism rates and dietary practices vary widely from individual to individual and across cultures, factors which have not been examined in this research.

Attitudes towards Food and Eating Behaviours

Attitudes towards food and food intake, as well as knowledge about healthy eating, can drive consumption behaviours (Andrews et al., 2010). For example, Bost and colleagues (2014) found that some parents used food as behavioural rewards or deterrents, resulting in childhood problems with obesity and emotional regulation (Bost et al., 2014). General eating practices, such as taking meals with family or eating in front of the TV, are considered

important factors in nutritional, behavioural and cognitive research (Australian Child and Adolescent Obesity Research Network (ACAORN), 2010). Zimmerman and Bell (2010) examined the health outcomes related to viewing television while eating and found that exposure to food advertising promoted unhealthy eating behaviour and could foster "…both lower-quality and higher-quantity food intake" (Zimmerman and Bell, 2010, p. 334). There is also evidence that being distracted from the act of eating during mealtimes, decreases the brain's ability to monitor satiation (Dye, 2011). Eating in front of the TV or computer has also been suggested as a factor in decreased social interaction and emotional attachment between children and parents (O'Keeffe and Clarke-Pearson, 2011). However, as Jago and colleagues (2013) demonstrate in their systematic review, it is difficult to draw definitive conclusions about eating behaviours, mealtime rules and media use given the array of different study designs and aims in the literature (Jago et al., 2013). See Table 7 for a summary of research reported in this section.

Table 7 Summary of effects of dietary practices on aspects of cognition

Research Aspect	Cognitive Performance	Attention Specific	Memory	Affect
Dietary problems (e.g. too much or too little food consumption and high consumption of fast foods)	(Almeida et al., 2013, Anjos et al., 2013, Taras, 2005) language and motor milestones (Iannotti et al., 2016), decline in cognitive performance from high consumption of fast foods (Dye, 2011), disruptions to brain function from Western diet (Francis and Stevenson, 2013)		Negative effect from high intake of saturated fats (Baym et al., 2014)	Problems of mood regulation (Anjos et al., 2013)
Well-balanced diet	Increases academic performance (Florence et al., 2008) (Owen and Sunram-Lea, 2011, Taras, 2005) Maintains synaptic plasticity (Gómez-Pinilla, 2008) Regulates sleep (Gómez-Pinilla, 2008) Promotes strong immune system (Baune, 2011, Calder, 2009, Gören and Tewksbury, 2011) Releases growth factors (Gómez-Pinilla, 2008)	Improves sustained attention control (McNamara et al., 2010)	Improves working memory function (McNamara et al., 2010) Positive effect on relational memory with appropriate intake of omega-3 fatty acids (Baym et al., 2014)	Regulation of mood (Anjos et al., 2013), Impulsivity (Anjos et al., 2013), Aggression (Anjos et al., 2013), general mental health (Gómez-Pinilla, 2008, Mozurkewich et al., 2011)

Eating breakfast as opposed to no breakfast	Better performance (Hoyland et al., 2009) (Dye, 2011) Rises in GI enhance reaction time (Hoyland et al., 2009) Ingestion of fat may slow reaction time (Hoyland et al., 2009)	Better performance especially in the morning (Hoyland et al., 2009)	Better performance especially in the morning (Hoyland et al., 2009) Increased glucose levels improve memory (Hoyland et al., 2009)	
School breakfast programs	(Taras, 2005) (Hoyland et al., 2009)			
Obesity	Negative effects on general cognitive performance (Barkin, 2013)	Negative effects on attention/mental flexibility (Barkin, 2013)	Negative effects on working memory (Barkin, 2013)	Inhibition control compromised (Barkin, 2013)
Meal configuration	Effects of carbohydrates are relative both to time of day and to protein intake (Hoyland et al., 2009) Carbohydrates can impair peripheral processing and reaction time (Hoyland et al., 2009) (Dye, 2011)	Lunchtime ingestion of fats and carbohydrates reduce ability to concentrate (Hoyland et al., 2009) (Dye, 2011) Accuracy rises in afternoon as concentration becomes more challenging (Hoyland et al., 2009) Protein intake appears to make one more susceptible to distraction (Hoyland et al., 2009)	Carbohydrates can variously improve or impair memory depending upon the time of day, carbohydrate type and ratio of carbs to protein (Hoyland et al., 2009) Carbohydrate: protein meals affect tryptophan levels which in turn, affect memory consolidation (Hoyland et al., 2009)	Carbohydrates can be associated with feelings of fatigue (Hoyland et al., 2009)

			Memory tasks appear to reflect nutritional interventions well (Hoyland et al., 2009)	
Grazing rather than eating 3 meals	Improved performance in verbal reasoning (Hewlett et al., 2009)		Improved performance in working memory (Hewlett et al., 2009)	
Food as reward or deterrent				Problems with emotional regulation (Bost et al., 2014)

Socioeconomic Status (SES)

As reported in the foundational study, *Neurons to Neighborhoods*, commissioned by the United States National Research Council and Institute of Medicine: "The course of development can be altered in early childhood by effective interventions that change the balance between risk and protection, thereby shifting the odds in favor of more adaptive outcomes" (Shonkoff and Phillips, 2000), p. 2). Conversely, the course of development can be altered in early childhood by the lack of necessary life experiences. That is the essence of brain plasticity. Life experiences directly and dynamically affect development, both positively and negatively (Posner and Rothbart, 2005). The study of SES provides an overview of developmental risk factors. Many of these factors are physical conditions, as the following quote demonstrates, hence, a consideration of socioeconomic status (SES) is included in this section.

> For the most part, high SES creates circumstances that lead to adaptive functioning. It enables the individual to more fully realize adaptive capacities and behavioral tendencies. By contrast, low SES constrains individuals from achieving maximum adaptive functioning and may exacerbate problems connected with maladaptive tendencies (Bornstein and Bradley, 2012, pp. 2-3).

The Definition

The definition of socioeconomic status, like that of executive functions, is nebulous. According to the OECD, SES concerns the

> …relative position of a family or individual on an hierarchical social structure, based on their access to, or control over, wealth, prestige, and power (Mueller and Parcel, 1981). Numerous studies have shown that a

> person's position on an SES hierarchy is related to a wide range of outcomes pertaining to their physical, economic, and social well-being. SES affects people's educational opportunities, their access to certain labour markets, their exposure to health and crime risks, and their lifetime earnings (Willms and Tramonte, 2015, p. 13).

An alternative view for considering SES is through the lens of capital (available resources and assets), including financial, human and social aspects (Bradley and Corwyn, 2002).

As with the consideration of executive functions, there appears to be common agreement on three core dimensions of socioeconomic status. These are: parental education, income, and occupation (Bradley and Corwyn, 2002, Hackman et al., 2010). However, changes in some dimensions sway levels of SES more than others (e.g. changes in income due to divorce or retrenchment versus gaining an additional tertiary degree) (Duncan and Magnuson, 2012).

SES, Cognition and Affect

Important changes in one of the key dimensions (i.e. parental education, income, and education) will exert differing influences on children depending upon when, in their childhood, the change occurs (Bornstein and Bradley, 2012, Duncan et al., 1998). SES factors create environments which strongly impact overall child development in a multitude of ways (Duncan et al., 1998, Hackman, 2012). For example, social conditions within low SES families often provide insufficient parent-child interactions which impair language development and self-regulation skills (Brito and Noble, 2014a, Hackman and Farah, 2009, Kuhl, 2011a, Noble et al., 2015). Poor cognitive/scholastic achievement relating to low levels of parental education, issues with motivation and self-efficacy are frequently found (Zimmerman, 2000). Socioemotional developmental problems are more prevalent in children from low SES environments, including problems with self-regulation (Baumeister et al.,

2001, Hammond et al., 2011, Vohs and Baumeister, 2011), life aspirations (Duncan and Magnuson, 2012) and personal dispositions (Amone-P'Olak et al., 2011, Duncan et al., 1998). As well, issues of mental health occur more often in both children and adults living in low SES situations, with high levels of stress being a main contributing factor (Amone-P'Olak et al., 2011).

Brito and Noble (2014) noted that prolonged stress on the brain of a child negatively impacts development of memory, social-emotional processing and self-regulation/cognitive control (Brito and Noble, 2014a). High levels of stress have been shown to alter the type of memory system an individual will employ, with high stress stimulating habitual memory over more cognitive flexibility (Schwabe, 2013). Raver and colleagues (2013) found that poverty and the stress from financial hardship were predictive of a child's executive functioning levels (Raver et al., 2013). Furthermore, this group stated, "…each additional year that a given family lived at or below the poverty line was associated with .10 SD lower score on that child's performance on a battery of three EF tasks" (p. 301). Raver and colleagues (2013) also noted reactive levels of temperament were predictive of executive functioning with more highly reactive individuals exhibiting poorer executive functioning.

SES, Health and Brain Development

Issues related to low SES in childhood are often negatively correlated with learned patterns of sleep, diet and physical activity which can lead to higher levels of obesity (Magarey et al., 2001, Magarey et al., 2004), sleep deprivation (Milne and Plourde, 2006), and more/more frequent health problems (Bradley and Corwyn, 2002). In particular, physical aspects such as low birthweight and poor nutrition affect normal cognitive development (Bradley and Corwyn, 2002, Hackman and Farah, 2009, Hackman and Farah, 2010). Additionally, family income has been shown to have a greater impact on underdeveloped brain structure in children from the lowest SES (Noble et al., 2015).

In 2009, Hackman & Farah published an important review of current literature on childhood SES and lifelong cognitive achievement. A principal outcome from this review was the finding of a direct relationship of a child's SES (as measured by parental education, parental nurturance, neighbourhood disadvantage, and family income-to-need) to the level of brain structure relating to language areas and the neocortex as measured through various neural and electrophysiological imaging techniques (Hackman and Farah, 2009). Work by Brito and Noble (2014a) supported this finding. These researchers found that children from low SES backgrounds had less well-developed language centres in their left hemispheres, attributed to less language stimulation, and, also less development in the hippocampus, amygdala and areas of prefrontal cortex structure, attributed to higher stress in a home environment dealing with poverty. Based on these and similar studies, it has been concluded that the range of factors characterised as SES change the structure and behaviour of an individual depending upon presence or absence in a child's environment. It should be noted, however, that the degree, combination, and influence of these factors will vary with individual circumstances, including levels of individual resilience (Jain et al., 2012, Miller et al., 2015, Werner, 2000). For example, Claro and colleagues (2016) demonstrated that a growth mindset (belief that intelligence can be developed) can mitigate against the effects of poverty (Claro et al., 2016).

Access to Digital Media

(For the purposes of this discussion, digital media will be defined as the use of any medium that is stored and/or retrieved via electronic digital technology. This includes the use of the Internet, television, mobile phones, computers, handheld tablets, and electronic gaming devices such as a Wii.)

Value is added (or subtracted) depending upon how individuals choose to interact with the digital world. Interaction with digital media provides a range of experiences to the user and, therefore, influences one's neural architecture, perceptions and behaviours (Johnson, 2006).

As Mills (2016) puts it, “Internet use can be considered an environmental exposure variable, similar to musical training or malnutrition” (Mills, 2016, p. 4). Succinctly, this is the justification for including digital media use within this section constructed to examine physical inputs to optimum brain function. The following discussion of technology use by children will have highlight two research areas. These are the effects of technology on the developing brain and the possible improvements to education that technology can provide.

The Effect of Technology on Brain Development

> Research published in the world’s most reputable medical and scientific journals shows that the sheer amount of time children spend watching TV, DVDs, computers and the Internet is linked with significant measurable biological changes in their bodies and brains that may have significant medical consequences (Sigman, 2010, p. 89).

In 2016, the American Academy of Pediatrics published media guidelines for children contained in a report entitled, *Media and Young Minds*. While acknowledging that the research base in this area is relatively small, the Academy nonetheless deemed it necessary to recommend a limitation of no more than one hour per day of screen time for children five years and younger. Excessive screen time for young children was found to negatively impact cognitive and language development and was associated with social/emotional delays (Hill et al., 2016).

High use of media is seen to impact on the development and distribution of attentional capacity (Moisala et al., 2016, Ophir et al., 2009, Swing et al., 2010). For example, Multitasking—the ability to engage in multiple tasks requiring some level of attentional control concurrently (Hembrooke and Gay, 2003)—has been associated with high levels of inattention (Moisala et al., 2016). As well, both adults and adolescents function poorly in

social interactions that require perspective taking if these interactions take place in cognitively demanding multitasking situations (Mills, 2016). In other words, if high levels of attention are demanded by two competing stimuli, attention available to one will suffer in preference to the other, such as one's ability to drive a car and send a text message at the same time. However, this does not mean that the impact of the digital world is all bad. In her review of the effects of Internet usage on adolescents, Mills (2016) merged findings from both experimental and empirical research. She concluded:

> The findings of this review suggest that cognitive changes are likely taking place [in adolescent brain structure and function resulting from digital media use], but that these changes are not necessarily impeding adolescents' or emerging adults' ability to successfully navigate our highly–connected world. Indeed, adaptation to these new technologies appears to be associated with greater integration into peer groups and even increased cognitive abilities such as faster task-switching (Mills, 2016, p. 10).

The key points of inquiry regarding digital media and cognitive development in children include the effects of screen time (i.e. television, computer, tablets, smartphones, and gaming devices requiring a screen) on:

- Levels of physical activity – Screen time is often seen to contribute to low levels of youth fitness/exercise and high levels of obesity (Boyce, 2007, Hands et al., 2011, Jago et al., 2013, Strasburger, 2011).
- Sleep – Many studies have investigated the effects of digital media on sleep in young children and adolescents. Sleep reduction (through nocturnal media access) and/or interruption (by social media use), disruption of melatonin production from blue light

emitted from screens, emotional arousal from gaming or exciting/disturbing media content, and poor sleep hygiene patterns (lack of sufficient exercise or regular sleep times) have all been shown to occur in conjunction with media use (Brown et al., 2011, Buckingham and Sefton-Green, 2003, Choudhury and McKinney, 2013, Livingstone, 2002, Thompson and Nelson, 2001, Vandewater et al., 2007, Zimmerman, 2008).

- Cognition – Digital media are influential environmental factors. Interaction with various medium will affect cognition. Media can be categorised as either non-interactive/passive or interactive. The format of a medium creates different cognitive loads and promotes or discourages selected skills development. For example, reading a printed text is non-interactive and targets visual and linguistic processing as contrasted with viewing a live webpage on the Internet (Johnson, 2006). Reading on the Internet is interactive and requires the coordination of a number of physical and cognitive skills, including mouse manipulation, increased pressure on the inhibition of distractions from such things as hyperlinks and pop ups (Johnson, 2006).
  Different aspects of the Internet require varying levels of cognitive load (e.g. emailing versus playing online real time, action video games (Foehr et al., 2005, Rideout et al., 2010). Some writers, such as Nicholas Carr, contend that increased Internet usage is creating a generation of *pancake people* (wide but superficial thinkers) versus *cathedral people* (deep, rigorous thinkers who read classic literature and ponder existence) (Carr, 2010). High mobile phone use has been reported to change cognitive functioning in teens such that testing produced results demonstrating faster but less accurate responses during higher level cognitive tasks involving working memory (Abramson et al., 2009). However, increasingly the research literature is finding positive learning outcomes in relation to media use (Schmidt and Vandewater, 2008).

These will be discussed further in the ensuing section, Technology and Improvements to Learning Outcomes.

- Memory – Memories are made through effort and focussed attention. Ready access to smartphones and the Internet has affected memory-making behaviours. Sparrow and colleagues (2011) found that googling information does not increase learning. Rather, the Internet "has become a primary form of external or transactive [i.e. a collective storage repository belonging to a group rather than an individual] memory" (Sparrow et al., 2011, p. 776) and that, instead of remembering specific information, we instead remember where the information was seen.

  Mental processing and physical involvement, such as handwritten notetaking, support better memory creation than does recording information via laptop or IPad (Lin and Bigenho, 2011). For very young children, real life experiences provide better memories than anything viewed via a digital screen (Brown et al., 2011, p. 1041).
- Attention – Early and heavy use of media have been implemented in problems of attention (Swing et al., 2010). Use of screens with children 3 years and younger is seen to pose a number of health issues including problems of attention, language development and passivity (Brown et al., 2011, Christakis et al., 2004). Several researchers have investigated the association of screen time and ADHD, although findings have been somewhat inconsistent (David Acevedo-Polakovich et al., 2007).

  Multitasking is another aspect of attention that is promoted via media. However, cognitive research firmly demonstrates that the brain cannot allocate focussed attention in more than one place at a time. Efforts to do so result in increased task completion times and a higher risk of error commission (Ophir et al., 2009).
- Self-regulation – Two strands of investigation emerge here. The first examines the impact that high media use has on the development of self-regulatory skills (LaRose

et al., 2003). LaRose et al. (2003) suggest that what has been termed *media addiction* could, in reality, be a continuum of behaviours towards addiction, the heart of which is poorly developed self-regulation. Further, the authors linked media use to attempts to alleviate depression. Employed as a mood regulator, media use tends to become a more pervasive pattern which decreased efforts to self-regulate. The second probes issues related to students with low self-regulatory skills being asked to operate in media-intensive (particularly web-based) learning environments (Dabbagh and Kitsantas, 2004). Dabbagh and Kitsantas (2004) state that student-centred, web-based learning can be counterproductive for students who have poorly developed self-regulation. Their work underpins the argument that students need well-established, basic executive functions to make the most of any learning opportunities, including 21st century digital environments.

- Motivation – Concerns around media use and motivation investigate the issues of passivity (Brown et al., 2011) and addiction (Gentile, 2009, LaRose et al., 2003, Song et al., 2004). However, other researchers posit that students are highly motivated by digital technology and that Internet use supports the development of intrinsic learning behaviours (Davidson et al., 2010).
- Violence and empathy – Media use influences social constructs and values. It has been postulated by a number of researchers that children are substantially influenced by the amount of violence and the dearth of empathy that is encountered in video games, television and social media interactions (Gentile et al., 2004, Slater et al., 2003).

Summing up the debate on media use and paediatric brain development, Choudhury and McKinney (2013) suggest that those who wish to take a positive view of digital media use and brain function (neuro-enthusiasts) focus mainly on plasticity—i.e. it is always possible to

improve functioning in a normal brain, no matter its chronological age. Those who wish to take a negative view (neuro-alarmists) will discuss plasticity in terms of the susceptibility and vulnerability of the young developing brain. These authors also point out that proponents of either view often confuse behavioural research (psychology) with brain research (neuroscience) (Choudhury and McKinney, 2013).

Technology and Improvements to Learning Outcomes

Technology can be viewed as "an important instrument in education" (Bransford et al., 2007, p.243). The National Research Council (2000) identified five means by which technology could augment classroom learning. These are:

- Simulating real-world problems in the classroom through digital media
- Allowing technological scaffolding such as 3-D modelling
- Increasing access to feedback through software programs and online interaction
- Encouraging the development of local and global communities via digital connectivity
- Expanding opportunities for teachers to learn (Bransford et al., 2007, p. 243).

Since these guidelines were published, much has been written about positive uses for technology in classroom-based education (Chauhan, 2017, Clement and Lovat, 2012, Griffin et al., 2012, Hicks et al., 2014, McKnight et al., 2016, Noss, 2012, Saavedra and Opfer, 2012, Shaw, 2001b, Voogt et al., 2013). Various writers have provided updated or additional guidelines (Hicks et al., 2014, McKnight et al., 2016). Rather than encompass digital technology use for all participants in education (i.e. students of all ages and teachers), updated guidelines on offer are most often subject (Hicks et al., 2014) or student specific (Chauhan, 2017, McKnight et al., 2016). Key research topics will now be discussed under the headings of Improving Student Outcomes and Subject-Specific Research.

However, as with any tool, the skill used to wield the technology impacts any ensuing outcome (Abramson et al., 2009, Derbyshire, 2009, Greenfield and Yan, 2006, Kemp and

Bushnell, 2011, Ophir et al., 2009, Subrahmanyam et al., 2001, Subrahmanyam et al., 2000, Wood et al., 2011b, Wood et al., 2011a).

Improving Student Outcomes

Studies on computer and Internet use to improve educational outcomes have delivered mixed and occasionally emotive research outcomes, especially in relation to effects on young, developing brains. Beltran and colleagues (2006) found a positive correlation between access to home computers and academic outcomes but commented that research into school-based computer use provided diverse, often negative correlations. In short, having a useful tool does not mean that the tool will be used well.

One main negative finding was the lack of transference of skills learned through computer programs (Rouse and Krueger, 2004), although it could be argued that the fault for this could equally lie with scaffolding provided by classroom teachers. School-based research has also revealed misuse of technology where students used computers for gaming rather than as learning tools (Sefton-Green, 2004). Some researchers expressed concerns that more use of digital media reduced real time social interaction (Livingstone, 2002). Finally, a number of government reports and policy documents have raised concerns regarding the developmental impact of screen time on younger children (Brown et al., 2011, Brown et al., 2010, Sigman, 2010). This last point is, perhaps, the most important, although each of these points begs the question of targeted, controlled use of technology for positive learning outcomes.

From a positive perspective, the constructive use of technology in a classroom has been found to provide the means to provide immediate and ongoing feedback to students (McKnight et al., 2016), improve scientific thinking (Chauhan, 2017), build richer learning experiences through the presentation of multisensory materials (Chauhan, 2017, McKnight et al., 2016), cater for differing learning speeds and interests (McKnight et al., 2016), open up

the confines of the classroom (Chauhan, 2017), and provide the means for student collaboration and cooperation (McKnight et al., 2016). Thus, it would appear that technology is neither good nor bad, depending upon the hand that operates the mouse.

Subject-Specific Research

Acknowledging that the world is now inherently digital, some researchers are exploring differences in reading perception, skills development and comprehension that may or may not be occurring as young children access texts in digital formats (Roschke and Radach, 2016). Others are investigating whether e-learning provides a more permanent memory when compared to traditional classroom learning (Hung et al., 2012, Hwang et al., 2015), whether digital reading comprehension tasks are more effective (Lysenko and Abrami, 2014) and uses for game-based learning (Barzilai and Blau, 2014, Howard-Jones, 2011a).

2.1.5 Summary of Literature to 2011

In Section 2.1, this chapter reviewed neuroscience research literature pertinent to learning and education. As was demonstrated, acceptance of neuroscience findings within the educational sphere is not universally embraced (Bruer, 1997, Snook, 2012, Bowers and Holyoak, 2016). Nonetheless, there is sufficient evidence that understanding how the brain learns at a biological level can improve how teachers teach and students learn (Ansari et al., 2012, Baker et al., 2012, Blakemore and Bunge, 2012, Carew and Magsamen, 2010, Cartwright, 2012, Fischer, 2009, Immordino-Yang and Damasio, 2007, Tokuhama-Espinosa, 2011).

Given that the brain enables the mind, much like a computer enables its software, this review gave specific attention to any elements identified in the literature that assisted in optimal brain function. Despite the ambiguity around a precise definition for executive functioning, three key dimensions emerged as foundational to cognitive development. These were inhibition, memory and cognitive flexibility (Center on the Developing Child at Harvard University, 2011, Diamond, 2013), although, social and emotional development were also

shown to be central factors (Best et al., 2009, Bodrova and Leong, 2003, Brackett, 2012, Daunic et al., 2013, DeSteno et al., 2013). In addition, appropriate sleep (Chaput et al., 2016), activity (Dishman et al., 2006, Etnier and Chang, 2009) and dietary behaviours (Gómez-Pinilla, 2008) support brain health . The use of digital media is an emergent area that appears to have physical as well as cognitive and emotional impacts on brain development and brain function (Choudhury and McKinney, 2013). The focus of review will now turn to a consideration of the means to assess and measure these elements.

2.2 Field-based Assessment and Measurement of Executive Function, Sleep, Physical Activity, Diet, and SES Factors

This section will examine key factors identified in the literature current at 2012 (as opposed to 2011 for the preceding section. The additional year is included in the measurement and assessment review as, it was at this point that the current research project was constructed. Literature will be reviewed in each of the measurement domains (executive function, student motivation, sleep, physical activity, diet and socioeconomic status) relevant to this project.

2.2.1 Measuring Executive Functions and Functioning

> There is no test or assessment battery that singularly assesses executive function. By necessity, both elements, the domain-specific content area and its regulatory executive control processes, are always present in any test. Thus, part of the challenge of assessing executive functions is separating cognitive and behavioral control functions from domain-specific functions. Frequently, the more novel and/or complex the task or situation, the greater is the demand for the executive functions. The more familiar, automatic, and simple the task, the less the child needs to recruit his or her executive functions BRIEF Professional Manual (Gioia et al., 2000a, p 13).

Initially, assessment work on executive functions focussed on adult populations (Hughes and Graham, 2002). However, executive functions mature over time and one cannot directly apply adult measures to child studies (Hughes and Graham, 2002, Hughes, 2011), or measures for children in their early years to adolescents (Beck et al., 2011). As Hughes and Graham (2002) point out, a central problem related to measuring executive function in adults (i.e. the need to maintain novelty, which leads to constant change to assessment tasks, which

in turn renders overall comparison difficult) is not a factor in assessment of children who are not as proficient at task habituation. However, assessment challenges for children as compared to adults involve lower levels of language proficiency and motivation to complete challenging tasks (Hughes and Graham, 2002, p. 133). Additional design issues when testing EFs include task impurity and low process-behaviour correspondence where one behaviour can be the result of several different processing difficulties (Hughes and Graham, 2002).

Language Proficiency

Several alternative tasks with decreased language components have been devised for young people. These include non-verbal tests such as the picture-based Day/Night task, pattern-making tasks that avoid simple repetitions or sequences, and tasks of fluency (e.g. generating names of objects in a particular category rather than the adult version—generation of words that do not begin with a particular letter) (Hughes and Graham, 2002, p. 134). Such test variants have allowed researchers to explore the development of executive functioning across the age spectrum (Hughes and Graham, 2002, Manly et al., 2001).

Distinguishing Individual Executive Functions

Given the interconnectivity of executive functions, a major consideration is to what extent individual functions, such as working memory, need to be teased out in the process to ensure that the measurement is targeted appropriately. As with the study of intelligence (Sternberg, 2005), the research literature on EFs contains a long narrative regarding the exact definition for and the feasibility of separating individual elements, especially attention and working memory. However, Diamond and Lee (2011) provide an excellent research overview of individual executive functions/dimensions in their paper, Interventions shown to Aid Executive Function Development in Children 4–12 Years Old. Like Hughes and Graham (2000), these authors stress that true measurement of EFs requires high-demand tasks. They note that, “The largest differences between those in programs that improve EFs and control

participants are consistently found on the most demanding EF measures. Everyone does fine when EF demands are less" (Diamond and Lee, 2011, p. 6).

Senn et al. (2004) have presented an alternative conceptual approach to examining individual EF skills using a micro/macro construction. The micro/macro notion views individual EF skills such as working memory (a micro skill) as underpinning larger (macro) constructs such as problem solving or social judgement.

Novelty Decay

Regardless of the specific function(s) under examination, maintaining a degree of novelty is essential when assessing EFs. The use of repeat measures can, therefore, be problematic as novelty decays with each trial (Diamond and Lee, 2011). Time lapse between trials and complex tasks that cannot be easily mastered are favoured if repeat measures (e.g. pre/post study designs) are required. As responses are often context driven, a change of context can also be employed to maintain novelty.

Factors in Test Delivery

There is a push for test batteries that reflect ecological validity—measurement within the natural environment (Goulden and Silver, 2009). Goulden and Silver (2009) define ecological validity as testing elements that are, firstly, required in the natural environment (e.g. a school classroom) and, secondly, can predict behaviours that occur in real life situations (p. 440).

The consideration of context and ecological validity also raises the question of test delivery mode (e.g. the choice between manual or computer-based testing). Hughes and Graham (2002) suggest that manual executive function tasks may be more sensitive to executive control difficulties, despite being less pure in maintaining consistent delivery. This is because manual tasks provide opportunities to note underlying behavioural differences that may not be evident in the quantitative data alone. As an example, these authors cite a study of hard to manage children attempting to succeed at a Tower of London task (a test often used to

measure problem solving and planning (Chang et al., 2011)) by trying to break the rules rather than attempting to find a valid solution (Hughes and Graham, 2002, p. 136). Using computer-generated quantitative data alone, the rule breaking behaviour would have remained unidentified. Hughes and Graham (2002) argue for some degree of qualitative input regarding the *how* and the *why* of the results to augment the quantitative *what* of the data (Hughes and Graham, 2002).

Social-emotional Aspects

A final consideration when assessing executive function is the social-emotional aspect required to employ goal-directed persistence and other self-regulatory behaviours (Goulden and Silver, 2009). As mentioned above, most assessment-related research into executive functioning examines aspects of attention and/or memory (usually working memory). However, the social-emotional aspects of executive control are equally important. For example, in younger children, the biggest indicator for successful problem solving was inhibitory control, whereas in older children, working memory was the strongest gauge for success (Senn et al., 2004). Additionally, there appears to be a solid test-related relationship between Theory of Mind development and the level of EF development in preschool children (Hughes and Graham, 2002, p. 132). Beck and colleagues (2011) reported a difference between conflict and delay tasks in both sensitivity and age appropriateness. These authors stated that conflict scales (i.e. measures of ability to deal with interruptions to goal-directed behaviour due to conflicting stimuli or changes to the task (Beck et al., 2011)) appear more sensitive than delay scales (i.e. measures of ability to delay gratification or inhibit/postpone a response (Beck et al., 2011)). Although, in relation to their test battery, conflict scales demonstrated an age ceiling of 4.5 years (Beck et al., 2011). This same study reported that delay tasks seemed less sensitive to developmental age and more suited to measuring levels of impulsivity in individuals (Beck et al., 2011). As Diamond and Lee (2011) noted, the

developmental stage of a child is an important consideration in how EFs are assessed, both individually and collectively.

2.2.2 Sleep Measurement Factors

There are several important factors involved in sleep measurement and school performance (Aton, 2009, Blunden and Chervin, 2010, Dewald et al., 2010, Geiger et al., 2010, Hetta et al., 2007, Kopasz et al., 2010, Lauderdale et al., 2008, Lewandowski et al., 2011, Meijer and van den Wittenboer, 2004, Orzeł-Gryglewska, 2010, Sadeh, 2011, Sadeh et al., 2003, Smaldone et al., 2007, Strasburger, 2011, Wilhelm et al., 2012). Factors relating to sleep and learning include sleep quantity (i.e. time in bed asleep) (Dewald et al., 2010, Lewandowski et al., 2011, Meijer and Wittenboer, 2000, Sadeh et al., 2003), sleep quality (sleep maintenance and sleepiness upon waking in the morning) (Dewald et al., 2010, Geiger et al., 2010{Lewandowski, 2011 #1056, Lewandowski et al., 2011) and sleep hygiene (habits associated with sleeping that affect production of melatonin—the hormone that controls sleep/wake cycles) (Blunden et al., 2012a, Lewandowski et al., 2011, Mindell et al., 2009). More recently, studies have focussed on variable sleep schedules where daily sleep/wake periods change substantially over the course of a week, for example, due to shift work requirements or nocturnal use of technology (Aton, 2009, Cain and Gradisar, 2010, Strasburger, 2011, Wilhelm et al., 2012, Zimmerman, 2008).

Sleep measurement is conducted using technology-dependent apparatus or via subjective report (e.g. a sleep diary). Examples of technological sleep measurement include the polysomnogram (Morgenthaler et al., 2008), electro-oculogram (Datta and Hobson, 2000), electromyogram (Datta and Hobson, 2000) and electroencephalogram (Datta and Hobson, 2000). Each of these machines is highly sophisticated and not applicable for field work, such as a large school-based study. An alternative piece of technology that can be used in the field

is an actiwatch (Meltzer et al., 2012), a wrist-worn device that measures activity levels (e.g. a *Fitbit*).

The use of subjective report versus an actiwatch was examined by Meltzer and colleagues (2012). These researchers note that in 2007 the American Academy of Sleep Medicine officially endorsed the use of actigraphy, which includes the actiwatch as being able to delineate "…sleep patterns, and to document treatment responses in normal infants and children (in whom traditional sleep monitoring by polysomnography can be difficult to perform and/or interpret..." (Meltzer et al., 2012, p. 463). However, technology comes at a higher cost than paper-based sleep logs, especially in school-based research.

There are problems in subjective reporting methods, such as sleep logs. Subjective reporting tends to under-report sleep wakings, and therefore, usually over-report total sleep time (Lauderdale et al., 2008). Writing in 2011, Sadeh maintained the view that the use of both subjective and objective (e.g. actigraphy) data collection are valid methods in sleep research (Sadeh, 2011). Hence, when funding is an issue, a sleep diary is a viable research tool.

2.2.3 Physical Activity Measurement Factors

Key dimensions in the study of physical activity examine the method of exercise/activity as well as the frequency, duration and intensity of effort (Corder, 2008). The elements of chronological age, physical setting and the degree of restriction applied (e.g. supervision or rules for a game) are further research considerations (Corder, 2008). In recent years, research regarding benefits of physical activity has been specifically linked to the executive functioning (Etnier and Chang, 2009). However, as these authors point out, the multiple definitions for executive functions and lack of clarity around co-dependence of each element is a research and measurement constraint.

The use of self-report methods of data collection is standard practice in measuring physical activity in children (Janz et al., 2008). However, there is evidence that the relationship between physical activity and health in youth is harder to measure than with an adult population due to higher levels of activity in children and longer lifetime exposure to disease-causing elements in adults (Corder, 2008, p. 977). Self-report in children lends itself to problems with over/under-reporting of activity with a tendency towards over-reporting of activity (Bai, 2012). Inaccurate data from a snapshot approach that does not necessarily reflect long-term activity patterns can also result (Corder, 2008). As with sleep, an accurate way to collect activity data in the field is via an accelerometer (Bonomi et al., 2009, Le Masurier and Tudor-Locke, 2003). However, again as with sleep, the cost is prohibitive in studies with large populations.

In relation to physical activity, measurement issues reflect the same research constraints as those noted with executive functioning and cognition (see Section 2.2.1) where precise measurement of impacting factors is confounded by the co-dependence of executive functions. As with sleep (see Section 2.2.2), the cost of technical measurement equipment in school-based research is prohibitive.

2.2.4 Dietary Measurement Factors

The main elements of dietary measurement include aspects of nutritional behaviours (including intake and time of consumption), environments for consumption, attitudes, and dietary knowledge ((ACAORN), 2010, Booth et al., 2006). Dieticians acknowledge specific challenges regarding research with children. As Hoyland et al (2009) identified, supporting literature is compromised by failures to explore and isolate the influences of meal composition including consideration of glucose index (GI) versus glucose load (GL), nutritionally at-risk (i.e. malnourished) versus healthy populations (aspects of SES), and younger children versus adolescents (aspects of the impact of age on metabolism).

Food related behaviours such as consumption practices (i.e. where meals/food are consumed), purchasing habits, and food availability also influence dietary habits and derived nutritional benefits. In relation to food intake, portion size and food classification (i.e. food group) are major measures. As mentioned in Section 2.1.4, Subsection Diet (see p. 84), the time of day food is consumed impacts brain function, with much child-related research focussing on the consumption of breakfast. With respect to SES, dietary interventions had the most pronounced benefits in nutritionally at-risk children especially when the study involved school-based breakfast programs (Benton et al., 2007, Dye and Blundell, 2002, Hoyland et al., 2009). Hoyland et al. suggested that school breakfast programs may also demonstrated positive results in children at risk because the provision of breakfast encouraged better attendance. Children had more chance to improve academically by virtue of greater time spent at school (Hoyland et al., 2009). It should be noted, these researchers observed that well-nourished children may still be benefitting from dietary interventions but the current approaches to measurement do not reflect this, inferring that the effects of SES need to be considered more deeply.

Dietary intake questionnaires are one primary method of data collection. Questionnaires are useful when dealing with large populations in disparate locations, when “food related behaviours are likely to be associated with the outcome of interest" or targeted as an aspect of intervention, and when a methodology calls for repeated measurements (Australian Child and Adolescent Obesity Research Network (ACAORN), 2010). Questionnaires provide a relatively small burden on researchers and are generally easy for anyone (e.g. classroom teachers) to accurately administer (Australian Child and Adolescent Obesity Research Network (ACAORN), 2010). While misreporting can occur in any population, younger children (due to cognitive immaturity relating to concept of time, memory, attention and food group knowledge) and adolescents (due to issues of body image and motivation) are more

prone to reporting errors (Livingstone and Robson, 2000). As Livingstone and Robson have demonstrated, reporting errors are usually reflective of under-reporting (Livingstone and Robson, 2000, p. 282). However, according to the ACAORN, older primary school children (i.e. ages 8-12 years) can developmentally provide valid responses regarding their dietary intake (ACAORN, 2010).

2.2.5 Factors in Measuring Socioeconomic Status (SES) Impact

Research designs which include considerations of SES allot varying degrees of importance to this factor. Most frequently, SES is used as a population descriptor in order to provide study context (Hoffman, 2012). The effects of socioeconomic factors have also been used collectively and individually as independent or dependent variables, as controlling factors and as a means to un-confound data sets (Hoffman, 2012). These approaches are taken to allow for the fact that students from lower SES backgrounds often demonstrate the most progress because their baseline position, relative to higher SES groups, means more progress can be made. However, despite the role researchers choose for SES, Hoffman believes that "So pervasive is the influence of SES that it is difficult to imagine a child development study where the researcher can avoid controlling on SES or considering its effects in generalizing results" (Hoffman, 2012, p. 126).

2.2.6 Implementing Programs

> Transferring effective programs into real world settings and maintaining them there is a complicated, long-term process that requires dealing effectively with the successive, complex phases of program diffusion. These phases include how well information about a program's existence and value is supplied to communities (dissemination1), whether a local organization or group decides to try the new program (adoption), how well the program is conducted during a trial period (implementation),

> and whether the program is maintained over time (sustainability). Moreover, if many people are to benefit, diffusion must be successful in multiple communities, and at each stage of the process, from dissemination through sustainability (Durlak and DuPre, 2008, p. 327).

Implementation of new programs in real world situations, such as a regular school classroom, can be a challenge for many reasons. These include problems related to:

- contextual change (Paunesku et al., 2015)
- upscaling of the intervention audience (Bywater, 2012, Paunesku et al., 2015)
- single-level (e.g. one-off training session), multifaceted (e.g. staff training accompanied by an intervention audit) or blended (multiple strategies implemented in line with a specific protocol) approaches (Powell et al., 2014)
- maintaining program fidelity (Durlak and DuPre, 2008)
- providing interventions that truly add value in a new or unique way (Durlak and DuPre, 2008)
- methods to ensure continuous monitoring of outcomes and process (Bywater, 2012).

The eight-factor model of successful program implementation from Durlak and Du Pre (2008) has emerged as most suitable for the purposes of this project and is presented in dot point form below. As a base-level feasibility study, this work will be measured by the first four points only during the analysis of study results in Section 4.4 as the final four have been addressed within the research structure. Durlak and Du Pre (2008) define key factors that provide successful program implementation as:

- fidelity—how much does the implementation correspond to the original intention of the program
- dosage—how much of the original program has been provided

- quality—how well elements of the program have been delivered
- participant responsiveness—how well the participants engage with the program
- program differentiation—how different is the program for what is already available
- monitoring of control/comparison conditions—research control conditions provided for assessment
- program reach—how well did the intervention reach groups for which it was intended and what proportion of these groups was reached
- adaptation— program modification changes in the program as a result of field tests (Durlak and DuPre, 2008, p. 329).

2.2.7 Common Measurement Considerations for Research with Children

Several common measurement considerations apply to each of the factors examined above to ensure efficient and reliable data collection. These include the burden on the researcher(s) related to time (Australian Child and Adolescent Obesity Research Network (ACAORN), 2010), cost (Australian Child and Adolescent Obesity Research Network (ACAORN), 2010, Bai, 2012, Corder, 2008, Meltzer et al., 2012) and sample size (Boyce, 2011, Livingstone et al., 2004). Additionally, the potential for bias (both with recall and through the measurement regime) and anomalies in behaviour from snapshot data require attention (Australian Child and Adolescent Obesity Research Network (ACAORN), 2010, Corder, 2008). Age of respondents and collection methods (e.g. interview, questionnaire, phone survey) are also key, especially in a primary school-aged population (Boyce, 2011). Each of these parameters much be factored into any research design and to the selection of outcome measures to produce valid results.

2.3 Developments in Research Post 2011

Discussion will follow the format developed in Chapter 2 as follows:

- neuroscience and education interactions, including MBE and educational neuroscience
- elements of a neuroeducation program, including working memory, attention, impulsivity and cognitive flexibility
- social and emotional neuroscience
- physical factors (sleep, diet, physical activity and digital technology) that impact on brain development.

Updated research will then be related to the current BBL Program with suggestions for changes and/or improvements based on more recent findings.

There has been substantial growth in the research literature in many areas pertinent to this work, most notably in the areas of neuroscience (or neurosciences) and education, educational neuroscience, human attention, cognitive flexibility, diet and cognition, SES and cognition, affective neuroscience and emotional neuroscience (see Figure 8). These diagrams were generated through the ProQuest Central database using peer-reviewed articles that appeared in scholarly journals only. Chronological search perimeters were all articles prior to December, 2011 and all articles from January, 2012 until September, 2017. Graphs for working memory and human attention are shown separately as the amount of research in these two areas so eclipsed the other search terms that their graphic representation was indiscernible.

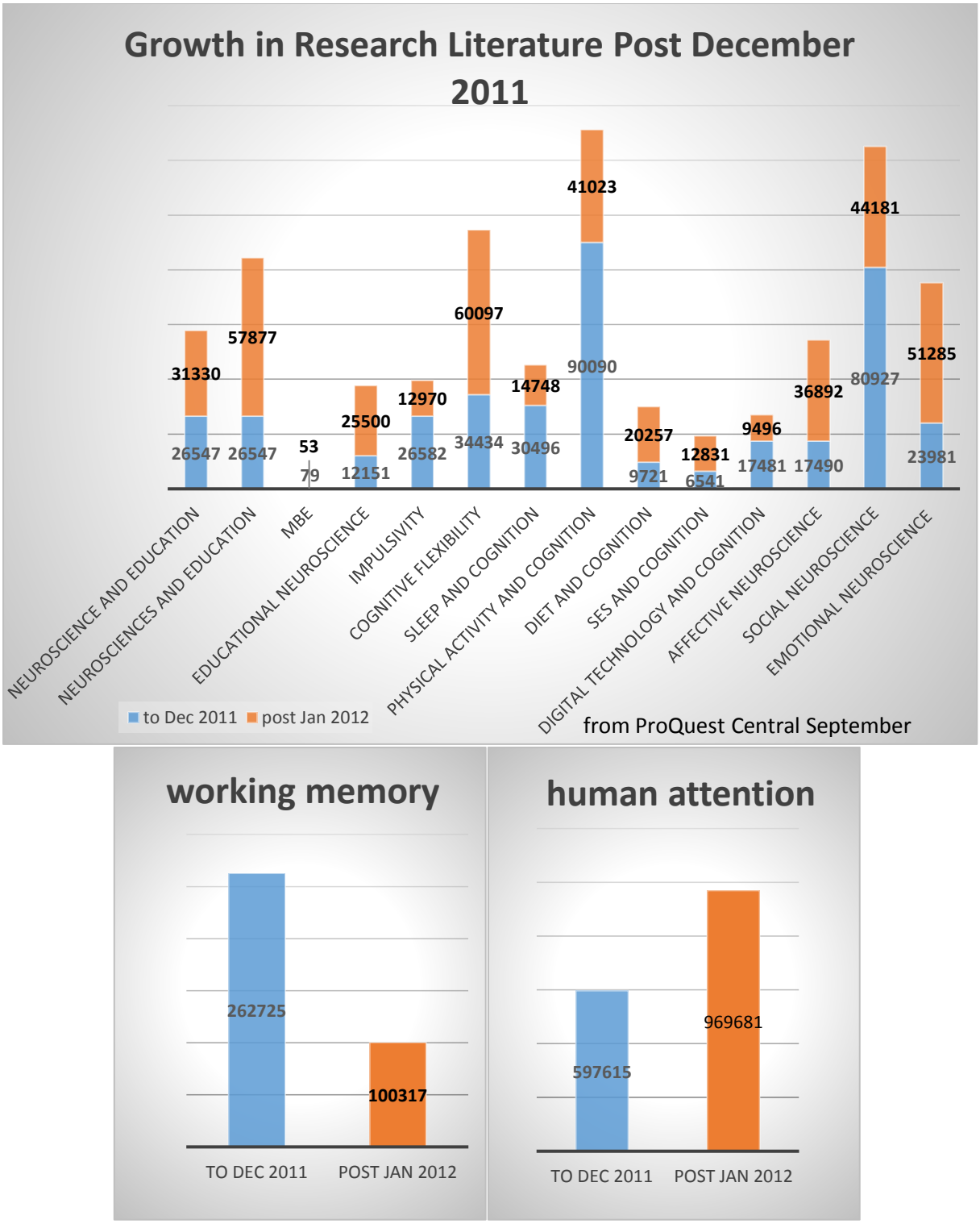


Figure 8 Comparative growth in research literature post 2011

2.3.1 Neuroscience and Education

In 2017, the relationship between neuroscience and education remained contentious (Bowers and Holyoak, 2016, Sigman et al., 2014). Despite a highly active neuroscience and education

research community, including Mind, Brain and Education (MBE) as well as educational neuroscience proponents, and strong interest from educators as demonstrated through conference attendances (Ansari et al., 2017), debate was still evident in the literature (Bowers and Holyoak, 2016). This debate had several strands. For the purposes of this discussion, the debate has categorised within two contexts as follows.

Firstly, the perspective that neuroscience has no place (Bowers and Holyoak, 2016), or an ill-defined place (Kraft, 2012, Snook, 2012), in education persists. As a side issue, there is division within the pro neuroscience and education contingent concerning the parameters of the discipline with different terms in use, such as educational neuroscience (Campbell, 2011), Mind, Brain and Educations (Stein and Fischer, 2011) and the awkward neuroeducational neuroscience (Howard-Jones, 2010). Secondly, implementation of neuroscience knowledge into the educational realm was seen as challenging and/or problematic (Snook, 2012, Lalancette and Campbell, 2012, Zocchi and Pollack, 2013). For example, the field of neuroethics as applied to education has highlighted several areas of concern (Ansari et al., 2012, Lalancette and Campbell, 2012, Zocchi and Pollack, 2013). Issues with the application of neuroscience to educational curricula exist (Clement and Lovat, 2012) as do issues around translational research (Sigman et al., 2014), and the persistence of neuromyths among teachers (Gleichgerrcht et al., 2015). These two areas will now be considered in more detail.

Neuroscience Has No Place in Education

By 2016, the neuroscience-has-no-place-in-education stance appeared to still have proponents. One such supporter, UK psychology Jeff Bowers, asserted that psychology is the science that should be influencing educational policy and practice, rather than neuroscience (Bowers and Holyoak, 2016). As Bower sees it, neuroscience has promised big but delivered nothing of real use as "…there are still no examples of EN (i.e. educational neuroscience) providing new insights to teaching in the classroom, there are still no examples of EN

providing new insights to remedial instructions for individuals, and, … there is no evidence that EN is useful for the diagnosis of learning difficulties." (Bowers and Holyoak, 2016, p. 628). Bowers contends that the original neuroscience and education analogy used by Bruer (1997) of 'a bridge too far' should be restated as a 'one-way street' in that neuroscience has something to offer to neuroscientists and psychologists but "…is irrelevant to the task of designing and evaluating instruction" (p. 630). In other words, neuroscience has nothing to offer educators who seem to be, in Bowers opinion, mere classroom technicians.

Like Bruer before him, Bowers is not a voice in the wilderness. Educational philosopher, Ivan Snook (2013) broadens the argument of Bowers, contending that, if mismanaged, educational neuroscience can be viewed as the latest in a long line of educational fads, including Brain Gym and multiple intelligences. Snook postulates that all stances within educational neuroscience literature can be categorised under four headings. These are:

- "Those which sound authoritative but which simply announce that at present brain scientists are ignorant
- Those which are true and educationally relevant but are either logical truths (tautologies) or known already from everyday experience or cognitive psychology [as per Bowers]
- Claims which are probably true and, in their place, of some interest, but have really no bearing on teaching [also as per Bowers]
- Those which express touching faith in neuroscience without any evidence to substantiate that faith" (Snook, 2012, p. 446).

Key supporters of educational neuroscience, John Gabrieli and Paul Howard-Jones and colleagues, have consistently rebutted Bowers' assertions (and by extension those of Snook), stating clearly what educational neuroscientists are trying to contribute to the education field as the following quotes demonstrate.

First, educational neuroscience is a basic science that has made unique contributions to basic education research; it is not part of applied classroom instruction. Second, educational neuroscience contributes to ideas about education practices and policies beyond classroom curriculum that are important for helping vulnerable students. Third, educational neuroscience studies using neuroimaging have not only revealed for the first time the brain basis of neurodevelopmental differences that have profound influences on educational outcomes, but have also identified individual brain differences that predict which students learn more or learn less from various curricula. (Gabrieli, 2016, p. 613).

EN [educational neuroscience] does not favor solely neural levels of explanation, and certainly does not suggest that educational efficacy should be evaluated solely on the basis of neural function. Rather, EN claims that studies of brain function can contribute, alongside behavioral data, to an understanding of underlying learning processes, and that understanding underlying learning processes is relevant to education and can lead to improved teaching and learning. As far as we are aware, there are no established EN research groups who claim that neuroscience, in isolation from psychology or other disciplines, holds any value whatsoever for education. Instead, the exploitation of data from neuroscience is part of a wider perspective on the sphere of causal influences operating on educational outcomes that, for example, now includes a focus on factors such as sleep, diet, stress, and exercise (Howard-Jones et al., 2016, p. 5).

The outcomes of the present study would appear to validate the views proffered by Howard-Jones and colleagues (2016) above. For example, an understanding of the underlying learning processes, such as those supporting sustained attention, supports teachers to assist students to improve their learning by improving directed attending skills. Additionally, teacher perspective of student behaviour moves away from assumed conscious disengagement or intellectual deficiency on the student's part towards an investigation and remediation of specific executive skills deficits.

Ethics and Implementation

For most researchers and educators in 2016, relational issues for neuroscience and education were more about *how*, rather than *if*, the relationship moved forward. Several academics, including proponents of Mind, Brain and Education (MBE), viewed neuroscience as one component that could deepen current understanding of how the brain learns, as expressed by Howard-Jones and colleagues (2016) above (see also Tokuhama-Espinosa diagram, p 26). However, ethical issues relating to how children are influenced during development by educational pedagogy and cultural mores required explicit consideration (Busso and Pollack, 2015, Snook, 2012, Stein and Fischer, 2011, Zocchi and Pollack, 2013).

As discussed in Section 2.1.1, the general educational context of a society is an important perceptual filter for classroom practice. As early as 2011, Stein and colleagues (2011) expressed concern that in educating children, societies must persuade rather than coerce; raise rather than design individuals to be functional citizens. Baker and colleagues (2012) went beyond the individual to suggest that much more notice needs to be taken of the social constructs around the schooling effect as neuroscience and education interacted (Baker et al., 2012). Busso and Pollack (2015) continued the ethics discussion around "the ways in which culture, politics and society intersect with the biological science" (p. 172) by identifying ethical issues around:

- using neuroscience language and images as merchandising ploys, such as titling a book using the term *brain-based* (e.g. brain-based play in preschool)
- the power of neuroscience language to shape cultural views, as, "…in modern, industrial societies, our understanding of the self – including beliefs, behaviours, and identity – is increasingly attributed to neurochemical processes" (Busso and Pollack, 2015, p. 172), meaning that, for example, the individual is excused from any personal responsibility for his/her actions where these actions can be attributed to having a compromised brain through emotional trauma or injury
- a propensity to brain-type or biologically label (i.e. reduce the individual to the level of his/her ability/disability, e.g. dyslexic, autistic, dyspraxic) which can lead to personal stigmatisation or, again, non-accountability for actions due to a compromised brain
- using oversimplified neuroscience to reinforce favoured practice, for example, that of single sex schools because boys and girls biologically mature at different rates
- practices that fall short of the biopsychosocial approach where all aspects of a child's life—biological, psychological and social—influence learning and behaviour
- relocating responsibility for behaviour from the individual to the individual's biological make-up (i.e. he's just wired that way) (Busso and Pollack, 2015).

Zocchi and Pollack (2013) presented a meta-analysis of ethical issues in neuroeducation, grouping their findings under the headings of scientific enterprise, prediction, neuro-manipulation, social considerations, philosophical considerations, and brain-based justifications (p. 57). However, their review echoed many of the issues highlighted by Stein and colleagues (2011) as well as Busso and Pollack (2015). Some of the issues identified include:

- brain-typing, including the use of brain scanning (prediction)
- designing children (neuro-manipulation), including the area of nootropics—the use of drugs to enhance cognition
- neuro-merchandising (social consideration)
- impact of neuroscience on educational practices (social and philosophical considerations)
- free will versus biological make-up (philosophical consideration) (Zocchi and Pollack, 2013).

In addition, Zocchi and Pollack (2013) identified six items relating to scientific enterprise through their meta-analysis, all of which, these authors recognised, apply to any scientific research field. These included statistical dilemmas, accurate communication of research findings, generalisability of findings, safety and risk factors, selective reporting in the literature and incidental findings (Zocchi and Pollack, 2013, p. 57).

Ethical considerations are always relevant to science (Marshall, 2006). However, any scientific advance is open to positive and negative implementation, as illustrated by the use of drugs to manage conditions such as attention deficit disorder or as cognitive performance enhancers during academic examinations. Issues raised above should serve to expand ethical awareness and demand high levels of professional conduct in the use of neuroeducation pedagogy (Zocchi and Pollack, 2013). They should not prevent its practice. As the present study demonstrated, there is much to be gained in bringing the science of learning into the exercise of teaching in terms of encouraging students to take personal control of their cognitive and emotional development through understanding what makes for optimal brain functioning and, by extension, learning.

Finally, there is still a call for more active interactions between researchers and classroom practitioners. “Educational neuroscience research and conceptual frameworks fill the pages of academic journals, but opportunities for dialogue between teachers and researchers are still relatively scarce” (Busso and Pollack, 2015, p.180). The danger of spawning new neuromyths as well as wasting time and energy on chasing educational fads remain as long as educators interact only as consumers rather than as critical professionals in pursuit of new scientific understandings of human learning (Busso and Pollack, 2015, Snook, 2012). This project represents one way forward for those in the teaching profession to move beyond the role of uniformed consumer.

2.3.2 Elements of a Neuroeducation Program

In 2014, Howard-Jones produced a review of available neuroscience-influenced, research-based interventions for the British Education Endowment Foundation. He employed three criteria for judging program efficacy as those that:

- “are likely, according to current findings, to have a positive impact on [educational] attainment and are therefore worth testing at a large scale
- need further testing to determine their likely impact on educational attainment
- or do not seem to have a promising impact on attainment” (Howard-Jones, 2014, p. 2).

Additionally, Howard-Jones provided ratings for the strength of available research evidence (low, medium, and high), as well as, how immediately applicable the program is to classroom use (Howard-Jones, 2014, p. 7). Interventions were assigned to one of three groups according to educational applicability. Group 1 contained the most developed programs in terms of educational application and were backed by the most promising evidence about their impact on educational outcomes. Group 2 programs were developed from a good scientific basis, but

needed further work to ensure appropriate classroom application. These programs required further evidence about their educational effectiveness. Finally, programs in Group 3 had the least evidence about their educational impact and needed the greatest amount of translational work (Howard-Jones, 2014, pp. 3-4). This author has categorised the interventions identified by Howard-Jones in terms that may assist more ready access by classroom teachers (see Table 8). The intervention types that form part of the BBL Program have been indicated by coloured infill.

Table 8 Classification of neuroscience-based interventions by evidence and classroom applicability (from Howard-Jones, 2014)

Skills Development	**Classroom Pedagogy**	**Underpinning Pedagogy**	**Assistive Technology**
Non- symbolic (*ability to understand number quantities*) and Symbolic Representation of Number (*understanding representations of number-e.g. 5*) [maths] M, A, 2	Brain Training of Executive Functions (*targeted enhancement of EF skills, e.g. inhibition control*) M, A, 2	Sleep, Nutrition and Hydration (*each contribute to optimum brain functioning*) L, N, 2	Neurofeedback (*influencing brain function by digital training & monitoring*) M, A, 2
Finger Gnosis Training (*using fingers to assist in counting*) [maths] M, N, 2	Interleaving (alternating topics with each revisited several times—see Spaced Learning) M, A, 2	Embodied Cognition (*learning through action and the actions of others—see Finger Gnosis & Neurofeedback*) M, A, 2	Transcranial Electrical Stimulation (*selective brain stimulation through electrical current applied to the scalp*) M, D, 3
Mental Rotation Skills (*visualising an object presented from another viewpoint*) [maths] L, D, 3	Learning Games (*engaging learners through uncertain reward strategy*) M, A, 2	Creativity (*inventing/creating new concepts& understanding their value*) L, A, 2	
Reading programs (*neural processes involved in mapping letter symbols to sound and understanding meaning*) [literacy] M, N, 1	Personalisation (*or differentiation—choosing different teaching approaches for individuals*) L, A, 3	Genetics (*considering the influence of genes on individual cognition*) M, D, 3	
	Spaced Learning (*learning content presented in several sessions with breaks in between sessions*) H, N, 1	Maths Anxiety (*high anxiety inhibits learning, especially it becomes a habitual response*) M, N, 1	
	Testing (*testing aids memory of studies materials*) H, A*, 1	Exercise (*physical activity increases learning neural networks efficiency*) M, N, 1	

Note: strength of evidence indicators: L = low, M = Medium, H = high
ready applicability to classroom indicators: N = near, A = moderate, D = distant
overall grouping by Howard-Jones indicators: 1 = Group 1, 2 = Group 2, 3 = Group 3
(* testing is considered moderately close to classroom application due to the lack of clear understanding of which testing effects are most supportive for memory improvement)

It should, perhaps, be noted that the work of Howard-Jones (2014) identifies neuroeducation elements largely from the perspective of researchers. Other neuroeducation elements identified in the research literature include radical embodied cognition (one step beyond embodied cognition which views mind as created through the combination of body, action, and perception with the inclusion of environment) (Crifaci et al., 2015, p. 22) and the use of neuroscience principles as the basis for pedagogy, for example, the brain's reward system and error correction (Potvin, 2013, Robb, 2016). Additionally, the sleep research literature is replete with evidence that lack of sleep affects cognitive and affective functioning. However, the impact of school-based sleep programs on behaviour change is notably lacking.

Definition of Executive Functioning

By 2016, the literature was still not in absolute agreement regarding a definition of executive functions. According to Carlson and colleagues (2016), "A primary challenge to measurement of EF [executive function] is that despite considerable empirical, clinical, and theoretical attention, consensus on its definition has remained elusive. Some definitions have emphasized associated brain structures whereas others have attempted to delineate the organization of diverse but interrelated cognitive processes" (Carlson et al., 2016, p. 45). As Jacob and Parkinson state, "Although there is some debate in the literature about the exact nature of executive function, many researchers believe that it comprises three or four related subcomponents, which include working memory, attention control, attention shifting, and response inhibition" (Jacob and Parkinson, 2015, p. 513).

Given the continued lack of expert consensus, this work will maintain the format developed in Chapter 2 *Literature Review* in reviewing research post 2011 and conceptualise executive functioning as based upon three central dimensions.

Three Dimensions of Executive Function

> Children who can remember information, who can regulate their attention, and who can maintain inhibitory control are in a better position to take advantage of opportunities for learning than children who struggle with problems of memory, inattentions, and impulsivity (Raver et al., 2013, p. 292).

The concept of three central *dimensions* (rather than *skills*) put forward by the Center on the Developing Child (2011) still appears the most useable from an educator's stance. Professor Martin Westwell, from the Science of Learning Research Centre, Flinders University, has represented Harvard's three dimensions of executive functioning as central to many other skills (see Figure 9). The use of a circular schema communicates the concept of core and higher order executive functions. This representation serves to point towards a range of skills but could mislead the less knowledgeable reader into believing that each of the skills in the outer ring is a stand-alone. Difficulties in defining executive functioning occur because each of the skills—both core and higher order—are distinct but interrelated or, as Miyake and colleagues (2000) expressed it, unified but diverse (Miyake et al., 2000).

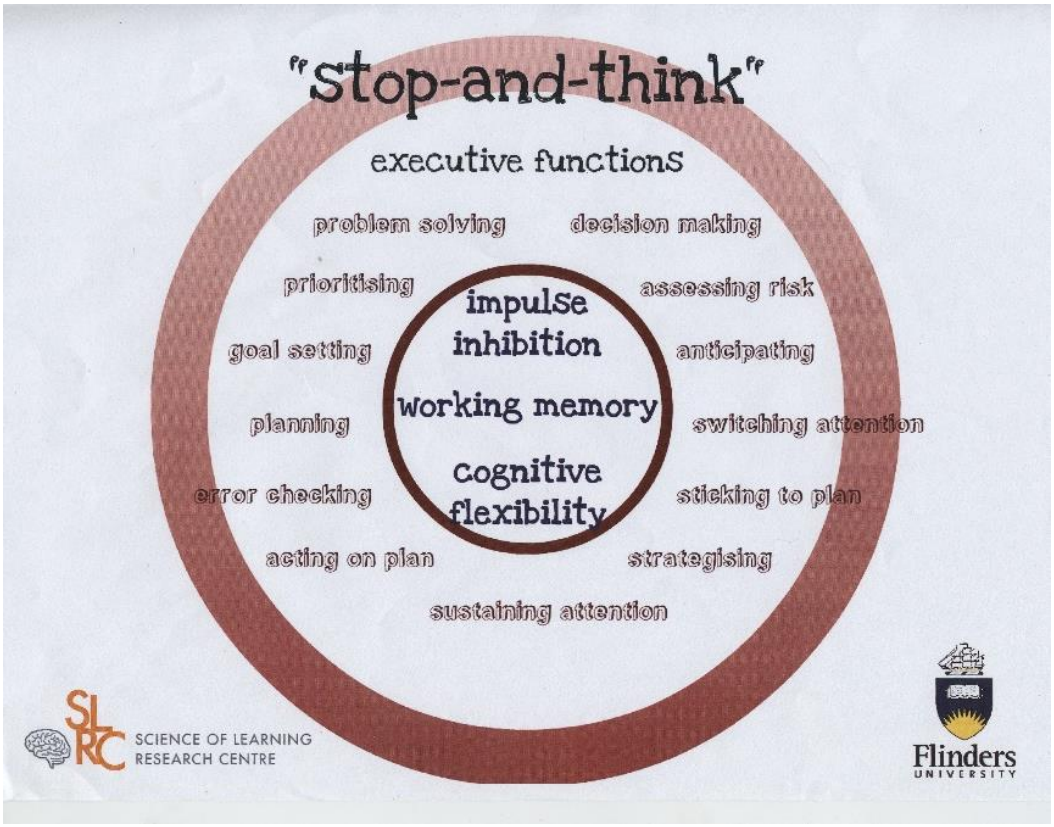


Figure 9 Westwell's overview of executive functions (Westwell, 2013)
(used with permission)

The inter-relational nature of executive function components was also still in dispute by 2016. Building on from the micro/macro notion of executive functions promoted by Senn and colleagues (2003), the idea of levels of executive functions skills (i.e. core and higher order such as reasoning and problem solving) had gained traction through the work of Collins & Koechlin (2012), Lunt and colleagues (2012) and Diamond (2013). However, this view was complicated by the fact that the core dimensions (inhibition, working memory and cognitive flexibility) develop over time and at differing rates from each other, with cognitive flexibility emerging much later (Davidson et al., 2006) and being highly dependent upon inhibitory control and working memory skills (Diamond, 2013). In 2013, Diamond proffered a relational diagram of research findings to add clarity to the field. This diagram reflects the difficulties in representing the overlapping nature of executive function elements in a two-dimensional format as much as it also provides a comprehensive overview (p 152).

Summarising research trends in executive function, Diamond (2013) noted five key points. These include:

- EF interventions tend to improve in students who are most behind (e.g. those from low SES backgrounds), seemingly regardless of the intervention type
- EF training appears to transfer but benefit most when the training taps more than one aspect of EF
- EFs grow under conditions that are demanding
- Repeated practice is key to EF development
- In studying EFs, the largest differences are found between intervention and control groups when EF demand is highest (Diamond, 2013, pp.154-155).

This evidence is important in the context of the current study because the BBL study results conflict with the first dot point which has been frequently replicated, although data would support the others.

Although differing viewpoints regarding definition and configuration of executive function abilities remain, since 2011, researchers have progressed in understanding the three core dimensions which will now be examined.

Inhibition Control

Inhibitory control remains an important, fundamental area of executive function to many researchers (Diamond, 2013, Diamond and Ling, 2016 , Logue and Gould, 2014) with the field progressing in its conceptualisation since 2011. As Diamond (2013) notes, "having the ability to exercise inhibitory control creates the possibility of change and choice" (Diamond, 2013, p. 137). A 2016 study by Fishbein and colleagues found that inhibitory control can be improved in children in the first year of school as part of the educational curriculum by using a targeted EF development program, in this case PATHS (Fishbein et al., 2016).

Using longitudinal data, Richland and Burchinal (2012) found a positive correlation between well-developed executive functioning skills in young children and subsequent strong development of complex reasoning skills. Based on their study results, the authors stated that "strengthening early executive-function skills, particularly inhibitory control, should be part of the growing [U.S.] national discourse around early childhood education as a tool to maximize children's potential for future academic and professional success" (Richland and Burchinal, 2012, p. 5). In support of this, Kim and colleagues (2013) demonstrated that results from hot and cool executive control tasks in young children were predictive of future problems, with hot tasks (where high levels of emotion are present) predicting behaviour problems but not academic performance, and cool tasks (where emotion is not really involved), specifically those engaging effortful attention, predicting academic performance but not behaviour problems (Kim et al., 2013). This evidence is important in the context of the current study because it supports the notion that inhibition control responds to targeted intervention and is central to academic success.

The literature on inhibition is still beset by confusion. Researchers agree that impulsivity is generally considered as a consequence of failed executive function (Bari and Robbins, 2013, p. 52) but there remains a plethora of terms for classifying behavioural inhibitory control. Variations include cool versus hot, motor versus choice, action versus choice, stopping versus waiting, top-down versus bottom-up, and restraint versus cancellation (Bari and Robbins, 2013, p. 53). Such confusion in terminology inhibits access to this important information by generalist educators which, in turn, can affect how quickly a focus on targeting executive functioning (e.g. inhibitory control) will be adopted by the teaching profession.

In their comprehensive review, Bari and Robbins (2013), offer both a distinction between cognitive and behavioural inhibition along with a further delineation of the latter concept. These authors suggest that cognitive inhibition is the management of response to thoughts,

perceptions, memories and emotions while behavioural inhibition encompasses action, choice and inflexibility/compulsiveness. Behavioural inhibition of action includes waiting, withholding and stopping. Behavioural inhibition of choice is synonymous with delayed (or deferred) gratification. Behavioural inflexibility/compulsiveness is termed *reversal learning* by these authors and refers to the ability to switch or change (Bari and Robbins, 2013,) p. 51). (NOTE: Other authors would associate these behaviours with cognitive flexibility. See discussion in Sections 2.1.4 Dimension 3: Cognitive Flexibility, p. 68 and Cognitive Flexibility, p. 139.)

In examining the various neurotransmitter systems that underpin executive function, Logue and Gould (2014) established that response inhibition is dependent upon increases of norepinephrine, serotonin and acetylcholine in the brain. Interruptions to production of these neurotransmitters cause disruption to executive functioning. Disruptions to the production of these neurotransmitters are caused by poor levels of fitness/obesity (Dishman et al., 2006), poor diet (Caleza et al., 2016), and lack of sleep (Chaput et al., 2016). This evidence is important in the context of the current study as it reinforces the importance of attending to brain health so that cognitive outcomes are optimised for every student.

Some executive functions appear to interfere with the execution of others when there is a shared aspect, such as working memory demand, or when there is limited capacity, for example, with youth or fatigue (Blackwell et al., 2014). Where executive function interference occurs, a performance trade-off (e.g. speed, memory, accuracy, perseveration) is found. Further, it would appear that children who are better at task switching have better capacity with working memory, theory of mind, delaying gratification, and using abstract rules (Blackwell et al., 2014). However, these same children are more susceptible to distraction than those who tend towards rigid and perseverating (i.e. continuing or repeating an action/thought/comment even though the behavioural prompt is gone) behaviours

(Blackwell et al., 2014, p. 357). These authors note a tendency to settle into a mindset for switching or perseverating that carries into adolescence (p. 357). This evidence is important in the context of the current study because educators need to understand the nuances of executive functions as well as their importance in order to tailor development for all students. This research also highlights the importance of patterns, or habits, of thinking that affect the deployment of executive functions.

Self-regulation

> Self-regulation is not limited to the social-emotional domain; it can also apply to cognitive behaviors, such as remembering or paying attention. In fact, research indicates that these two facets of self-regulation are related: children who cannot control their emotions at age four are unlikely to be able to follow the teachers' directions at age six, and will not become reflective learners in middle and high school. (Tools of the Mind, 2014)

Unsurprisingly, the research field has not consolidated one definition of self-regulation since 2011. There are still a number of researchers and practitioners who use the terms self-regulation and self-control interchangeably (Mamayek et al., 2016, Vohs et al., 2008), while others continue to see self-regulation as an overarching concept that includes the aspect of self-control (Hofmann et al., 2012, Posner et al., 2013). This is expressed by Bodrova and Leong (2014) on their Tools for the Mind website as follows:

> Self-regulation is a critical competency that underlies the mindful, intentional, and thoughtful behaviors of younger and older children alike. The term self-regulation refers to the capacity to control one's impulses, both to stop doing something, if needed (even if one wants to continue

> doing it) and to start doing something, if needed (even if one doesn't want to do it). However, it goes beyond simply being self-control…. Self-regulation is not to be confused with obedience or compliance; when children are truly self-regulated they behave the same way whether or not an adult is watching. (Tools of the Mind, 2014)

This view is echoed by Raver and colleagues (2012);

> Self-regulation includes children's ability to manage or modulate positive and negative emotions, to inhibit or control their behavior, and to shift and focus their attention. (Raver et al., 2012, p. 247)

For those who separate the two concepts, there appears to be a temporal component where self-control is short-term (faced with an immediate stimuli) and self-regulation (habitual moderation of thoughts, actions and behaviours) is more embedded behaviour. This evidence is important in the context of the current study as it highlights a barrier for educators. As Kraft (2012) identified, the field of education already lacks consistent, clear conceptual principles that shape practice (Kraft, 2012). Confusion in the cognitive sciences will only exacerbate the challenge of creating a science of learning and will increase the difficulty of incorporating strategies to improve self-regulation in students.

A focus on developing self-regulating behaviour in children is important for many reasons. Individuals with better self-regulation skills perform better academically and in life (Diamond and Ling, 2016 , Shechtman et al., 2013, Zimmerman and Kitsantas, 2014). For example, Zimmerman and Kitsantas (2014) demonstrated that measures of self-regulation, rather than self-discipline, are highly predictive of academic outcomes. Highly self-regulated individuals appear to enjoy better health and personal well-being (Diamond and Ling, 2016 , Nicholls et al., 2016, Vieira et al., 2013). Further, it would appear that children of today are

much less self-regulated than past generations (Bodrova et al., 2013) and that low SES has a greater negative effect on physical health when an individual exercises self-control, although better psychosocial outcomes still occur (Miller et al., 2015). This evidence is important in the context of the current study because it indicates that SES may be a pedagogical consideration when constructing educational approaches to EF improvement.

Delayed Gratification

Along with a sense of time, sufficient working memory, and self-regulation skills, trust in the source of a potential reward has emerged as an important factor in exercising delayed gratification (Michaelson et al., 2013). Inability to wait for something has also been linked to childhood obesity (Caleza et al., 2016). Conversely, Yu and colleagues (2016) found that preschool children with good delayed gratification skills outperformed their peers in relation to both working memory and motor inhibition tasks, although the authors note that the most successful children tended to be at the older end of their study population of children between 37 and 53 months (Yu et al., 2016a). There appears to be an association between delayed gratification skills and temporal processing ability (i.e. sound processing, particular when it is language related) (Reinelt et al., 2014). Children who used diversion rather than stoicism were better able to wait for a reward, especially if the diversion was not related to the reward (Steelandt et al., 2012). This evidence is important in the context of the current study because it would indicate three things. First, teachers must ensure that students can trust that delaying gratification will actually deliver the expected outcome. If not, teachers risk reinforcing the belief that behaviours delivering instant gratification (e.g. calling out or demanding immediate attention) are most useful (Michaelson et al., 2013). Second, being able to delay gratification is associated with better academic and life outcomes, thus, it is a vital skill to acquire if one is to become a useful citizen contributing positively to society—a goal highlighted in Section 2.1.1. Third, it appears that supporting students to develop strategies

for managing themselves while waiting for an expected reward provides the best cognitive outcome, hence, appropriate waiting strategies need to be taught.

Brock and colleagues (2014) conducted classroom-based research that demonstrated links between student abilities to delay gratification and their ability to manage non-instruction time (e.g. waiting for instructions or transitioning between activities). Students with poor delayed gratification skills, achieved the least progress in maths during the school year and had the lowest teacher ratings for learning-related behaviour (i.e. a composite of four teacher rating measures used in the study). Additionally, the authors found that more time spent in direct instruction from teachers supported students with poor delayed gratification skills to make acceptable levels of academic progress and implement positive learning-related behaviours (Brock et al., 2014). This evidence is important in the context of the current study as it demonstrates a direct link to levels of executive function and academic outcomes. Further, this research underscores the negative effects on academic progress and the allocation of teacher resources where executive skills are under developed.

Research continued to reinforce the ties between delayed gratification abilities and aspects of wellbeing including substance abuse (Lovallo, 2013, Stevens et al., 2014), obesity (Caleza et al., 2016, Volkow and Baler, 2015), aggression (Herndon et al., 2015, Mittal et al., 2013), delinquency (Herndon et al., 2015, Piquero et al., 2016) and friendship issues (Fink et al., 2015).

Attention

> People tend to make mistakes when they think too much or too little about ongoing, routine activities (McVay and Kane, 2012a, p. 1).

Exploration into the complexity of human attention systems remains a highly-researched area see Figure 8, p. 116) with new attention-related networks have been identified in the brain as

recently as 2012 (Petersen and Posner, 2012, Posner, 2012). Paediatric research into attention is concerned with a wide range of conditions including attention training, prematurity, developmental disabilities (e.g. ADHD or autism), mental health (e.g. depression, schizophrenia or Alzheimer's disease), aging, sleep, bilingualism, mindfulness/meditation, and boredom. This section will review literature relevant to children and adolescents published after 2011, excluding literature on prematurity. Sleep literature has previously been reviewed in Section 2.1.4.

- Attention training—Levels of focused attention and the lack of impulsivity at age five were predictive of a child's engagement with learning at age nine (Martin et al., 2012a). Training preschool children in reflection skills improved performance on card sorting tasks (set-shifting) (Espinet et al., 2013). Additionally, training executive attention in young children produced both functional and behavioural change in the trained population where trained children were quicker and more efficient in attending behaviour. This effect was still evident two months post intervention (Rueda et al., 2012). This evidence is important in the context of the current study because it supports the two central concepts that executive functions—in this case, attention—can

  In a study of university undergraduates, results indicated that individuals with lower levels of executive control, especially in behavioural inhibition, tended to multitask more than their peers. The researchers suggested that higher levels of multitasking behaviour occurred in this group because they were less able to block out distraction and remain on-task (Sanbonmatsu et al., 2013). There was also a functional difference in inhibiting emotional distraction as opposed to neutral or non-emotive distraction (Ziaei et al., 2014). This evidence is important in the context of the current study

because it underscores the importance of establishing good executive skills levels early to prevent later difficulties.

- Mindfulness or Mindfulness/Meditation—"Meditation can be defined as a form of mental training that aims to improve an individual's core psychological capacities, such as attentional and emotional self-regulation" (Tang et al., 2015, p. 213). Mindfulness/meditation is young in research terms but there is evidence that this practice causes functional brain changes in the areas responsible for attention, emotion and self-awareness (Tang et al., 2015). Meditation training may induce learning that is not stimulus- or task-specific, but process-specific, and thereby may result in enduring changes in mental function (Desbordes et al., 2012). Mindfulness training may serve to alter alpha brain activity and thereby, improve attention (Kerr et al., 2013). Ainsworth et al. have speculated that "mindfulness/meditation might usefully target deficits in executive attention that characterise mood and anxiety disorders" (Ainsworth et al., 2013, p. 1226). This evidence is important in the context of the current study because it represents an addition means by which to improve core executive functions. Furthermore, Garland and colleagues have proposed the Mindfulness-to-Meaning Theory in an effort to account for the positive effects of mindfulness/meditation (Garland et al., 2015). This will be discussed further in the section, *Positive and Negative Emotions*, below.
- Boredom—"Boredom seems to be associated with poor attentional capacity combined with negative attitudes, resulting in an inability to become involved with any occupation" (Martin et al., 2012b)—at least in one theoretical view (Eastwood et al., 2012, Mercer-Lynn et al., 2014). Perhaps contrary to this section's initial quote, Krannich and colleagues (2016) have demonstrated that boredom arises when an individual is over- or under-challenged, and not just as a function of attentional

capacity (Krannich et al., 2016). According to Pekrun and colleagues (2014) boredom and academic achievement have a reciprocal relationship where high levels of boredom produce poor academic results, and where poor academic results produce high levels of boredom. This evidence is important in the context of the current study because, as Pekrun and colleagues suggest, boredom needs to be thought of as a central *academic emotion* (Pekrun et al., 2014) and be afforded more consideration by both educators and researchers.

Working Memory Post 2011

This study relies on the updated definition of WM provided by Diamond in *Executive Functions (2013)* as the ability to hold information in mind while mentally working with it where the information is usually not perceptually present (Diamond, 2013). However, since 2011, the role of working memory (WM) in learning has been further constructed but choice of definition still appears dependent upon academic paradigm. Although the relationship of inhibitory control and WM is remains unclear (Diamond, 2013), proponents of computational modelling see WM and inhibition as so interrelated that increasing the load on one, increases the load on the other (Diamond, 2013). Within psychology, WM—or working memory capacity (WMC)—is conceptualised as part of a broader executive attention (Conway et al., 2005a, Engle, 2002, Kane and McVay, 2009, McVay and Kane, 2012a) or as part of a central executive in keeping with the Baddeley and Hitch model (Buchsbaum and D'Esposito, 2017). Additionally, interest in the state-based model of working memory continues (Nee and Jonides, 2013).

WM continues to be seen as fundamental to many cognitive processes including activation of goals, staying on task, following a conversation or holding a thought in mind for future action (D'Esposito and Postle, 2015). Diamond points out that WM is quite distinct from recall, both in function and in neural biology (Diamond, 2013). However, WM and selective focused

attention seem to have the same underlying neural basis (Diamond, 2013) which would give some weight to the state-based model of working memory. McVay and Kane (2012) have linked levels of mind wandering to an individual's working memory capacity and attention control with mind wandering more pronounced in individuals with lesser developed skills (McVay and Kane, 2012b, McVay and Kane, 2012a). This later research is central to educators and to this study as it reinforces the importance of strengthening working memory function, where possible, to achieve the best learning outcomes for students. Further, the accumulated evidence reinforces the notion that working memory and the close neurological relationship between working memory and selective focused attention would seem to indicate that improvements in either area will have flow-on effects to the other.

Cognitive Flexibility

As stated in Chapter 2, *Literature Review*, cognitive flexibility refers to the ability to adapt cognitive processing strategies when encountering new and/or unexpected situations (Canas et al., 2003) and involves restructuring of knowledge on both conceptual and procedural levels (Spiro and Jehng, 1990). Both inhibition control and WM are required to change perspectives in that one must deactivate (inhibit) previously held views to be able to activate new ones. Dick (2012) found that problems with cognitive flexibility in set-shifting tasks were dependent upon both attentional inertia and negative priming (Dick, 2012). Low and colleagues (2012) demonstrated that language is an important factor in cognitive flexibility in terms of working through conflicting information (e.g. false belief scenarios where at least one participant has outdated, or false, information and others are in possession of up-to-date, or true, information) (Low and Simpson, 2012). These finding underscore the fundamental importance of inhibitory control for higher order thinking and learning and increases the need for educators to explicitly support the development of inhibitory skills in students.

Diamond (2013) categorises four types of thinking which require cognitive flexibility, all with direct impacts on the academic curriculum. These categories are:

- Change of spatial perspective (e.g. envisioning changes in appearance for a rotated object). The most obvious curriculum connection here is the area of mathematics. However, spatial perspective is also important in visual arts and in predictive thinking—understanding that appearances can change depending upon one's viewpoint.
- Change of interpersonal perspective (e.g. employing empathy). This evidence unites the areas of cognition and affect and emphasises the need to learn and practise the integration of thinking and feeling.
- Change of conceptual perspective (e.g. thinking outside the square). Changes to conceptual perspective bring about solutions to problems. Locating conceptual perspective within the core executive functions provides evidence for the need to directly foster this ability in students.
- Adjusting behaviour to meet changing demands, admit error, and take advantage of unexpected opportunities (Diamond, 2013, p. 149). This point encapsulates the skills needed to collaborate successfully with other which is a key component of 21st century learning.

Brain Training

> Depending on the type of training and the level of maturation of the individual, training may influence developmental trajectories in different ways….the immature brain structure might set limits on how much can be achieved with training, but … immaturity can also have

> advantages, in terms of flexibility for learning (Jolles and Crone, 2012, p. 1).

The brain training market has continued to flourish into the second decade of the 21st century, with the debate about the value of brain training keeping pace (Simons et al., 2016). In 2014, this debate reached a crescendo when two open letters, both from large groups of scientists, were released with diametrically opposed findings from comprehensive reviews of the same research literature. The first research group consisted of 70 professionals from the Stanford Center on Longevity and the Max Planck Institute for Human Development who claimed that improvement in cognitive function could not be proven in any scientifically meaningful way (Allaire et al., 2014). The second group of 133 professionals argued that the literature could and did provide ample proof that brain training is beneficial (Merzenich, 2016).

In 2016, a research team led by Daniel Simons published a wide-ranging literature review on brain training in an attempt to settle the ongoing dispute. Simons and colleagues (2016) contended that it was possible for two groups of experienced scientists to reach opposite conclusions from the same literature on brain training because there had been no clear standards of measure employed by the field. In their paper, Do "Brain Training" Programs Work?, Simons and colleagues set standards of best practice for brain training interventions and reported the following.

> …we find extensive evidence that brain-training interventions improve performance on the trained tasks, less evidence that such interventions improve performance on closely related tasks, and little evidence that training enhances performance on distantly related tasks or that training improves everyday cognitive performance. We also find that many of the published intervention studies had major shortcomings in design or analysis

> that preclude definitive conclusions about the efficacy of training, and that none of the cited studies conformed to all of the best practices we identify as essential to drawing clear conclusions about the benefits of brain training for everyday activities (Simons et al., 2016, p. 103).

This evidence is important in the context of the current study because the concept of brain training is central to the notion of improving academic outcomes by targeting improvements in executive functioning. Simons and colleagues provide a differential definition of brain training which aligns with approaches such as the BBL Program. This definition distinguishes brain training from practice or rehearsal in terms of its flow-on effect.

> We use the term "brain training" in the same way that it is used by these companies [for profit brain training companies e.g. Cogmed]): to refer to practicing core cognitive abilities with the goal of improving performance on <u>other</u> cognitive tasks, including those involved in everyday activities (e.g., at school, at work, in sports, at home, while driving). Furthermore, we distinguish cognitive training interventions from studies of skill acquisition and learning—those that focus on how practicing a skill (e.g., music, math) can improve <u>that</u> skill. Instead, we focus on transfer of training from one task or skill to another (Simons et al., 2016, p. 105).

Attempts to improve executive functioning in children can be classed as either process-based (practice and more practice) or strategy-based (development of explicit strategies, for example, deep breathing to de-escalate stress responses) (Jolles and Crone, 2012). As Jolles and Crone (2012) noted, some of the most effective training programs combine process- and strategy-based approaches to achieve positive outcomes. These authors cite the example of writing instruction for children with dyslexia where training in writing or training in attention

alone did not produce the results that attentional training followed by specific instruction in writing provided (Jolles and Crone, 2012, p. 2). Klingberg (2016) suggested that, as cognitive training and cognitive development show similarities in neural effects, cognitive (or brain) training could "provide a controlled way to experimentally study the effect of environment on brain development" (Klingberg, 2016, p. 100). For both commercially-based and curriculum-based brain training approaches, researchers understand that not every individual benefits in the same way or to the same extent from every program (Ellis and Boyce, 2008). The big remaining challenge is to understand what benefits whom and why (Karch et al.). Buschkuehl and colleagues (2012) identify several points for further investigation including length of training, task difficulty, baseline ability levels, gender, age, and motivation (Buschkuehl et al., 2012, p. 176). This evidence is important in the context of the current study because it suggests that brain-training can be perceived as synonymous with education. That is, an educator's core aim is to train students to think critically, interact/communicate effectively and become functional, literate, numerate, contributing citizens. Understanding what types of brain training will produces flow-on effects or support better uptake of academic instruction for which groups of students will, by logical extension, improve academic outcomes and classroom practice.

The Social and Emotional Brain

> The ability to regulate one's emotions is one of the keys to leading a healthy and productive life (Silvers et al., 2013, p. 2).

The study of emotions and affect has grown enormously since 2011 (see Figure 8, p. 116) with many researchers now calling for the consideration of emotional states/affect to be included in all developmental investigative protocols (DeSteno et al., 2013, Rappaport and Corbally, 2016). Recent work has called into question the way that emotional and cognitive

function are conceptualised. Rather than specific brain areas dedicated to emotional or cognitive processing, such as the construct of a limbic system, many scientists now posit a theory of distributed function. Phelps and colleagues (2014) go so far as to state that the concept of the limbic system is obsolete and that there are, in reality, multiple neural systems underlying emotion and cognition (Phelps et al., 2014).

Refinements in research techniques and academic paradigms have extended understanding of the social and emotional capabilities of young children. For example, Southgate and Vernetti have demonstrated that children as young as six months are able to consider mind states in others in relation to probable actions (Southgate and Vernetti, 2014). Baron-Cohen and colleagues provided a comprehensive overview of paradigm shifts related to theory of mind and affective development in their book, *Understanding Other Minds: Perspectives From Developmental Social Neuroscience* (Baron-Cohen et al., 2013) where the developmental ages at which proficiency is reached in a number of affective skills are revised downwards. This evidence is important in the context of the current study because it indicates that many emotional filters and patterns of emotional perception are firmly in place by the time children reach school. As emotions strongly influence memory and learning, specific social and emotional learning programs need to be part of everyday curriculum.

Positive and Negative Emotions

In a meta-analysis of functional brain research studies on emotion, Lindquist and colleagues (2015) found that although there are no dedicated brain areas to positive or negative emotional processing, there are some regions which display a preference for negativity over positivity which the authors posit might be related to Baumeister's concept of negative bias. Furthermore, these authors proposed that the brain employs a 'flexible affective workspace' when processing emotions that is tied to internal body sensations used to direct attention (Lindquist et al., 2015).

The relationships of emotions to wellbeing and to cognition continue to be of primary interest. In 2013, Kok and colleagues proposed a positive upward spiral model between positive emotions, positive social connectedness and physical health (Kok et al., 2013). Additionally, mindfulness/meditation has taken hold in this area of research with Garland and colleagues (2015) advocating a Mindfulness-to-Meaning Theory (Garland et al., 2015). This theory combines the mindful coping model (2009) and the upward spiral model of flourishing (2010) and rests on the premise that mindfully reappraising and savouring events generates meaning (Garland et al., 2015) with meaning being one of the key components of emotional wellbeing (Hicks et al., 2016). As has been demonstrated, emotions provide a strong perceptual bias for what will or will not capture attention. Understanding what promotes positivity will aid the construction of effective learning environments in schools.

Social Contagion

Social contagion – the dissemination of behaviours, affective states or illnesses across networks (Christakis and Fowler, 2013). Centrality, cohesion and structural equivalence compose the three core facets to social contagion {Liu, 2017 #1412}. Centrality refers to the degree of closeness between people. Cohesion is defined as the degree of interconnectedness of people and structural equivalence indicates people that occupy an equal position within the social structure (Liu et al., 2017).

Social contagion is an important concept for educators and relates to earlier discussion on changes in 21st century learning. The speed and distance that ideas and behaviours can now spread has been greatly enhanced by modern technology, especially social media. For example, social contagion is not, as previously believed, dependent upon face-to-face contact and has been shown to occur through social media, such as Facebook and Twitter (Kramer et al., 2014). People now issues invitations, check in with friends in distant locations, buy, sell

and advertise online. They also have greater access to individuals they wish to bully and intimidate (Canty et al., 2016).

Growth Mindset

Growth mindset, the belief that intelligence can be improved by effort and focussed learning (Dweck, 2006) continues to be a nucleus of research, with further evidence to suggest that one's outlook impacts on both effort and outcome (Komarraju and Nadler, 2013). Research into growth mindset is important to the education community but is also in danger of being misused if not anchored effectively into a broader understanding of the science of learning (Dweck, 2015). More recently, research based on an understand of growth mindset as disposition has been found to moderate the effects of poverty on academic achievement (Claro et al., 2016). However, as Dweck (2015) stresses, a growth mindset assists students, but they still need to focus on the learning process (Dweck, 2015).

Nurture and Belonging

> Interpersonal processes (nurture) are essential for physical processes (nature) to occur (Meyer et al., 2013, p. 165).

Research investigating nurture, belonging and brain development since 2011 has tended to consider efficacy of intervention as well as support processes and approaches within various underpinning academic frameworks. Britto and colleagues (2017) writing for the *Lancet* early childhood development series, stated that to be truly effective all early childhood interventions needed to be collaborations between the health, nutrition, education, child protection and social protection sectors as well as "anchored in nurturing care" (Britto et al., 2016, p. 91). Schofield and colleagues (2013) highlighted the need to focus on adult-adult as well as child-adult nurturing relationships to break intergenerational maltreatment cycles

(Schofield et al., 2013). This evidence acknowledges the need to foster solid partnerships between schools and families to provide for the best student outcomes.

Meyer and colleagues (2013) provided a concise summary of the impact of nurture on brain development. They note that, given appropriate nurture, nascent human emotional development follows a regular progression from simply distinguishing distress & contentment (present at birth) to the discrimination of pleasant and unpleasant experiences before the ability to identify individual emotions manifests. The amygdala (responsible for emotions, especially negative emotions, survival and memory, especially, emotional memory) begins to mature within the first few *months*, with septal (pleasure) areas taking the first few *years* of life to begin maturation. Neurotransmitters, responsible for communication between neurons, associated with focus, attention and memory continue to increase until about age three and then decrease to adult levels. It is at this stage, these authors contend, that children can begin independent self-monitoring and regulation of emotions (Meyer et al., 2013). However, if a nurturing environment in not present, this process is interrupted with negative impacts upon the networking of positivity. This evidence is important in the context of the current study because it identifies the developmental point at which emotional regulation and metacognition manifest—i.e. about three years of age. Therefore, it is reasonable to expect that any children entering preschool at age four and school at age five who lack basic self-monitoring and self-regulation should be given access to emotional-focused intervention programs as part of overall school readiness procedures.

Resilience is a construct often associated with nurture and wellbeing. However, as Pluess and Belsky (2013) pointed out, resilience deals with protective factors and processes that help some individuals deal with *adversity* better than others. These authors suggested that it is equally true that some individuals deal with *advantage* better than others due to personal learned patterns of behaviour, physiology and genetic features. Hence, they proposed the

construct of vantage sensitivity as a positive partner for resilience and proffer differential-susceptibility thinking as an overarching theory (Pluess and Belsky, 2013). This evidence is important in the context of the current study because it expands the overall view of emotional constructs that are important for individual well-being and cognition and helps to further delineate a variety of approaches that may be required by a range of learners.

Emotional Vocabulary

A broad emotional vocabulary supports positive development of emotional (Ornaghi and Grazzani, 2013) and behavioural (Clegg et al., 2015) function. Analysing data from The Avon Longitudinal Study of Parents and Children (formerly the Avon Longitudinal Study of Pregnancy and Childhood), Clegg and colleagues (2015) demonstrated that a child's expressive language level (ability to communicate to others) at age 2 years and receptive language level (ability to make sense of communication from others) at age 4 years were important contributing factors to emotional and behavioural function at 6 years (Clegg et al., 2015).

Both the amount of rich language experienced (i.e. being extensively talked with or to rather than just being in an environment of talking) in the early years of life and SES environment impact all vocabulary development, including emotional vocabulary (Fernald et al., 2013, Marulis and Neuman, 2013, Weisleder and Fernald, 2013). Acquiring new emotional vocabulary through social interaction has been shown to be influenced by the facial expression of the teacher with positive facial expressions encouraging better uptake (Clément et al., 2013). The knowledge the emotional climate created around emotional vocabulary learning affects student uptake is important for classroom teachers who wish to get the best outcome from their efforts.

Explicit training in emotional vocabulary development coupled with application training can translate to better independent functioning, as shown by San Juan and colleagues, for 3-4 year

old's on false belief tests—a component of strong Theory of Mind functioning (San Juan and Astington, 2017), and by Yoder and colleagues, for children with Down syndrome (Yoder et al., 2014). The use of directive self talk (Manfra et al., 2014) and the integration of social-emotional learning with literacy instruction (Daunic et al., 2013) have both been associated with better self-regulation skills. This evidence reinforces the importance of specifically targeting the development of self-regulation skills to produce the best possible learners.

Chapter 3 Methods

This study has been designed to systematically investigate questions and data that arose during the three-year development phase of the Being the Best Learner You Can Be (BBL) Program between 2009-2011. A randomised controlled trial (RCT) with mixed methods (both qualitative and quantitative measures) was used to evaluate the study questions. Specific units of analysis were identified as individual and group student change across the 20-week period of program intervention (i.e. two South Australian school terms). Change was measured pre and post intervention on seven outcome measures (see Table 10, p. 158). The primary measures for this study directly assessed attention (Conners' Continuous Performance Test) and working memory (Working Memory Battery, visuospatial subtest). Impulsivity was a central measurement parameter within the attention test. Additional data about student executive functioning was gathered from parent assessment using the Behavior Rating Inventory of Executive Function (BRIEF) and teacher assessment using the Student Behaviour Rating Scale (SBRS). Student attitudes towards learning and themselves as learners, which forms a backdrop to performance was measured using the Motivation and Engagement Scale (MES). Data about the physical input practices of sleep, physical activity and diet were collected using the ACES 7-day Sleep diary, the Physical Activity Questionnaire for Older Children and the Modified Child Nutrition Questionnaire respectively. SES was measured by school location with individual information provided via the Student Background Questionnaire (see Appendix 9). Specific data on behaviour practices regarding digital technology use was not generated as the scope of this project is already extensive. This represents a study limitation within the context of the literature review.

Section 2.2 examined field-based measurement practices and issues relating to key aspects of this research project available during preparation of the study design and ethics proposal in

2012 (i.e. executive function, sleep, physical activity, diet and socioeconomic status) in relation to child populations. Across each of these elements, accurate measurement in child population studies required specific developmental considerations when compared to studies with adults. However, a range of measurement tools have been designed to address these requirements which provided the outcome measures selected for this project.

3.1 DESIGN

3.1.1 Study Participants

To control for possible confounding variables, student participants were limited to a population of South Australian year 4 and 5 students (children between the ages of 9 and 11 years). Excepting those students with specific learning difficulties, study participants in this age range had the prerequisite academic, emotional and social skills to participate in the lessons and data collection regimes but were less likely to be facing the additional complications of puberty. Participating schools were drawn from the public sector to avoid homogenised school populations arising from parental choice or any private school's religious/social focus.

Recruitment was opened to schools within metropolitan Adelaide during the latter half of 2013. The recruitment processed ceased once the required number of participating Year 4/5 classes was achieved within the seven Categories of Disadvantage as defined by the Index of Educational Disadvantage Category rating system. This index is used by the South Australian Department of Education and Child Development (DECD). The index reflects SES to determine additional funding aimed at offsetting issues related to low income/high social disadvantage communities. Category 1 represents the most disadvantaged.

The recruitment process included a call for expressions of interest via the DECD electronic newsletter, entitled the Xtra. (see Appendix 4). The Xtra is a method of internal

communication for DECD employees and provides departmental information of processes and policies as well as notices concerning professional development or projects such as the current study. Information regarding the study was also circulated to educational sites by DECD regional support services personnel and by word of mouth between principals. (See Appendix 5 for program information and consent forms.) Recruitment was completed late in Term 4, 2013.

Final selection criteria included the class teacher's willingness to participate in lessons, support program delivery, and assist with assessment requirements. These requirements were detailed in the information sheets provided to schools and families (see Appendix 5). Signed consent forms were collected from all participating principals, teachers and student parents/carers. Only sites with no previous direct student exposure to the BBL Program were eligible for inclusion. While all students participated in class lessons, only students whose parents/carers had opted in (i.e. returned consent forms) participated in the testing regime.

3.1.2 Research Questions

At commencement, this study hypothesised that the BBL Program would produce better outcomes (in the defined areas of measurement) compared with usual teaching practice in Year 4/5 students across a range of schools representing the gamut of socioeconomic conditions. The defined areas of measure are identified and explained in Section 3.2 below. The specific research questions are re-stated here for the reader's convenience.

Primary Question

(Executive Function)

How and to what extent is the BBL Program more effective in increasing the specific executive functions of working memory, attention (both directed and sustained) and self-regulation (especially impulsivity) as compared to a control group receiving usual classes?

Secondary Questions:

(Motivation and Attitude)

1. How and to what extent does student attitude towards school and learning reflect executive function levels as measured by the test battery?

(Physical Aspects--Sleep)

2. How and to what extent does an individual student's sleep profile influence levels of executive function?

(Socioeconomic Status)

3. How and to what extent do student mindset (i.e. perception about his/herself as a learner) and teacher/parent views of student ability align with objective executive function performance, especially in relation to SES?
4. How and to what extent do study outcome measures relate to socioeconomic status (SES) as defined by a school's Index of Educational Disadvantage rating?
5. How and to what extent do outcome measures from the BBL Program intervention reflect levels of SES?

(Portability)

6. How and to what extent did the BBL Program demonstrate positive outcomes (i.e. feasibility in delivery and acceptability to teachers and/or students) for the study population?

3.1.3 Power Calculations

Continuous performance testing is a standard method of measuring an individual's abilities to sustain and direct attention and deal with impulsivity (Conners, 2014). Continuous performance testing has been a research tool for measuring executive functioning since its first reported use by Rosvold and colleagues in 1956 (Rosvold, 1956). (See p. 171 for information on the CPT). In this work, the Conners' Continuous Performance Test (CPT) was designated as the main study measure and was used to calculate the research power required

(i.e. to determine the required number of student participants for statistically valid results). Reaction Time (RT) was chosen as the basis of the study's power calculation as this was the central factor highlighted in Conners' and colleagues (2003) work to explore the validity of continuous performance testing in their normative study (Conners, 2003b). This measure was selected to determine effect size due to its strong statistical validity relative to other CPT performance indicators. In making the necessary power calculations, the following assumptions, based on the published literature, were applied:

- The required number of units (i.e. classes) for randomisation was determined to be 12 using an intra-cluster correlation coefficient for classroom based interventions = 0.03
- The effect size for Reaction Time (RT) comparing ADHD children with normal children in the normative study is 0.43 (Conners, 2003a)
- An assumed average classroom size of 25 (based on regulations for class sizes within South Australian schools where 25 is the ceiling for year 4/5 classes in the lowest SES schools)
- Therefore, the Design Effect (deff) = 1 + [(25 – 1) * 0.03] = 1.72
- A sample size of 86 in each group would deliver an 80% power to detect an effect size of 0.430 using a two-group interaction with a 0.05 two-sided significance level.
- Multiplying the deff (1.72) by minimum sample size (86) provides a figure of 147.92 or 148 students.

Therefore, the recruitment aim was 148 students per condition (i.e. intervention and control groups) making a target total of 296 student participants required by the power calculations. Based on an average class size of 25 students, 12 classes were recruited to allow for six in each program condition (i.e. control and intervention) spread across three broad categories of the socioeconomic spectrum.

3.1.4 Randomisation

Cluster randomisation to one of the two groups was conducted at the level of the school to avoid contamination across classrooms within a single educational site (Doyle and Hickey, 2013). The computer-generated randomisation schedule, *Sealed Envelope*, was applied by an independent allocator and stratified to ensure an even mix of socioeconomic status (SES) ratings in each group to eliminate researcher bias (Sealed Envelope Ltd, 2001). The intervention group received the BBL Program for 20 weeks while the control group experienced their usual programmed classroom activities for the same period.

3.1.5 Settings

The recruitment process provided twelve Year 4/5 classes (student age range 9-11 years) in ten separate sites, totally 294 students. As mentioned, schools were vetted to ensure an even spread across socioeconomic status levels as defined by the Index of Educational Disadvantage. These categories were grouped into low (categories 1-2), medium (categories 3-5) and high (categories 5-7) strata. Geographic location within the greater Adelaide metropolitan area was not a determining factor for selection. Participating schools and classes are shown on the following table.

Table 9 Study participants by school code, SES and Adelaide metropolitan location

School	Cat. of Disadvantage	Metro Location
BAN	Low (Levels 1-2), (**2 classes**)	inner northern
GP	Low (Levels 1-2)	inner northeast
HAM	Low (Levels 1-2)	inner northern
BUR	Medium (Levels 3 ,4 & 5)	northern
ET	Medium (Levels 3 ,4 & 5)	eastern
HILL	Medium (Levels 3 ,4 & 5)	inner northeast
SD	Medium (Levels 3 ,4 & 5)	northern
CRA	High (Levels 6-7), (**2 classes**)	southern
HG	High (Levels 6-7)	eastern
STR	High (Levels 6-7)	eastern

3.1.6 Oversubscription

Recruitment ceased once a total of twelve eligible class groups across the three categories of disadvantage was achieved. Three additional school sites and two class groups in already participating schools were declined on a first come-first selected basis.

3.1.7 Pilot Phase, 2013

Prior to full implementation, key aspects of the study were trialled in a single Year 4/5 classroom at a primary school in eastern Adelaide during Terms 3 and 4, 2013. This school was chosen for two reasons. First, its principal had previously led one of the four schools where the BBL Program was developed and, thus was willing to support this study. Second, the school's large student population provided several eligible classes from which to select willing teacher(s).

This researcher delivered an hour-long session to staff at a weekly staff meeting to explain the BBL Program, its underpinning research and the pilot phase requirements. Teachers of Year 4/5 students were asked to express interest in participating in the pilot. Copies of information and consent forms were provided which included contact details for this researcher and her supervisors should any further questions arise (see Appendix 5). As there were three interested teachers, selection of the pilot class was left to the school's principal. This was done to best accommodate school timetables, BBL Program study space requirements and teacher capacity—factors best judged from the principal's perspective. Neither the pilot school nor subsequent data from this site were included in the 2014 project.

3.1.8 Data Collection (Main Study)

There were two major data collection points: prior to and following the program intervention period during the 2nd and 3rd South Australian school terms (28th April – 26th September, 2014). Data were collected at both points for the Behaviour Rating Inventory of Executive Function, Motivation and Engagement Scale, and Student Behaviour Rating Scale.

Sleep data were gathered from students in the active group only at the commencement of the BBL Sleep Unit in Week 11 of the intervention. It should be noted that the most ideal research design would have allowed for sleep data to be collected from the entire cohort. This was not done here as the investigation of sleep was part of the intervention content, and provided only a secondary data set. Additionally, in line with concerns from the university Ethics Committee, it was decided to contain the amount of required baseline and post-intervention data classroom teachers were expected to collect.

Students received the ACES 7-day Sleep Diary in Week 9 and the ACES sleep knowledge questionnaire in Week 10 of the intervention program (see Appendix 6), prior to the start of the BBL Sleep Unit. The sleep knowledge questionnaire was administered again in Week 15 of the intervention following the final sleep session in Week 14. (See Table 11, p. 162). Data from the sleep knowledge questionnaire was used to gauge student learning during the unit, rather than for statistical analysis in this project. Reference to this data set is included here to provide a complete overview of all information collected.

Table 10 Summary of all outcome measurements

Measure	**Data Type**	**Analysis**	**Test Dates**
Conners' Continuous Performance Test II (CPT-II) (student response)	Ratio	Pre/post	
Memory measures Pyschophysics Toolbox Working Memory Test Battery (WMTB) (student response)	Ratio	Pre/post	
Behaviour Rating Inventory of Executive Function (BRIEF) (parent response)	Ratio	Pre/post	
Social Emotional Wellbeing Survey (SEW) [ACER] (student response) *2013 Pilot only*	Ratio	Pre/post	
Motivation and Engagement Scale (MES) (student response) *Replacement for the SEW in 2014*	Ratio	Pre/post	
Student Behaviours Rating Scale (SBRS)[ACER] (teacher response)	Ratio	Pre/post	
ACES 7-day Sleep Diary (student response-part of course)	Ratio	Commencement of BBL Sleep Unit	
ACES pre/post sleep knowledge test (student response-intervention group only & part of Program)	Ratio	Pre/post BBL Sleep Unit, weeks 9 and 15	
Interviews and Student Focus Groups (randomly selected teacher & student response)	Categorical	Post	

Data on physical activity using the Physical Activity Questionnaire for Children (PAC-Q) (see Appendix 7), and diet using the Modified Child Nutrition Questionnaire (see Appendix 8) were collected at baseline only. Questionnaires were administered in class in whole group sessions.

Parents received a student background questionnaire (see Appendix 9) at the first collection point along with the BRIEF. Where the first BRIEF was returned without the student background questionnaire, another background questionnaire was included at the second data

collection point as this information was not time sensitive. Data was lost to the study where the student background questionnaire was not returned after this second attempt.

Administration of the individual computer-based tests for attention (the CPT) and working memory (WMTB) required both adult supervision and a quiet room somewhere within the school, preferably within easy reach of the participating classrooms. Computerised testing was done on an individual basis. Due to cost and licencing restrictions, there were two laptops containing the continuous performance test for attention and only one able to assess visual-spatial working memory. Consequently, data collection was undertaken by a roster of eight adult volunteers who already possessed mandatory South Australian Department of Education and Child Development (DECD) clearances and were, therefore, allowed to be on school sites in direct contact with students. Volunteers included two education department teachers and two education department teaching assistants as well as two third year psychology students and one post-graduate psychology student undertaking a teaching degree from UniSA and one honours psychology student from Central Queensland University (Adelaide campus). Students were involved in the pre testing phase and DECD employees in the post phase. This arrangement was driven by the university calendar and changes in to student availability.

Training in test administration was delivered by this researcher to all volunteers, along with detailed written instructions, that accompanied each laptop, regarding log in information and testing regime requirements. Training sessions were 45-minute sessions during which the researcher explained the testing process and demonstrated the computer tests. Volunteers were asked to take each test as though they were student participants and to note the researcher's language and procedure. Volunteers were asked to follow the general script provided as part of the written instructions. The researcher stressed that no assistance should be given to students once the testing commenced, even if they appeared to be off-task.

However, if a session ended in a non-result, the student could be asked once to re-sit the test if they had seemed confused by the process. Additionally, the researcher accompanied each volunteer on their first session to ensure the agreed process was used. Assessment rosters were prepared and continually updated by the researcher to ensure that all students in the study were tested.

Pre and post measurements were conducted using the questionnaires/tools outlined below (see Table 10, p. 158) and, administered by persons blinded to group allocation. Most data collection occurred during the school week immediately prior to, and after, the intervention period. Due to various factors, (i.e. the individual licencing nature of the computer-based tests, limited laptops containing these tests, individual administration requirements, restrictions to timeslots for testing in each school site, and available supervisory personnel) computerised testing required more than one week to assess all students during both pre- and post-testing. While this was unavoidable, given the resources and conditions, spreading the computerised testing period over three weeks pre and post intervention meant that testing conditions were more open to variation for students tested at different distances from school holidays and from the end of the intervention regime. Possible implications of this will be discussed in Section 5.1.2.

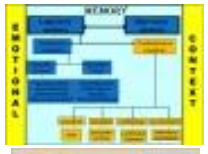
3.1.9 Program Delivery, 2014

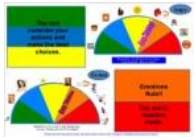
Program implementation took place over two consecutive school terms – between April and September, 2014. To ensure that data collection in 2014 would be as streamlined as possible, selections of the BBL Program 20-week intervention, including the battery of research measures, were pilot tested at one school site during Terms 3 and 4, 2013 (see Section 3.1.7). As a result, two outcome measures were altered (see Section 3.2.2).

In 2014, the 20-week program was delivered weekly in 45-minute lessons to each of the six classes in the intervention condition. All sessions occurred on either Monday or Friday due to the presenter's work commitments. Geographic distance between participating schools meant that three classes were delivered on Mondays, with the other three on Fridays. Although delivered on different days of the week, the presenter took great care to ensure that each class received the same lessons (i.e. structure, materials and activities) albeit not necessarily in the same order, using the program outline below (See Table 11, p. 162).

Once the 20-week program and post data collection were completed in Term 4, 2014, five of the six classes in the control group received four to six lessons each as a way of thanking them for their participation.

Table 11 Overview of 20-week BBL intervention program

1	2	3	4	5	6	7	8	9	10
What is 'being the best learner'? Key principles Tests & training & terms Self-review form  	Your Brain What helps. What hurts. **Executive Functions** Neurons Connect Game  Your Patterns- Your Plan	**Memory** Training & Strategies Memory Bottleneck Roman Room, short term memory checker, Making Connections, Moving Memory, Cognitive Fun Website  	**Memory, Emotions, & Attitude**  Under Pressure Game  Developing vs Fixed intelligence (Growth Mindset) Emotion Poem	**Attention** - caught/trained Visual/ auditory Bop It, Robot Robot, Multitasking; Two Teacher Talk  	**Action/ Reaction/ Distraction** Distraction Chart Distraction Game Sheep Dash Cognitive Fun Website Lumosity	**Perception**  Senses vs our view Optical Illusions How the brain knows what it is seeing Where you focus determines what you perceive & learn – blind spots/ binocular vision	**Emotional Literacy** – Vocab Emotional Intensity  Emotion Robot; Resist the Bubble; Emotion Meters	**Emotional Literacy** Learning Self-Regulation   7-day sleep diary data collection begins	**HOTS – Tools for the Brain**  Problem solving What's the Same Game; Groups Game, wooden puzzles Sleep knowledge test given

11	12	13	14	15	16	17	18	19	20
Sleep Unit – ACES Program Part 1	**Sleep Unit** – ACES Program Part 2 Your Patterns-Your Plan	**Sleep Unit** – ACES Program Part 3	**Sleep** – BBC page, Neuroscience for Kids page, recap 	**Perception**  Unifix cubes & 30 Sec. Draw, What am I drawing? Broaden & Build Theory Sleep knowledge test given	**Emotional Literacy** - Delayed Gratification Marshmallow Test w/ video  	**Emotional Literacy** – Mindfulness Exercise   Handout	**Brain & Body** Building body maps  Brain Balance Game Importance of nutrition & movement/ exercise	**HOTS** Different types of thinking-auditory, visual, word and problem solving—deductive and inductive 	**Bringing it all together**  

- **Program assumes 45 minute lessons**
- **What I need to know**: for marshmallow test—anyone who is Islamic (they can't have marshmallows): for mindfulness exercise—anyone with a chocolate allergy.
- **Follow up websites will be provided at the end of each lesson.**
- **Students will be expected to complete their weekly practice schedule of the individual tasks agreed in Session 2- 'Your Patterns-Your Plan' based on the results of the Self-Review form**
- **Does the classroom have an interactive Smartboard?**

3.2 Outcome Measures: A Mixed Methods Approach

This study employed an embedded mixed methods design based on the six key elements for mixed methods research expounded first by Julia Brannen as early as 1989 and most recently and more clearly by Alan Bryman in his 2014 paper, *June 1989 and beyond: Julia Brannen's contribution to mixed methods research*. Summarising this research paradigm, Bryman posits that high quality mixed methods research must consider the need for:

1. a rationale for the use of a mixed methods approach
2. researchers to be explicit about the nature of the mixed methodology regarding epistemological location
3. all data collection approaches to be linked to research questions
4. research to be implemented in a technically competent manner
5. transparency regarding the relationship of the quantitative and qualitative data sets
6. integration of qualitative and quantitative data sets (Bryman, 2014)

The first of these points will be discussed immediately below. The remaining points will be considered within Section 3.2.3 Qualitative Measurement.

3.2.1 Mixed Methods Rationale (Bryman, Point 1)—Performance and Perception

The BBL Program can be characterised as a phenomenon placed under the (ecologically valid) microscope of academic enquiry within its natural setting—a classroom within a primary school site (McVay et al., 2009). While the main study construct was a randomised controlled trial of program implementation and effectiveness, school classrooms are far removed from well controlled laboratory settings. There are, simultaneously, many factors at play in the school-based educational process. Factors pertinent to this study will now be highlighted.

Factors Impacting Classroom-based Research

Constructing cross-classroom comparisons in classroom-based research (i.e. research that considers changes to student outcomes, including learning and behaviour, through the application of environmental variables such as teacher behaviours, physical layout, targeted interventions, and/or instructional strategies (Conroy et al., 2008)) is subject to variations between individual students, class cohorts, and class teachers (Conroy et al., 2008). For example, in this work there were differences in class cohorts in relation to SES that were built into the study design. Additionally, the teachers in this study had varying levels of classroom experience ranging from in their first five years of teaching to close to retirement. As well as, while most teachers were employed permanently in their positions, three were on one-year contracts and new in their school environments (see Table 12).

Table 12 Participating teachers by site, gender, stage of career and permanency

Site	Gender	Stage of Career	Permanency
BAN1	M	mid	permanent
BAN2	F	mid	permanent
BUR	F	late	permanent
CRA1	1 female, 1 male	mid	contract/permanent
CRA2	M	mid	permanent
EF	F	early	contract
GP	F	late	permanent
HAM	1 female, 1 male	late/mid	permanent
HG	M	mid	permanent
HILL	F	early	contract
SD	F	mid	permanent
STR	M	mid	permanent

In terms of curriculum variation, schools and classes generally have an extensive variety of other academic and social programs simultaneously in use. For example, two schools in this study were using the Australian behaviour management program, *Play is the Way*. Others were using an Australian social skills program called *What's the Buzz?*. Typically, these programs are selected to create student change across a school and were not discontinued with the introduction of another intervention such as the BBL Program. This is an unavoidable factor that complicates classroom-based research and this study. More broadly, school communities and individual classrooms are affected by their social construction, including leadership style, size, social complexity (e.g. as measured by SES factors or bullying behaviours) (Gottfredson and DiPietro, 2011).

The focal points of measured change in this study were key aspects of student executive functions, especially attention and working memory. While measurable, these capacities are not static or fixed in individuals. Rather, they vary, sometimes considerably, depending upon the degree of novelty, personal perception, emotional content, interest, and many other psychological and physical elements present at any given time. Furthermore, the separate measurement of attention, working memory and disposition is problematic in that experts vary in the exact definition of each term and in the relationship between attention and working memory (Diamond, 2013, Piquero et al., 2016). Finally, there is a distinction between the level of overall individual skill, and that demonstrated in an individual performance as performance is also prey to physiological and psychological factors such as illness, fatigue and elevated emotions, including embarrassment or fear of failure. The emotional relationship of the student to others in the school setting is an additional factor (Hargreaves, 2000). When as student is having a bad day on testing day, this will impact the data also. However, employing statistical procedures, such as calculated power requirements, are in place for precisely this reason (Boyce, 2011, Gottfredson and DiPietro, 2011).

Bearing these inherent limitations in mind, outcome measures were selected for this research based on an expected ability to highlight change to attention, working memory and personal engagement over the period of two South Australian school terms (22 weeks with a two-week holiday break in the middle). Data collection tools were selected to capture changes in individual executive functioning and personal practice (e.g. changes to sleep patterns and skills practice regimes). These tools and their selection criteria are discussed in detail in Section 3.2.2 for quantitative measures and Section 3.2.3 for qualitative measures.

A Need for Additional Qualitative Data

A central aim of the BBL Program is to foster each student's positive attitudes towards testing, practising and reviewing their personal development. Hence, some qualitative data were required to examine individual perceptions of change that, firstly, may or may not be reflected in the snapshot of computer-based testing or specifically focussed standardised questionnaires (Creswell, 2013) and/or, secondly, may or may not be part of the researcher's current understanding due to unconscious bias or lack of awareness (Dolan and Peasgood, 2008, Markson et al., 2008, Park et al., 2014). Further, the author sought to capture the nature of experiencing the BBL Program itself – what aspects were valued, what were not and to increase understanding of the feasibility and acceptability of the program. As was demonstrated by Durlak and Du Pre (2008), the two characteristics of adaptability (i.e. flexibility of implementation) and compatibility (i.e. degree of match or contextual congruence) an innovation has with the environment in which is deployed directly affect its success (Durlak and DuPre, 2008).

3.2.2 Quantitative Measurements

The quantitative measures (Table 10, p. 158) for this project fall into three broad categories. These are:

- Measures of individual *executive function* at baseline and at completion, using the computer-based CPT and working memory tests and parent/teacher reports
- Measures of *motivation and engagement* at baseline and completion using self-reports and parent/teacher reports
- Measures of *sleep* patterns at sleep unit baseline (Intervention Group only)

Quantitative Planned Analysis

Data were analysed in the Statistical Package for Social Sciences (SPSS) using a three-factor mixed model with repeated measures and analysis of variance. The data set was scrutinised for normality of data and distribution, including sphericity, with outliers removed prior to analysis.

The selection of measures has been constructed to respond to all research questions as explained in Table 13 following.

Table 13 Summary of Measurements in relation to research question and rationale for use

Measure	Research Question	Rationale for Use
Continuous Performance Test (CPT)	Primary question and secondary questions 2, 3, 4, 5	As the main outcome measure in this study, the CPT was selected to collect data on individual student performance change between baseline and post intervention testing for aspects of attention, including impulsivity inhibition. These skills are central to executive functioning.
Working Memory Test Battery, spatial subtest	Primary question and secondary questions 2, 3, 4, 5	Working memory is a core executive function which this test sought to measure. Data was collected at baseline and post intervention to gauge changes to individual student performance.
Behavior Rating Inventory of Executive Function (BRIEF)	Primary question and secondary questions 3, 5	The BRIEF was given to all parents with children in the study at baseline and post intervention. It was expected that this data would be able to corroborate student performance on the objective computer-based tests—the CPT and Working Memory subtest.
Motivation and Engagement Scale (MES)	Secondary questions 1, 2, 3	The MES was given to all students at baseline and post intervention. The purpose of MES data was to link student emotional context to their performance on tests for attention and working memory. Emotional context has been demonstrated as an impacting factor on performance.
School Behaviour Rating Scale (SBRS)	Primary question and secondary questions 3, 5	The SBRS was given to all teachers in the study for each participating student. The purpose of this tool was to collect data on a student's general functioning within the school environment to gauge links between performance on the computer-based tests for executive functioning and overall conduct within the school setting.
7-day Sleep Diary and Sleep Knowledge Test	Secondary questions 2, 5	Data from the 7-day sleep diary and sleep knowledge test provided information on student sleep hygiene, quality, quantity and overall patterns which informed the BBL unit on sleep as part of the intervention. Analysis of sleep data provided background on the sleep aspect of physical inputs which have been shown to affect executive function and academic performance. This data was compared to student outcomes on the computer-based tests.
Physical Activity Questionnaire for Older Children (PAC-Q)	Secondary question 5	Information on student patterns of physical activity provided background on this aspect of physical inputs which have been shown to affect executive function and academic performance. This data was compared to student outcomes on the computer-based tests.
Modified Child Nutrition Questionnaire (MCNQ)	Secondary question 5	Information on student diet provided background on this aspect of physical inputs which have been shown to affect executive function and academic performance. This data was compared to student outcomes on the computer-based tests.

Executive Function Measures

In 2009, the definition of executive function developed by Dawson and Guare (2004) provided the foundation for the BBL Program (Dawson and Guare, 2004). This decision was made by the researcher based on both the definition's face validity and general transferability into a primary school setting. The current research design was selected to match key elements of the BBL Program design and, therefore, includes both a test of working memory (working Memory Battery spatial short-term memory test) (Lewandowsky et al., 2010)and distinct testing of attention with an emphasis on inhibition of impulsivity (Connors' Continuous Performance Test or CPT) (Conners, 2003b).

During test selection, consideration was given to the finding by Hughes and Graham (2002) that manual executive function tasks may deliver more sensitive outcomes in relation to impairment in executive control. Findings by Clariana and Wallace (2002) that students with higher attainment levels tend to benefit most from computer-based assessment were also contemplated (Clariana and Wallace, 2002). However, the use of computer-based assessments was chosen for the following reasons:

- Manual testing required higher levels of administration resourcing which were not readily available
- The geographic spread of the test sites made it impossible for only one or two test administrators to complete all requirements—with manual testing, the more test administrators, the higher the risk of variation to testing conditions
- Therefore, computer-based testing delivered the most standardised test conditions
- In school settings, people were more likely to recognise and, therefore, less inclined to interrupt, computer-based testing than face-to-face testing while in progress.

It is also acknowledged by the research community that a true test of executive function skill(s) must contain a degree of novelty (Anderson, 2002, Diamond, 2013) for *every*

individual. In a regular classroom, it is never possible to guarantee the novelty level for every task, for every student. However, achieving novelty was one deciding factor in the selection of computer-based tests as main outcome measures. Both the CPT and Working Memory Battery subtest are norm-referenced tests (Russell et al., 2003) which specifically created to maintain novelty of presentation and make interactive adjustments to level of challenge. Neither of these characteristics could be as effectively achieved through standardised paper-based or presenter-based tests for all students in any one classroom (Russell et al., 2003).

Primary Measure: Conners' Continuous Performance Test II (CPT-II)

NOTE: Variations in spelling of Conners'/Connors'/Conner's/Connor's occur throughout the literature. The Psychcorp-Pearson Education online catalogue lists the test as ***'Conners' Continuous Performance Test II (CPT II)'*** *hence, this will be the terminology used here.*

Table 14 Overview of CPT testing

Test Focus	Responding Group	Administration	Conditions
Student attentional control, impulsivity, and working memory	Students in both intervention and control groups	At baseline and post intervention	Individually via computer, at school but outside the classroom

A continuous performance test is a standard method of measuring an individual's abilities to sustain and direct attention and deal with impulsivity (Conners, 2014). This type of testing has been used in relation to executive function, especially in relation to disability, for several decades. The first reported version of a continuous process test was by Rosvold and colleagues in 1956 (Rosvold, 1956). The CPT II (and the updated CPT III) is one of four main standardised continuous performance tests used across a range of child and adult populations. As the test is able to measure attention, impulsivity and activity control, it is often but not exclusively used with Attention-Deficit Hyperactivity Disorder (ADHD) diagnoses (Conners, 2003b). The CPT II is also considered useful in detecting and/or measuring additional executive functions including working memory, internal ordering, time perception, and motor control. It has reported reliability ratings of 0.95 for omission errors

and 0.94 for errors of commission (Reddy et al., 2010) citing (Connors & MHS Staff, p. 483). Authors of the test report that test validity falls within an acceptable statistical level, i.e. that it is *good*. (Reddy et al., 2010) citing (Connors & MHS Staff, p. 483).

Administration

The CPT-II is a computer-based tool that can be used across multiple sites and takes 14 minutes per individual to complete (Psychcorp - Pearson Education, 2011). (Note: during testing in school settings, this time was increased to approximately 20 minutes per individual due to test explanation time and the computer logging on/off process for each student.) Between the selection of the CPT II, ethics approval and funding to secure a second version of the Continuous Performance Test, marketing companies in Australia discontinued sale of the CPTII in favour of the updated CPTIII. Although the tests were billed to be unchanged except for software support improvements (Conners, 2014), when the CPTIII arrived, some major differences were discovered. The CPTII presents white letters on a black background as attentional targets, while the CPTIII has reversed the colouring and altered the font. In addition, the length of practice time prior to the test is reduced in the latter version. To counteract this inconsistency, care was taken to ensure that each student used the same version of the continuous performance test in both the pre and post testing sessions. As the point of this measure was to track any change at an individual level, it was reasoned that the data would still provide the required information without bias or compromise.

Scoring

Both versions of the Continuous Performance Test internally convert the raw scores into T scores when asked to report a test outcome and compare two or more tests for progress. Information is provided on measures of inattention (CPPT item errors of commission and omission), impulsivity (CPT item variability), sustained attention (CPT item HSE ISI) and vigilance (CPT item HRT ISI). Data are also available on response style (conservative-emphasis on accuracy over speed, balanced or liberal-emphasis on speed over accuracy),

detectability, error type (omissions, commissions, perseverations), and reaction time (slow, average, or fast). As the main measure of this research, data were analysed for change and compared across each of these factors in relation to individuals, active versus control status and socioeconomic elements.

Secondary Measures:

Working Memory Test Battery

Table 15 Overview of Working Memory Battery subtest use

Test Focus	Responding Group	Administration	Conditions
Student visuospatial working memory	Students in both intervention and control groups	At baseline and post intervention	Individually via computer, at school but outside the classroom

Working memory is a core executive function that underlies cognitive flexibility and other higher order executive functions (Diamond, 2013). The Working Memory Test Battery (WMTB) is a computer-based assessment using the Psychophysics Toolbox software and a MATLAB based operating system (Lewandowsky et al., 2010). The battery assesses working memory through four subtests: memory updating, sentence span, operation span and spatial short-term memory and focused on both verbal (subtests for memory updating, sentence span and operation span) and spatial content domains (subtest for spatial short-term memory) and the functional considerations of storage and retrieval in all subtests (Lewandowsky et al., 2010).

Independently, the four Working Memory Test Battery subtests each had good validation statistics for child populations (Lewandowsky et al., 2010). This means that the visuospatial subtest of the Working Memory Test Battery has been reliably adapted for children within the age range of this study and can be independently administered with valid results (Lewandowsky et al., 2010). Further, working memory is a core executive function and the measure of this function is important in determining the effects of the BBL Program.

Testing Alterations Resulting from 2013 Pilot

The 2013 pilot process demonstrated that the full battery of tests in the Working Memory Test Battery was not viable for two reasons. Firstly, the time required for an individual student to undergo the entire test was prohibitive, averaging 45 minutes per student. Secondly, the underpinning literacy and numeracy fluency required for three subtests (memory updating, sentence span, and operation span) significantly disadvantaged students with English as a second language and those with specific learning difficulties (see Table 16). As Table 16 demonstrates, most students in these two categories are found in the low SES group. The fourth subtest, the spatial short-term memory test, was retained for the study as it is a visual-spatial test which does not require reading or mathematical fluency for successful test completion. This means that test results come closer to measuring working memory capacity only without being complicated by reading or mathematical proficiency. Collecting reliable data regarding changes to working memory was an important aspect of this study.

Table 16 Percentage of population with English as a second language and with identified disability

SES Level	Number of Respondents	English as Second Language	Students with Identified Disability
Low	35	48%	11%
Middle	91	17%	14%
High	100	10%	5%
TOTAL	226	19%	9%

Administration

The Working Memory subtest was administered in the same way as the CPT. Students were individually tested using the laptop containing the test, within their school sites but outside of their classrooms. In the baseline test situation, the time and day of testing was recorded. Post intervention testing schedules were designed to repeat the same time and day conditions

when each individual was tested at baseline. The amount of time required to complete this test was dependent upon a student's success rate. The test would terminate after the student had four unsuccessful attempts at the highest level of difficulty reached.

Scoring

In the 2014 full study condition, only the spatial memory test was used. As mentioned, the test design allows for a subtest to be administered separately or as part of the full battery and still collect data on working memory storage and retrieval (Lewandowsky et al., 2010). Subtest results are generated by the computer program and provided as a single cumulative score of correct responses. Pre and post test results were compared for significant changes at the level of individual, intervention condition, and SES.

Behaviour Rating Inventory of Executive Function (BRIEF)

Table 17 Overview of BRIEF use

Test Focus	Responding Group	Administration	Conditions
Student executive function proficiency	Parents/caregivers	At baseline and post intervention	Individually via paper-based questionnaire, sent home and returned to school

The BRIEF looks at behaviour regulation and metacognition (thinking about thinking, feeling and behaviour) separately and, also as an aggregate by providing a Global Executive Composite score (Gioia et al., 2000a, Gioia et al., 2000b). This test was selected over other instruments, such as the Connors Parent Rating Scale, largely as it was constructed around the dynamics of executive function development as opposed to detecting developmental difficulties. In addition, it uses language which primes the rater's attention towards executive functioning rather than problems of behaviour.

The BRIEF inventory was normed on a general population of students between the ages of 5 and 18 years who were screened for use of performance enhancing medication such as Ritalin and for any identified special education needs (Gioia et al., 2000a, Gioia et al., 2002). The BRIEF reliability statistics are sound, with an internal consistency ranging from .80±.98 for

parent and teacher forms and clinical and normative samples as determined using the Cronbach Alpha coefficient measure. Repeated use of the BRIEF is supported by test-retest T score differences that demonstrate a T score stability over a 2 to 3 week period (Gioia et al., 2000c). T scores vary for the specific item. However, all are within the statistically acceptable range. During the norming process the BRIEF was analysed for statistical anomalies due to different raters (e.g. mothers, fathers, grandparents, carers) and for the effects of SES using educational background as a socioeconomic indicator, important features for this study. In each instance, the test reliability was not compromised by different raters or SES (Gioia et al., 2000a) p 44).

Administration

The BRIEF is a paper-based checklist consisting of 86 items (Gioia et al., 2000a). Respondents must rate each item on a three-point scale (Never, Sometimes, Often). Prior to and at the completion of the 20 week BBL Program intervention, parents/carers were asked to complete the BRIEF and return it to the class for collection.

Scoring

The 86 items are grouped into the subcategories indicated in Table 18, below. Answers of Never score 1 point. Sometimes equals 2 points, and Often receives 3 points. Although an odd number of options in a Likert scale will tend to bias responses toward the middle option (Kulas and Stachowski, 2009), asking parents about behaviour from their children usually elicits a very personal and strong response. Having strong opinions tends to negate a tendency to select the middle option (Kulas and Stachowski, 2009).

Raw scores derived from each BRIEF subgroup were converted into T scores using the age and gender tables provided in the test manual. In addition, subgroups combined to provide raw scores for behavioural regulation (BRI) and metacognition (MI) which also convert to T scores.

Table 18 Construction of BRI, MI and GEC scores for the BRIEF

Behavioural Regulation (BRI)	Inhibition Shift Emotional control	Scoring T scores above 60 on any item place the response in the range for clinical concern.
Metacognition (MI)	Initiation Working memory Planning/organisation Organisation of materials Monitoring	
Global Executive Composite (GEC)	BRI + MI scores (Gioia et al., 2000a)	

A global executive composite score (GEC) is derived by totalling the raw BRI and MI. Raw scores from these combinations were again converted into T scores using the age and gender tables in the manual. T scores above 60 are considered indications for clinical concern. In the current work, the focus is on overall profile patterns and any significant change in profile in relation to the research questions, rather than on clinical diagnosis.

NOTE: In keeping with good professional practice, classroom teachers were informed when students returned scores indicating clinical concern. The researcher took care to stress that performance on one test conducted under research rather than clinical conditions is not grounds for a diagnosis. However, the school might wish to consider further investigation or professional referral.

Motivation and Attitudinal Measures

Social Emotional Wellbeing Survey (SEW)

(Pilot Phase Only)

Table 19 Overview of MES use

Test Focus	Responding Group	Administration	Conditions
Student social and emotional context	Students in both intervention and control groups	At baseline and post intervention	Individually via paper-based questionnaire, administered to the class group within the classroom

The Social Emotional Wellbeing Survey (SEW) is scored by Australian Council for Educational Research (ACER). This is an Australian tested and normed measure used to gauge student social and emotional growth. The test takes approximately 30 minutes to complete. Students respond to a variety of questions using a four point Likert scale. Pertinent to the timeline of this study, the test may be administered bi-annually (equivalent to two school terms or 20-weeks instruction time) to show development over time. In addition, the test is flexible enough to be administered to specific year levels from preschool to Year 12 (Australian Council for Educational Research, 2012). Information provided from this test includes attitudes towards school, school work, and personal ability. ACER reports that the Social Emotional Wellbeing Survey (SEW) was subject to a rigorous methodological analysis using the Rasch measurement analysis and multi-level modelling which resulted in a Cronbach alpha reliability outcome of $\alpha = 0.9$ (Australian Council for Educational Research, 2012).

In 2013, the test regime pilot revealed three serious complications with the Social Emotional Wellbeing Survey (SEW). Firstly, the requirement of approximate equal numbers of boys and girls in each class, with a minimum of ten per gender proved problematic. While gender is considered in class design, many schools do not contain a balance of males to females in all year levels. The pilot class, for example, had ten females and 19 males which meant that the group barely met test validity criteria. The validity of the test data was further undermined when one of the female students unexpectedly moved interstate two months into the trial. Secondly, the design of the SEW required data analysis by the supplier, ACER. At the outset of the project, the researcher was told that all data from the project could be analysed for a single cost (private email correspondence). However, when data was analysed for the pilot study, it became clear that ACER would calculate for each school analysis rather than for the overall project. Thus, cost became a prohibitive factor. Finally, the data analysis provided

addressed the data at a class level, rather than a student level with the raw data rendered inaccessible to this researcher. As the study design needed to have individual student outcomes for the analysis design, the SEW was replaced with the Motivation and Engagement Scale for the full 2014 study due to cost, ownership of data, ability to manipulate and interrogate data, and uncertainty about meeting class gender constraints.

The Motivation and Engagement Scale (MES)

(Full Study Phase Only)

Test Focus	**Responding Group**	**Administration**	**Conditions**
Student social and emotional context	Students in both intervention and control groups	At baseline and post intervention	Individually via paper-based questionnaire, administered to the class group within the classroom

The Motivation and Engagement Scale (MES) is a student self-report questionnaire normed in Australia. It is designed to measure six motivation and engagement boosters (three cognitive and three behavioural dimensions) and five maladaptive behavioural dimensions (Martin, 2012, p. 17). These are discussed in detail under *Scoring* below.

The test manual acknowledges the principles that underpin the BBL Program, including individual difference, malleability of attitude/behaviour depending upon metacognition and the importance of focussed self-improvement based on altered patterns of thinking/behaving. The test assesses aspects of higher order executive function (e.g. planning, task management) and underlying attitudes that represent perceptual/learning biases (e.g. self-belief, learning focus, and valuing)—a key consideration for its selection. Finally, the MES examines emotional context (e.g. anxiety and uncertainty control). As questionnaire items are generically named (i.e. self-belief, persistence, learning focus, valuing, task management, planning, disengagement, self-sabotage, uncertain control, failure avoidance, and anxiety) item names will be italicised for clarity when discussed in subsequent chapters.

Psychometric properties for the MES were assessed using a confirmatory factor analysis (CFA) and examined for variance across the eleven motivational factors and 44 questions within the test. Independent variables such as age and gender were also examined. The test's author reports at length on these analyses in the test's User Guide (Martin, 2012). In all aspects of the analysis, the CFA provided an "excellent fit" taking into account the factor loadings and other statistical requirements outlined (Martin, 2012, p. 42). Thus, the MES can be considered to have good external validity with the targeted child population of this study (Martin, 2012, Martin, 2009).

Administration

Students are asked to respond to 44 questions using a 5-point Likert scale where 1 denotes strongly disagree and 5 is strongly agree. The MES can be administered individually or as a class task. Students may seek clarification for questions provided no assistance is given in response selection. In this study, students received the questionnaire from their respective teachers as a class-based task. Administration time was dependent upon the literacy and self-reflection skills of each student.

Scoring

Student responses are manually scored under the major headings of Boosters, Mufflers & Guzzlers, and Global Motivation Quotients (MQs). Boosters or adaptive responses include items of self-belief, persistence, learning focus, valuing, task management, and planning while Mufflers & Guzzlers or maladaptive responses are defined as disengagement, self-sabotage, uncertain control, failure avoidance and anxiety.

Raw scores for each of the eleven Boosters and Mufflers/Guzzlers are derived from totalling responses to the item's respective four questions and using one of two methods described in the User Manual (Martin, 2012) p 15). In this study, Method 2 was undertaken whereby, the

four-item total was multiplied by 5 and translated into a motivation quotient using the tables provided.

Adaptive scores for thought (self-belief, learning focus and valuing of education) are added together to produce a motivation quotient (MQ). Adaptive behaviours are measured by compiling scores for persistence, task management and planning. In the same way, MQs are derived for mufflers (anxiety, failure and uncertainty) and guzzlers (disengagement and self-sabotage), as illustrated in Table 20. The best outcome is reflected by high adaptive and low maladaptive scores, with possible scores ranging between 4 and 20.

Table 20 Construction of global scores (Martin, 2012)

Item	Derivation of Score
Global Booster Thoughts	Average of self-belief, learning focus and valuing motivational quotients (MQs)
Global Booster Behaviours	Average of persistence, task management and planning MQs
Global Muffler	Average of uncertainty control, failure avoidance and anxiety MQs
Global Guzzler	Average of disengagement and self-sabotage MQs

School Behaviours Rating Scale (SBRS)

Table 21 Overview of SBRS use

Test Focus	Responding Group	Administration	Conditions
Student social and emotional proficiency	Classroom teachers	At baseline and post intervention	Individually via paper-based questionnaire given to teachers at their school

The School Behaviours Rating Scale (SBRS) measures observable school behaviour in primary aged students. It provides a tool for teachers and psychologists to assess behaviour and determine targets for intervention. The Scale measures strengths and needs, is easy to administer and score, and is time efficient (Gardon, 2010, p. 7). As questionnaire items are generically named (i.e. general classroom behaviour, general playground behaviour, getting along with others, development of social skills, attempting tasks presented and aggressive behaviours) item names will be italicised for clarity when discussed in subsequent chapters.

The SBRS has sound psychometric qualities with subscale internal consistency scores ranging between .88 and .96, and test-retest reliability coefficients ranging from .86 to .97

(Gardon, 2010, p. 65). It has been developed in Australia using data from classroom teachers on almost 2000 students aged 5 to 12 years of age. (Gardon, 2010).

Administration

The SBRS is a paper-based rating scale for teachers. Respondents rate each student on a seven-point scale ranging from Never (1), Sometimes (4) and Very Often (7). The SBRS comprises 51 behavioural items which measure observable school behaviour across six domains including: General Classroom Behaviour; General Playground Behaviour; Getting Along with Other Students; Attempting Tasks Presented; Development of Social Skills and Aggressive Behaviours. The SBRS can be used to provide explicit information about a student's strengths, target areas for intervention, support functional assessment and provide a measure for pre and post intervention efficacy (Gardon, 2010).

Scoring

The SBRS is manually scored on a sheet specifically designed to align question items with relevant subscales. Item responses are tallied and divided by the number of items in each subscale, as item numbers vary across domains. This action provides a competency score which can then be compared to the baseline competency score related to a student's age and gender. Competencies vary between genders, with the baselines for females being considerably higher. Baseline competencies for primary students by gender are as follows:

Table 22 SBRS baseline competencies by gender (Gardon, 2010)

Domain	General Classroom Behaviour	General Playground Behaviour	Getting Along with Others	Development of Social Skills	Attempting Tasks Presented	Aggressive Behaviours
Males	≥3.32	≥3.84	≥3.64	≥3.84	≥2.26	≥3.61
Females	≥4.66	≥5.18	≥4.39	≥5.18	≥3.76	≥5.21

Sleep

Table 23 Overview of sleep testing

Test Focus	Responding Group	Administration	Conditions

7-day Sleep Diary	Students in intervention group	Week 9 of intervention, prior to sleep unit and sleep knowledge test	Students collect information as per diary each day for 7 days as a homework task

The Australian Centre for Education in Sleep (ACES) 7-Day Sleep Diary were given to the six active classes (see Appendix 6). Data on sleep were collected in two ways. Students were asked to keep a 7-day sleep diary in Week 9 of the intervention, prior to the commencement of the BBL Program unit on sleep in the middle of the intervention (Weeks 11-14, see program overview, p. 162).

The sleep unit was introduced at the midpoint in the Program for three reasons. Firstly, after ten weeks of neuroscience in the classroom lessons, students had developed an understanding of brain plasticity and the effects of a range of behaviours (e.g. inhibition versus impulsivity, or physical activity) on brain development and function. Secondly, data from the 7-day sleep diary was purposely gathered before commencing the unit on sleep. This was done in the ninth week of the program so that the data could be collected just prior to the end of the school term. Thus, the information would reflect sleep habits during a normal school week and not be influenced by any information provided in the BBL sleep unit. As well, the BBL Program presenter had the holiday break to analyse the data in preparation for discussion with students when introducing the sleep unit materials. Individual sleep hygiene patterns along with sleep quality and quantity were derived from this instrument. Collection of a second 7-day diary at the end of the BBL Program intervention was not possible due to time conflicts caused by DECD pressures to collect a range of systemic data. As the aim of the BBL Program was to educate students about the impact of sleep on the brain and learning, rather than to specifically change sleep behaviours, the researcher decided to abandon collection of this follow-up data as a measure of behaviour change in sleep practice was beyond the scope of this work. Another factor was teacher availability. Teachers found it difficult to ensure that

their students repeated the 7-day monitoring regime due to teacher own ill health (two teachers—HG and STR) and subsequent absence from class and/or systemic pressures taking the teachers out of their classrooms for whole days (two teachers—BAN1 and BAN2) (see discussion Section 5.1.3). These pressures were unforeseen and not flagged by schools during preliminary discussions with the researcher prior to the school's acceptance in the study.

As part of the BBL Program, sleep data were collected for the active cohort only and was analysed in SPSS. Sleep data were interrogated for patterns relating to SES and executive function performance for sleep quality, sleep quantity and sleep pattern over seven days. A unit on sleep is included in the BBL Program to further assist students to understand all the factors that impact on their learning success. It is not the aim of this research to examine changes in sleep behaviour, per se. Rather, the focus is on the relationship of sleep habits to executive functioning.

Other Data (Diet, Exercise and Family)

Background Data

Test Focus	Responding Group	Administration	Conditions
Student Background Questionnaire	Parents/caregivers in both intervention and control groups	At baseline. If no response, again at post intervention collection	Individually via paper-based questionnaire, sent home and returned to school
Modified Child Nutrition Questionnaire (MCNQ)	Students in both intervention and control groups	At baseline.	Individually via paper-based questionnaire as a class group at school.
Physical Activity Questionnaire for Older Children (PAC-Q)	Students in both intervention and control groups	At baseline.	Individually via paper-based questionnaire as a class group at school.

Additional data were collected relating to student age, ethnicity (including a non-English speaking background), school card status (a financial means-tested, State government card which absolves a family from school fees), health or disability diagnoses, diet at baseline

using the 14-item *Modified Child Nutrition Questionnaire* and activity levels at baseline using the *Physical Activity Questionnaire for Older Children (PAQ-C)*. This information was collected to broadly characterise the study population (for generalisability) and to compare performance with levels of SES. As noted above, the short form of the BBL Program used for this study did not include curriculum on diet or physical activity as many targeted programs are currently in use in South Australian schools. However, as demonstrated in the literature review, diet and physical activity levels directly impact optimal brain functioning and, therefore, learning. For this reason, study data sets include both these aspects as a way to further examine the study population.

The measurement of student motivation and engagement, sleep, physical activity and diet was collected via student self-reporting tools. Self-reporting methods inherently carry difficulties with recall, willingness to disclose, and inaccurate self-assessment (Australian Child and Adolescent Obesity Research Network (ACAORN), 2010, Koriat, 1993) . An additional difficulty when seeking self-reported data from children can be their desire to give the right answer rather than the accurate answer (Australian Child and Adolescent Obesity Research Network (ACAORN), 2010). A tool's process of validation and norming is designed to address such difficulties for specific populations and, therefore, was an important consideration in the selection of assessment tools.

The 14-item *Modified Child Nutrition Questionnaire* is a dietary questionnaire normed on Australian children which allows the assessment of dietary patterns associated with positive energy balance as well as food behaviours, attitudes and environments (Wilson et al., 2008). This tool was chosen for the current study because, in contrast to most dietary assessments, it goes beyond a measurement of nutrient consumption to consider dietary patterns associated with both healthy eating and better cognitive functioning—factors identified in the literature review as central concerns.

The *Physical Activity Questionnaire for Older Children (PAQ-C)* (Kowalski et al., 2004) is a self-report questionnaire that has been well validated and used for large population studies. Internal validity, responsiveness to age/gender and test re-test reliability are considered good (Thomas and Upton, 2014). It measures moderate to vigorous activity levels in children between the ages of 8-14 years of age. This tool has been identified as one of the best available by a number of review teams (Biddle et al., 2011, Chinapaw et al., 2010, Welk and Wood, 2000). The PAQ-C contains ten items, with all but the last measuring levels of activity. The final question gauges whether the seven days reported in the questionnaire had been relatively normal or interrupted by illness or other circumstances.

3.2.3 Qualitative Measurement - Teacher Interviews and Student Focus Groups: Epistemological Location of Approach (Bryman Point 2)

Collection of significant change stories is a recognised qualitative research tool within a phenomenological context. Originally developed to evaluate social-economic programs, the collection of significant change stories is seen as a highly valuable tool for assessing programs with "diverse, complex outcomes, with multiple funders and stakeholders groups" (Dart and Davies, 2003, p. 152), especially where a program is *evolving and stakeholders are learning as they go what is truly desired* [author's emphasis] (Dart and Davies, 2003).

As the BBL Program is in an evolutionary state with diverse, complex outcomes involving multiple stakeholders, this tool seemed highly appropriate for the current study. In the original study proposal, collection of significant change data was proposed to take a written format with the option of an interview, if this seemed more desirable to participants. At the point of data collection (i.e. the end of the 20-week intervention), it was obvious that a face-to-face rather than written methodology for collecting significant change stories across the board was most appropriate. This decision was taken for the following reasons:

- A 15-minute semi-structured interview was seen to be the smallest possible time commitment required of time-poor classroom teachers to collect the desired data
- More data would be provided verbally than in written form, especially by students
- Given the difficulty encountered in collecting other study data in written format, it was predicted that data would be more readily collected with fewer omissions in the data set
- Using a disinterested third party interviewer, when the researcher was no longer present at the school site, the data would be free from researcher bias during collection
- The study timeline allowed for only one pass at qualitative data collection as interview, by necessity, took place in Term 4 and the class composition would disappear at the end of the school year
- Student interviews using a focus group format would eliminate the need for a single student to work independently with an unfamiliar adult.

Qualitative Planned Analysis

Interview and focus group questions were specifically designed to assess the range and quality of experiences from participation in the BBL Program, including any perceptions of change to student executive functioning—the primary hypothesis of this work. Further, the qualitative data collected added to the data regarding student attitude, learning outcomes and executive functions, also measured by the quantitative battery. The purpose of all qualitative data in this study was to probe whether participants:

1. Perceived benefits from taking part in the program and if so, what main themes emerged?
2. Perceived problems/difficulties and if so, what themes emerge?

Interviews and focus groups were conducted at each school setting by a UniSA staff member who was not involved in any aspect of the project and had no prior knowledge of the BBL Program. It was expected that interviews and student focus groups would provide data on

central themes with data analysis undertaken independently by an insider—the author and an outsider—a second UniSA staff member involved in neither the BBL Program nor collection of BBL qualitative data, as per Bryman Points 5 & 6 (p. 122).

As understanding of and respect for the use of qualitative data in answering many complex research questions has grown, so too have the variety of analytical approaches (Saldaña, 2012). One key method for qualitative data analysis is the use of some type of coding system devised to fit the unique requirements of a data set. However, as Johnny Saldana writes in his highly-respected book, *The Coding Manual for Qualitative Researchers*,

> All research questions, methodologies, conceptual frameworks, and fieldwork parameters are content specific….Coding is just one way of analyzing qualitative data, not the way. (Saldaña, 2012) p.2

The current study employed the application of evaluation coding as the best means to examine its specific research questions. Evaluation coding is "the application of non-quantitative codes onto qualitative data that assign judgments about the merit and worth of programs or policy" (Rossman and Rallis, 2003, p. 492). Furthermore, according to Rossman and Rallis, evaluation data are well placed to deal with activities, characteristics and outcomes of programs or policy initiatives and can tease out descriptive, comparative and predictive concepts by examining information regarding skills, attitudes, feelings, behaviour and knowledge (Rossman and Rallis, 2003).

All data from teacher interviews and student focus groups were analysed independently by the insider (this researcher) and the outsider (a university staff member without connection to or prior knowledge of the BBL Program and not present at data collection). Data from teacher and student interviews were considered separately and then combined to ensure that any issues specific to positional perspective were not overlooked. Coding differences between the

insider and the outsider were indicated by (I) and (O) respectively. The outside coder did not highlight aspects of the discussions around difficulties with the program or willingness to participate in a similar program in the future in her codes. As these concepts were clearly dealt with in the data, often in answer to direct questions, the coders reached consensus on data validity and this information was included in the analysis.

On completion of the evaluative coding process, coded material was examined thematically. The thematic construction employed the qualitative analysis approached outlined by Jennifer Attride-Stirling in her comprehensive 2001 paper, *Thematic Networks: an analytic tool for qualitative research*, which calls for codes to be initially reviewed for basic (lowest order) themes. Basic themes then inform the construction of second order themes, which Attride-Stirling refers to as organizational themes or the clustering of basic themes into similar issues. Finally, global themes or conclusions are derived from the collection of organizational themes (Attride-Stirling, 2001).

Focus Groups as a Viable Methodology

Focus group data collection is a standard qualitative tool which can gather information about perceived significant change (Brannen et al., 2004, Morgan, 1996). Focus groups are characterised by the need for a focussed purpose to the discussion between a specific collection of people. Groups may be homogenous or random samples depending upon the purpose of the research. Group construction directly effects how well outcomes can be generalised to similar groups, as in the case of product testing market research or attitude to treatment procedures (Freeman, 2006).

For the present work, importance was placed upon seeking recurrent themes about a population of 153 students of similar age, situated in six differing educational settings. According to Krueger, (as reported in Freeman, 2006), results from this type of qualitative

data are more likely to be transferable if data are drawn from a sufficient number of randomly sampled, homogenous individuals (Freeman, 2006). Given that focus group construction for this project provided results from over 15% of a randomly selected, pre-existing but homogenous population (four students from each of the six different class groups across the SES spectrum), it is argued that results of focus group analysis meet Freeman's criteria and therefore, should have some generalisable validity.

Student Focus Group Rationale

While it was considered ethically viable to interview teachers individually, this logic did not follow through for students. Students were interviewed in a group of four to provide a more comfortable and peer-supportive environment as well as to provide the interviewer with a more professionally acceptable situation to being an unknown adult in a closed room with an individual, primary-aged student. This latter scenario is a direct contravention of regulations from the Department of Education and Child Development. As the six focus group sessions took place after a holiday break and at varying points during Term 4, 2014 depending upon interviewer availability, a set of objects used during the classroom implementation of the BBL was used as memory joggers. (see Appendix 10 *Background for Qualitative Interviews and Focus Groups*)

Sample Size

A further major consideration in qualitative research is the sample size of the data set. Morse (2000), a primary authority on qualitative sample size, suggests that several factors come into play when determining the size of a qualitative sample. These include the quality of data, the scope of the study, the nature of the topic, the amount of useful information provided by each participant, the basic study design and any data reported by the participant as relevant to related others (i.e. that raises new concepts requiring exploration) (Morse, 2000).

In the present work, the study design determined that qualitative data would only be collected from participants within the active group at the end of the intervention since the focus of data collection was on perceived experiences and possible change from interaction with the BBL Program. Population size totalled 153 students and eight teaching staff from six class groups within busy school settings. It was determined that teachers would be interviewed individually or in groups of two for convenience to school administration (i.e. there is a cost attached to taking a teacher out of class to be interviewed). The ideal for student groups was seen to be four participants, providing a total of 24 student viewpoints, approximately 15% of the student population. It was reasoned that four students would provide a large enough group to deliver a range of opinions but not so large as to become unwieldy (Smithson, 2000).

Technical Competence (Bryman Point 4)

Deriving the best data from individual interviews and focus groups requires practice and experience. It also requires careful preparation (Smithson, 2000). Within South Australian state schools, data collection from school students requires specific training and clearance from the State government. An interview regime and open-ended questions were agreed between this researcher, primary supervisor, interviewer (a trained university doctoral researcher with no relation to the study or any of its stakeholders) and a second university-based collaborator with expertise in qualitative research to assist with analysis who also had no relation to the study or stakeholders. Interviews and focus groups were held at each school. Proceedings were recorded, transcribed and de-identified prior to analysis. To guard against unintentional bias, the researcher took no part in the recording, transcription or de-identification processes and could only access the de-identified materials throughout the data analysis phase.

3.2.4 Mixed Methods Considerations for the Data

Underpinning Research Questions (Bryman Point 3)

A mixed methods approach was purposely adopted for this work as it would be impossible to adequately address the research questions solely using either a qualitative or quantitative method. Taking into consideration the range of research designs, a convergent parallel design (also referred to as triangulation or concurrent design) was selected (Creswell, 2013). The success of the intervention was determined through a comparison of the time/group interaction and via comparative analysis of the qualitative and quantitative data sets.

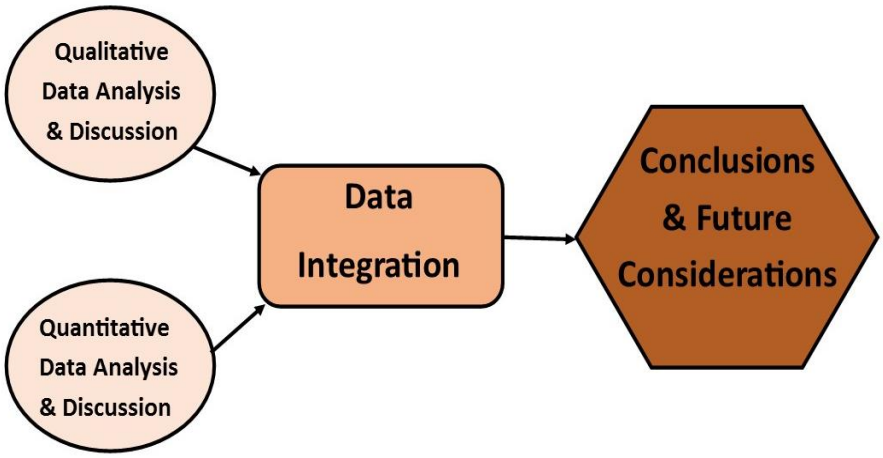


Figure 10 Convergent parallel design construction
Adapted from Creswell (2013)

Qualitative Data Analysis (Bryman Points 5 & 6)

Where a research design employs a mixed methods model, Bryman has mandated both transparency regarding the relationship of the quantitative and qualitative data sets and integration of qualitative and quantitative data sets. One inherent weakness in qualitative research is the risk of interpretive bias. To offset this risk, data from interviews and focus groups were analysed using an insider/outsider approach explained above. The insider/outsider approach was selected as it was seen to offer the most balanced analysis process. The need for consensus between two independent coders provided a significant barrier for researcher bias as the author both developed and delivered the BBL Program

during the study. Once the initial, independent analyses were completed by each analyst, results were compared.

Results are detailed in the following chapter Section 4. As per a mixed methods research methodology, qualitative and quantitative results were combined to support or refute the study's hypotheses and to provide both breadth and depth in understanding the experience of participating in the program.

3.3 Summary of Methods

An outline of the methodology used to conduct this work was detailed in Section 3. Study design, including power calculations, randomisation, recruitment, piloting of measures, pre and post data collection and program delivery were presented in Section 3.1. In Section 3.2, all outcome measures were described. Quantitative and qualitative plans of analysis were explained, along with best practice guidelines for mixed methods research.

Chapter 4 Results

4.1 Participation and Data Sets

Two hundred ninety-three students were recruited to the *Being the Best Learner You Can Be* (BBL) Program study across twelve Year 4/5 classes within ten separate school sites. At the first data collection point on the 24th March, 2014, five students had left their respective schools, bringing the participant population to 288 students in either the intervention or control groups. One student in the control group began the intervention but was withdrawn, resulting in a final total of 287. It was not possible to include new participants past the study start date (see Figure 11 for the CONSORT flow of participants through the study).

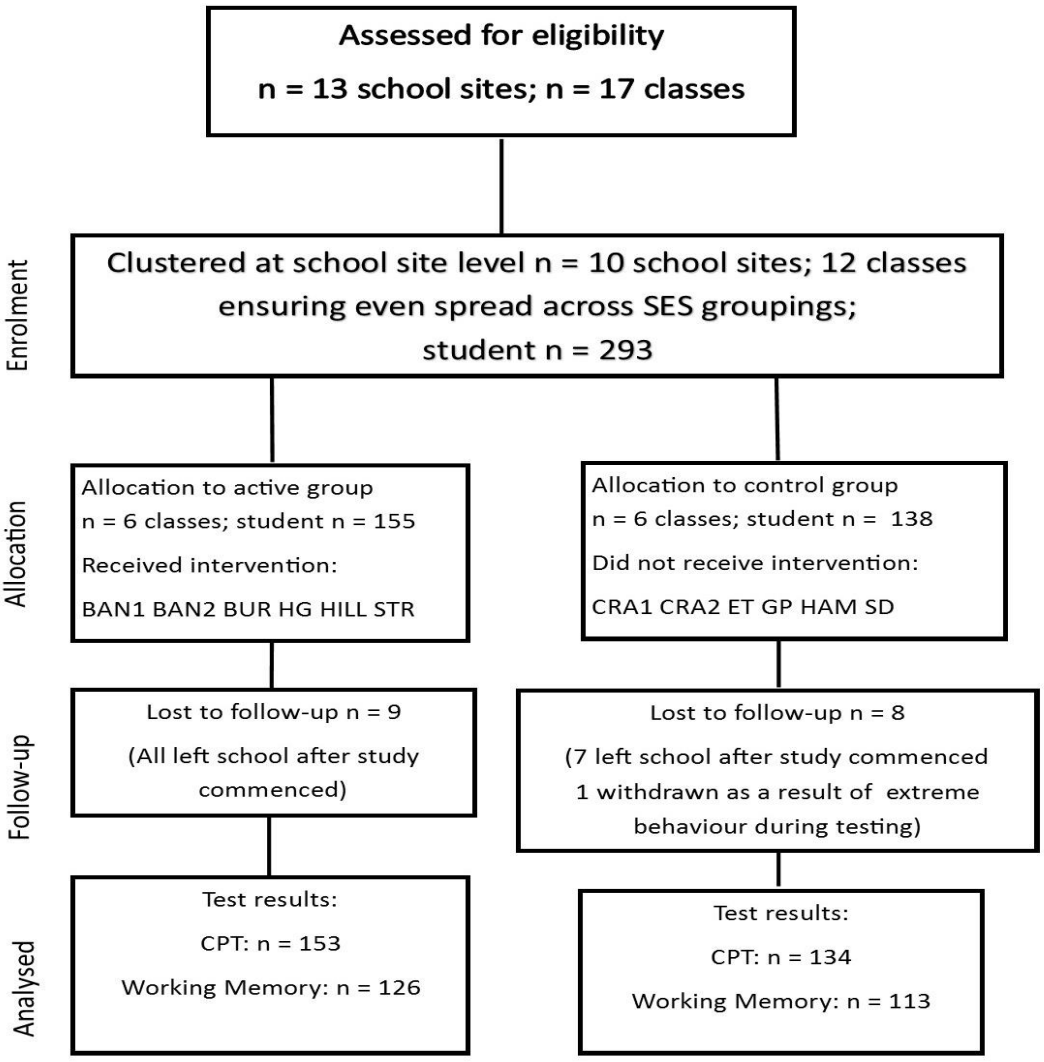


Figure 11 CONSORT flow chart for study population participation

Throughout the intervention period, student numbers remained steady in some classes but not in others (see Table 24). As will be discussed later in Section 4.3.3, student mobility had an impact on program delivery in the low SES classes (see Changes to Class Composition).

Table 24 Class stability throughout intervention

Student Numbers	BAN1	BAN2	BUR	HG	HILL	STR
At Study Week 0	19	20	31	28	25	30
New at Week 10	3	3	0	1	0	0
New at Week 15	1	2	0	0	0	0
Students Lost to Class	2	1	0	1	2	0
Percentage Change over Study	31%	30%	0%	7%	8%	0%

NOTE: low SES mid SES high SES

DECD places a cap of 24 students per class in low SES sites

4.1.1 Response Rates

At Recruitment

Table 25 outlines the study subscription rate of 92.7% by class from an available pool of 316 students. Subscription is based on the number of parent consent forms returned to the school permitting individual students to be included in the testing regime (see Appendix 5 for information and consent forms). Participant percentage represents the number of students for whom data were collected. Reasons for non-subscription are discussed Section 5.1.

Table 25 Study participants by school code, SES, class size and participant numbers

School	SES by School	Class Size	Participants Enrolled	Participants at Commencement	Subscription Percentage	Participant Percentage
BAN1	LOW	24	20	19	83.3%	79.2%
BAN2	LOW	23	21	20	91.3%	86.9%
GP	LOW	24	14	14	58.3%	58.3%
HAM	LOW	24	20	18	83.3%	75%
BUR	MID	31	31	31	100%	100%
ET	MID	29	29	29	100%	100%
HILL	MID	25	25	25	100%	100%
SD	MID	25	25	25	100%	100%
CRA1	HIGH	26	23	23	88.5%	88.5%
CRA2	HIGH	27	27	27	100%	100%
HG	HIGH	28	28	27	100%	100%
STR	HIGH	30	30	30	100%	100%
TOTALS		**316**	**293**	**288**	**92.7%**	**91.1%**

NOTE: low SES mid SES high SES

At Data Collection Points

Table 26 provides an overview of data return rates for each measure. Although responses to student background questionnaires were collected once, only 194 questionnaires were returned from the full cohort of intervention and control group participants from a possible pool of 288 at the first data collection point and 287 at the second data collection point. A further 32 student behaviour questionnaires were received at the second data collection point, bringing the total to 226 (78%) subjects providing background information.

Table 26 Overview of data returned by class and SES-excluding sleep information

Site	BRIEF 1	BRIEF 2	Background	MES 1	MES 2	PAQ-C	Nutrition
BAN 1	10/19 53% 1 CNS*; 8 M 1 LSBI	7/19 37% 11 M; 2 LS	9/19 47% 7 M; 1 LSBI	18/19 95% 1 IC; 1 LSBI	14/19 74% 4 M; 2 LS	17/19 89% 3 M; 1 LSBI	18/19 95% 1 M; 1 LSBI
BAN 2	8/20 40% 12 M; 1 LSBI	7/20 35% 12 M; 2 LS	11/20 55% 8 M; 1 LSBI; 1 LS	19/20 95% 1 M; 1 LSBI	14/20 70% 2 IC; 4 M 1 LSBI; 1 LS 1 data pt M	20/20 100% 1 LSBI	16/20 80% 4 M; 1 LSBI
GP	6/14 43% 8 M	4/14 29% 9 M; 1 LS	8/14 57% 5 M; 1 LS	13/14 93% 1 M 1 data pt M	8/14 57% 1 IC; 4 M; 1 LS; 1 data pt M	13/14 93% 1 M	12/14 86% 1 IC; 1 LS
HAM	9/18 50% 8 M; 2 LSBI 1 WD	7/18 39% 9 M; 2 LSBI 1 WD	9/18 50% 9 M; 2 LSBI	14/18 78% 2 IC; 2 M 2 LSBI	14/18 78% 1 IC; 2 M 2 LSBI; 1 WD	13/18 72% 3 IC; 2 M 2 LSBI	18/18 100% 2 LSBI
BUR	22/31 71% 9 M	15/31 48% 6 M	26/31 84% 5 M	31/31 100% 6 data pts M across 5 students	31/31 100% 1 data pt M	27/31 87% 4 IC	31/31 100%
ET	18/28 64% 9 M; 1 LSBI; 1 LS	17/28 61% 10 M; 2 LS	21/28 75% 6 M; 1 LSBI; 1 LS	25/28 89% 1 IC; 1 M 1 LSBI; 1 LS	21/28 75% 1 IC; 5 M 1 LS	21/28 75% 6 M; 1 LSBI; 1 LS	18/28 64% 11 IC; 1 LSBI; 1 LS
HILL	21/25 84% 4 M	18/25 72% 5 M; 2 LS	23/25 92% 2 LS	25/25 100% 2 data pts M from 2 students	19/25 76% 2 IC; 2 M;; 2 LS	25/25 100%	25/25 100%
SD	23/25 92% 2 M	18/25 72% 7 M	20/25 80% 4 M	23/25 92% 2 M	23/25 92% 2 M	23/25 92% 2 M	24/25 96% 1 M
CRA 1	20/24 83% 4 M	21/24 83% 3 M	21/24 83% 3 M	24/24 100%	24/24 100%	24/24 100%	24/24 100%
CRA 2	24/27 89% 1 CNS; 2 M	26/27 96% 1 M	26/27 96% 1 M	27/27 100%	27/27 100%	25/27 93% 2 IC	27/27 100%
HG	26/27 96% 1 data pt M 1 LSBI	25/27 93% 1 M; 2 LSBI	25/27 93% 2 M; 1 LSBI	27/27 100% 1 LSBI	16/27 59% 10 M; 2 LSBI	26/27 96% 1 IC; 1 LSBI	27/27 100% 1 LSBI
STR	29/30 97% 1 M	30/30 100%	29/30 97% 1 M	30/30 100%	30/30 100%	30/30 100%	30/30 100%

NOTE: low SES mid SES high SES
Grey shading denotes data collected from students at school
CNS = could not score due to missing data M = form not returned LS = student left school LSBI = left school before intervention commenced IC = form returned but incomplete
WD = withdrawn from study

4.1.2 Pre/Post Testing Phases

Assessors visited each school site at least twice and sometimes up to four times in both the pre and post testing phases to administer computerised tests. Despite this, 16 CPT tests (5% of study population) and 35 tests of working memory (12% of study population) are missing from either pre or post data collection due to student absence. During the pre-test condition, five students either did not finish the CPT or were required to re-sit it to produce a viable result. Of these students, four were in the active condition. At the post intervention, all students in the active condition successfully completed the CPT at their first attempt. The student in the control condition did not participate in the follow-up testing due to absence on testing days (see Table 27).

Table 27 Breakdown of missing student data for CPT testing by school and SES

Class	CPT pre	CPT post	CPT TOTAL	WM pre	WM post	WM TOTAL
BAN1	2 repeated test	0	**0**	3	1	**4**
BAN2	1 did not finish	0	**1**	1	4	**5**
GP	1	1	**2**	2	1	**3**
HAM	0	3	**3**	0	2	**2**
BUR	1 repeated test	2	**2**	5	2	**7**
HILL	0	0	**0**	0	0	**0**
SD	1	1	**2**	1	0	**1**
ET	1 did not finish	3	**4**	0	4	**4**
CRA1	0	0	**0**	0	0	**0**
CRA2	2	0	**2**	2	2	**4**
HG	0	0	**0**	1	2	**3**
STR	0	0	**0**	1	1	**2**
TOTAL	***4 missing *2 did not finish *3 repeated—could not be scored at first attempt**	**10**	**16**	**16**	**19**	**35**

NOTE: low SES mid SES high SES

4.2 Quantitative Results

Seven research questions are addressed in this data analysis. Data concerning the main hypothesis, that the BBL Program would positively impact on student executive function performance, is presented in Section 4.2.1. Questions of motivation and attitude are considered and those regarding SES are addressed in Section 4.2.2. Data related to physical factors (i.e. sleep, diet and physical activity) are analysed in Section 4.2.3.

4.2.1 Continuous Performance Test (CPT) & Working Memory Subtest Results

Outcome measures on the eight Continuous Performance Test (CPT) subtests and the test of visual spatial working memory were calculated for all students and the data set scrutinised for normality of data and distribution, with outliers removed prior to analysis. Sphericity was also verified, and if violated, the Greenhouse-Geisser correction was applied.

A two factor (condition by time) mixed model analysis of variance with repeated measures on time was used to explore interactions between time and condition to answer the primary research question. The subtests for inattention (errors of omission and errors of commission), impulsivity (variability), and sustained attention (HSE ISI) were designated as central to supporting the primary hypothesis.

Significant time by condition interactions are discussed below for each subtest, including any post hoc investigations (See Table 28 for itemised means and standard deviations). Significant main effects for time (i.e. pre and post intervention) and for condition (i.e. active or control groups) are then reported.

Table 28 Two factor time by condition interaction mean and standard deviation results at Time 1 and Time 2

Subtest		Active Group		Control Group	
		Mean	SD	Mean	SD
Detection	**Time 1**	53.76	10.16	51.27	13.12
	Time 2	50.14	15.51	48.71	17.43
Omission	**Time 1**	50.59	10.11	50.29	11.13
	Time 2	49.82	10.02	50.73	9.86
Commission	**Time 1**	54.62	9.78	52.66	9.67
	Time 2	52.70	9.53	52.45	9.54
Hit Rate	**Time 1**	45.99	8.46	46.80	9.40
	Time 2	45.45	9.28	46.87	9.09
Vigilance	**Time 1**	52.47	11.13	53.21	11.60
(HRT SD)	**Time 2**	53.00	12.36	55.97	11.54
Impulsivity	**Time 1**	50.52	11.49	51.17	11.48
(Variability)	**Time 2**	50.52	11.26	54.61	10.82
Manage Fatigue	**Time 1**	52.27	10.51	51.03	11.16
(HRT ISI)	**Time 2**	53.12	11.57	54.42	11.59
Sustain Attention	**Time 1**	52.01	10.76	50.88	11.80
(HSE ISI)	**Time 2**	52.71	11.41	54.39	11.50
Working Memory	**Time 1**	169.87	16.68	167.65	17.51
	Time 2	175.13	19.81	169.85	19.03

NOTE: lower scores denote better performance on all items *except* Working Memory

Results from Time x Condition Analysis (Primary Hypothesis)

The two-factor ANOVAs resulted in a significant time by condition interaction for input change/impulsivity (variability) and sustained attention (HSE ISI). The interaction for vigilance (HRT SD) approached significance (See Table 29). There was no significant

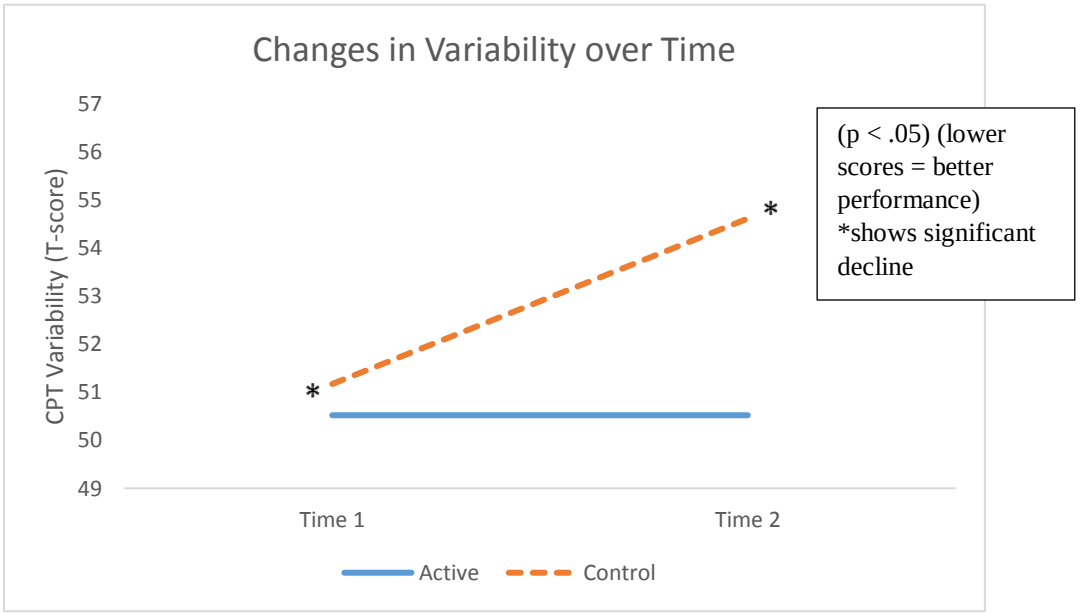
interaction for errors of detection, omission, and commission, hit rate, fatigue (HRT ISI) or working memory.

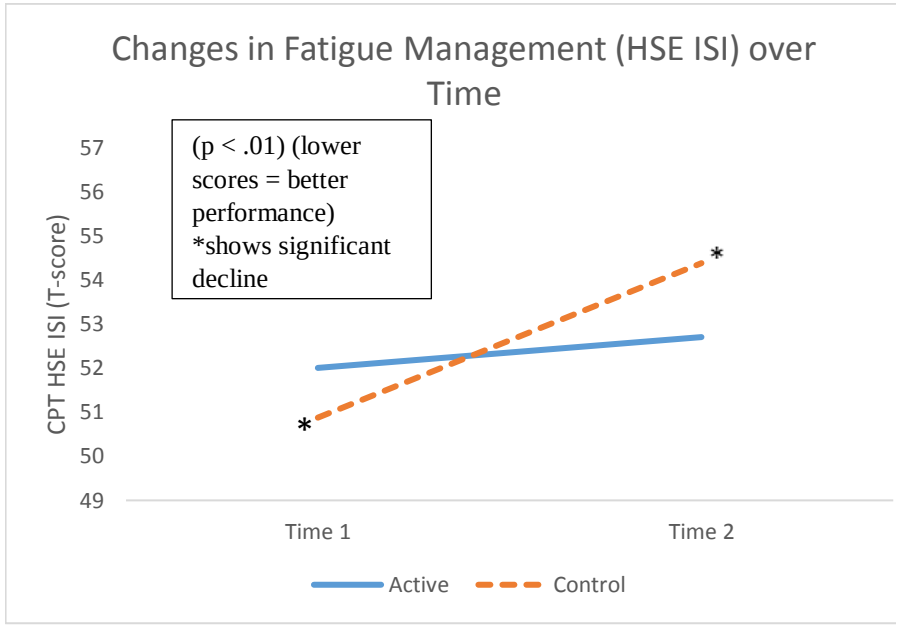
Overall, there was a decline in performance across the complete cohort between Time 1 and Time 2 for variability, sustained attention (HSE ISI) and vigilance (HRT SD) with each of these factors also resulting in a time main effect (see Table 30). For the active group, decline was minimal while the control group declined significantly (see Figure 12).

The CPT produces composite scores for inattention, impulsivity, sustained attention (HSE ISI) and vigilance (HRT SD) and rates responses as either no indication, some indication or strong indication of clinical concern. Table 31 demonstrates the number of students by class grouping and levels of clinical concern. Appropriate school staff were informed when a strong clinical concern was indicated for a student at both Time 1 and Time 2.

Table 29 CPT overview for time by condition

Subtest		Total Mean	Total SD	Relationships
Detection	**Time 1**	52.60	11.68	N/S
	Time 2	49.48	16.42	
Omission	**Time 1**	50.45	10.56	N/S
	Time 2	50.23	9.94	
Commission	**Time 1**	53.74	9.76	N/S
	Time 2	52.59	9.51	
HRT	**Time 1**	46.36	8.89	N/S
	Time 2	46.09	9.21	
Vigilance (HRT SD)	**Time 1**	52.81	11.33	Overall performance declined between Time 1 and Time 2
($F(1, 261) = 3.36$, $p = .068$)	**Time 2**	54.34	12.06	with the decline in control group performance approaching significance
Variability	**Time 1**	50.81	11.47	There was no significant change in the active group between
($F(1, 261) = 5.33$, $p < .05$)	**Time 2**	52.37	11.23	Time 1 and Time 2, but a significant reduction in the performance at Time 2 in the control group
Fatigue Management (HRT ISI)	**Time 1**	51.71	10.81	N/S
	Time 2	53.71	11.57	
Sustained Attention (HSE ISI)	**Time 1**	51.50	11.24	There was no significant change in performance between
($F(1, 261) = 3.94$, $p < .01$)	**Time 2**	53.47	11.46	Time 1 and Time 2 for the active group, while the control group decreased significantly
Working Memory	**Time 1**	168.82	17.08	N/S
	Time 2	172.64	19.59	





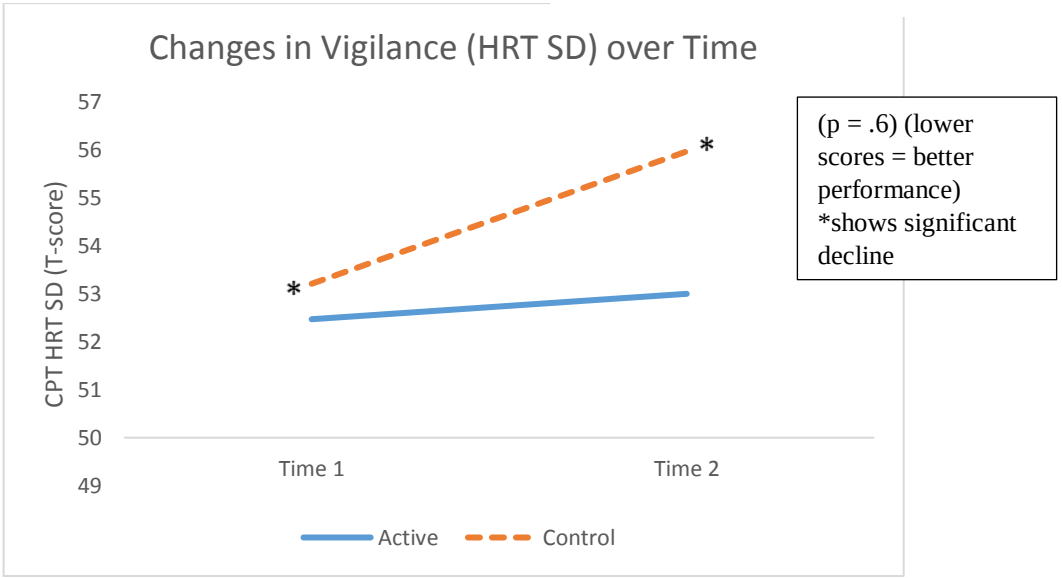


Figure 12 Graphs to illustrate the two factor time by condition significant interactions

Main Effects

A time main effect was found for six of the eight CPT subtests and for working memory within the two-factor (time by condition) analyses (see Table 30). Student performance improved over time for detection, commission, and working memory. Performance declined for vigilance (HRT SD), input change/impulsivity (variability), fatigue (HRT ISI), and sustained attention (HSE ISI). No significant time effect was observed for errors of omission or speed of response (HRT).

Table 30 Significant time main effects for two factor interaction

Subtest	**Time 1**	**Time 2**	**Significance**	**Performance**
Detection (F(1, 285) = 8.03)	M = 52.60, SD = 11.68	M = 49.48, SD = 16.42	p < .01	Improved
Omission	M = 50.45, SD = 10.56	M = 50.23, SD = 9.94	NS	
Commission (F(1, 261) = 4.10)	M = 53.74, SD = 9.76	M = 52.59, SD = 9.51	p < .01	Improved
HRT	M = 46.36, SD = 8.89	M = 46.09, SD = 9.21	NS	
Vigilance (HRT SD) (F(1, 261) = 7.21)	M = 52.81, SD = 11.33	M = 54.34, SD = 12.06	p < .01	Decreased
Variability (F(1, 261) = 5.34)	M = 50.81, SD = 11.47	M = 52.37, SD = 11.23	p < .05	Decreased
Fatigue (HRT ISI) (F(1, 261) = 7.39)	M = 51.71, SD = 10.81	M = 53.71, SD = 11.57	p < .01	Decreased
Sustained Attention (HSE ISI) (F(1, 261)= 8.82)	M = 51.50, SD = 11.24	M = 53.47, SD = 11.46	p < .01	Decreased
Working Memory (F(1, 237) = 17.39)	M = 168.82, SD = 17.08	M = 172.64, SD = 19.59	p < .01	Improved

Table 31 Number of students with no, some or strong indication of problems in composite CPT areas of attention at Time 1 and Time 2

		CPT Inattention			CPT Impulsivity			CPT Sustained Attention			CPT Vigilance		
Class	**Time**	**No**	**Some**	**Strong**	**No**	**Some**	**Strong**	**No**	**Some**	**Strong**	**No**	**Some**	**Strong**
BAN1	Time 1	8	5	6	11	6	1	10	7	2	15	3	1
	Time 2	8	6	7	10	7	1	8	5	5	10	7	1
BAN2	Time 1	10	3	6	15	2	2	12	2	5	14	4	1
	Time 2	7	4	6	13	4	2	10	5	4	12	5	2
BUR	Time 1	12	13	6	17	7	7	22	7	2	15	12	4
	Time 2	12	13	4	14	12	3	19	6	4	17	10	2
CRA1	Time 1	13	5	5	19	2	2	14	6	3	12	11	0
	Time 2	10	6	7	18	2	3	15	5	3	14	8	1
CRA2	Time 1	15	9	1	18	4	3	20	5	0	18	5	2
	Time 2	13	11	1	15	7	3	16	6	3	17	5	3
ET	Time 1	6	11	6	15	5	3	13	6	4	13	8	2
	Time 2	6	10	7	13	5	5	11	11	1	16	4	3
GP	Time 1	3	6	4	8	4	1	6	5	2	6	5	2
	Time 2	6	4	3	9	3	1	5	5	3	8	2	3
HAM	Time 1	4	4	6	8	5	1	8	2	4	6	8	0
	Time 2	3	4	7	8	3	3	5	3	6	6	4	4
HILL	Time 1	12	3	7	11	7	4	12	10	0	16	3	3
	Time 2	9	7	6	17	2	3	11	7	4	13	5	4
HG	Time 1	17	6	3	18	6	2	18	6	2	16	7	3
	Time 2	15	6	5	18	4	4	21	3	2	14	9	3
SD	Time 1	14	5	4	15	7	1	17	5	1	14	8	0
	Time 2	12	5	6	17	4	2	14	8	1	15	7	0
STR	Time 1	13	8	9	19	11	0	19	7	4	22	8	0
	Time 2	17	11	2	17	8	5	21	6	3	25	5	0

NOTE: No =no indication of problem, Some = some indication of problem, Strong = strong indication of problem
Colours indicate SES level - Low SES, Middle SES, High SES

There was only one condition main effect found in the two-factor analysis. This was for variability ($F(1, 261)$, $p < .05$) with the active group ($M = 50.52$, $SD = 11.26$) consistently outperforming the control group ($M = 54.61$, $SD = 10.82$) in managing input change/impulsivity (vigilance).

Results from Three-Factor Analysis (Secondary Hypothesis regarding SES)

A three factor (condition by time by SES) mixed model with repeated measures analysis was used to address secondary questions concerning SES with post hoc investigations as necessary. Significant interactions are discussed prior to reporting significant main effects for time, condition and SES (see Tables 32 (Active cohort) and 33 (Control cohort) for mean and standard deviation overviews).

Significance was observed in the three-factor interaction (time by condition by SES), the secondary hypothesis, for omission and vigilance (HRT SD), with variability approaching significance. A condition by SES interaction was found for omission and for sustained attention (HSE ISI). No significant time by SES interaction emerged. (See Table 34).

Omission Time by Condition by SES Interaction

A three-factor (time by condition by SES) interaction was significant for omission ($F(2, 257) = 3.66$, $p < .05$). An interaction between condition and SES ($F(2, 257) = 3.71$, $p < .05$) was also significant. Using Bonferroni corrections, no significant differences between SES groups for the active condition at Time 1 were found, but at Time 2, the active high SES group had significantly improved relative to the active low SES group. No relative change was found for the control group at either Time 1 or Time 2. Although it should be noted that the control group had very different (i.e. higher) scores at Time 1 when compared to the active group. Improvement in the active, high SES group along with a decline in performance of the active, low SES group explain the condition by SES significance (see Figure 13, p. 210).

Table 32 Three factor time by condition by SES interaction mean and standard deviation results – Active Group

ACTIVE GROUP		Low SES		Middle SES		High SES	
Subtest		Mean	SD	Mean	SD	Mean	SD
Detection	Time 1	52.66	12.62	55.04	9.06	53.29	9.25
	Time 2	50.06	16.59	50.00	17.55	50.74	12.59
Omission	Time 1	50.28	9.76	50.17	10.47	51.17	10.16
	Time 2	52.73	11.92	49.60	9.77	48.09	8.51
Commission	Time 1	53.74	6.60	56.79	10.73	53.24	8.95
	Time 2	52.72	9.08	54.52	8.83	51.03	10.25
Hit Rate	Time 1	48.09	8.63	45.24	8.93	45.29	7.81
	Time 2	47.53	8.97	44.39	9.84	45.05	8.89
Vigilance	Time 1	52.90	11.15	52.58	10.90	52.09	11.50
(HRT SD)	Time 2	56.99	13.59	53.00	13.71	50.35	9.35
Variability	Time 1	50.93	9.98	48.76	12.55	51.86	11.40
	Time 2	52.84	14.79	51.40	11.44	48.20	7.60
Manage Fatigue	Time 1	54.44	12.56	52.44	9.17	50.67	10.10
(HRT ISI)	Time 2	57.60	14.10	52.71	11.81	50.53	8.40
Sustain Attention	Time 1	52.55	11.52	51.77	12.48	51.86	8.52
(HSE ISI)	Time 2	54.02	9.50	54.31	13.33	50.38	10.43
Working Memory	Time 1	149.95	53.24	154.00	51.50	167.46	36.22
	Time 2	140.93	67.51	156.16	53.22	166.19	49.49

Table 33 Three factor time by condition by SES interaction mean and standard deviation results – Control Group

CONTROL GROUP Subtest		Low SES		Middle SES		High SES	
		Mean	SD	Mean	SD	Mean	SD
Detection	Time 1	55.74	11.81	50.81	13.06	49.16	13.64
	Time 2	47.67	22.46	48.16	19.49	49.97	10.38
Omission	Time 1	57.78	18.49	49.78	7.52	46.71	5.63
	Time 2	56.12	12.70	49.96	7.54	48.54	9.15
Commission	Time 1	54.86	6.60	52.19	10.94	51.92	9.79
	Time 2	54.00	8.65	54.46	9.23	49.72	10.05
Hit Rate	Time 1	49.69	11.76	47.52	8.96	44.56	7.91
	Time 2	48.31	9.43	46.44	8.34	46.49	9.68
Vigilance	Time 1	59.05	13.89	53.42	11.05	49.84	9.52
(HRT SD)	Time 2	59.44	12.61	55.72	10.85	54.32	11.40
Variability	Time 1	53.74	15.48	52.02	10.89	48.97	9.13
	Time 2	56.79	10.80	55.01	11.09	53.06	10.55
Manage Fatigue	Time 1	55.47	13.54	50.68	8.89	48.97	11.21
(HRT ISI)	Time 2	59.23	12.36	54.09	10.66	52.13	11.45
Sustain Attention	Time 1	57.62	13.53	49.88	10.80	48.16	10.46
(HSE ISI)	Time 2	61.74	12.59	52.39	11.50	52.30	9.26
Working Memory	Time 1	155.31	44.45	155.72	48.51	160.26	36.61
	Time 2	135.09	75.20	140.94	62.00	164.68	38.68

Table 34 CPT summary of analysis for three factor interaction, time by condition by SES

Subtest Three-factor Interaction	**Subtest Two-factor Interaction Condition x SES**	**Relationship**
Detection	Not significant	Not significant
Omission ($F(2, 257) = 3.66$, $p < .05$)	Omission ($F(2, 257) = 3.71$, $p < .05$)	No change was observed across the control cohorts while the active high SES group improved between Time 1 and Time 2 while the active low SES group declined.
Commission	Not significant	Not significant
HRT	Not significant	Not significant
Vigilance (HRT SD) ($F(2, 257) = 5.00$, $p < .01$)		Significance was due to relative movement between the two high SES groups from Time 1 to Time 2, as well as, the high and low SES groups within the active condition.
Variability	Not significant	Not significant
Fatigue Management (HRT ISI)	Not significant	Not significant
Sustained Attention (HSE ISI)	HSE ISI ($F(2, 257) = 3.98$. $p < .05$)	Students performed in keeping with their SES with the active group outperforming the control group.
Working Memory	Not significant	Not significant

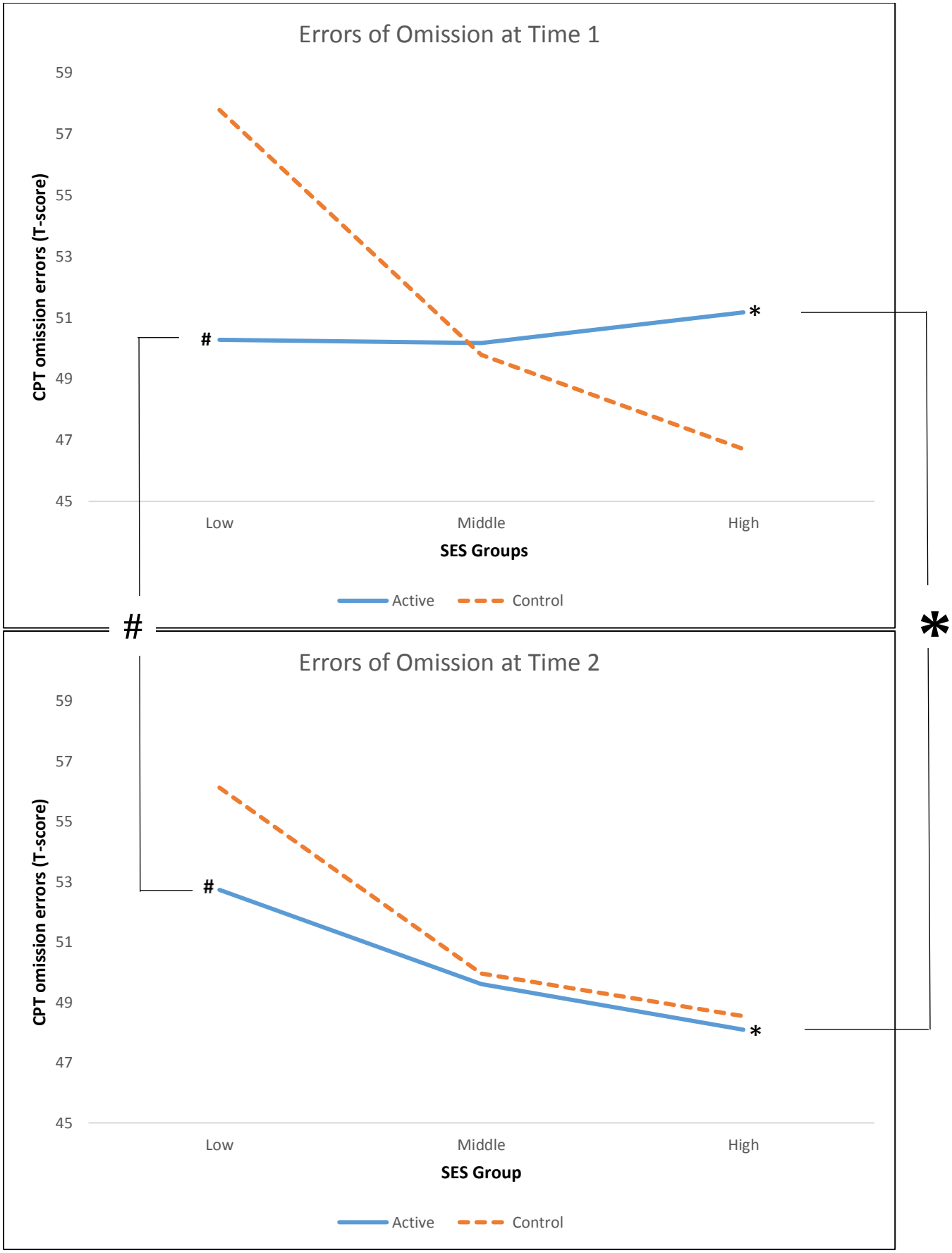


Figure 13 Graphs to illustrate the three-factor time, by condition, by SES interaction for errors of omission
significant decrease over time, * significant improvement over time (lower score denotes better performance)

Vigilance (HRT SD) Time by Condition by SES Interaction

A significant three factor (time by condition by SES) interaction was observed for sustained attention (HRT SD) ($F(2, 257) = 5.00$, $p < .01$). Significance was due to relative movement between the two high SES groups from Time 1 to Time 2, as well as, the high and low SES groups within the active condition. At Time 1, the control high SES group outperformed the active high group while the active low group outperformed the control low group. At Time 2, performance by the active high SES group improved ($M = 50.35$, $SD = 9.35$) while the control high SES group ($M = 54.32$, $SD = 11.40$) declined. Within the active cohort, the low SES group ($M = 57.54$, $SD = 13.83$) declined significantly in relation to the high group (active low to high SES (Mean Difference = 7.20, Std Error = 2.57, $p < .05$). In the control condition, the difference between low ($M = 59.20$, $SD = 13.36$) and high ($M = 49.84$, $SD = 9.52$) SES was significant at Time 1 (low to high SES (Mean Difference = 9.35, Std Error = 2.61, $p < .01$). At time 2, there was no significant difference due to a decline in performance by the control high SES group relative to both the middle and low groups (see Figure 14). This is the same dynamic found in the Omission subtest above.

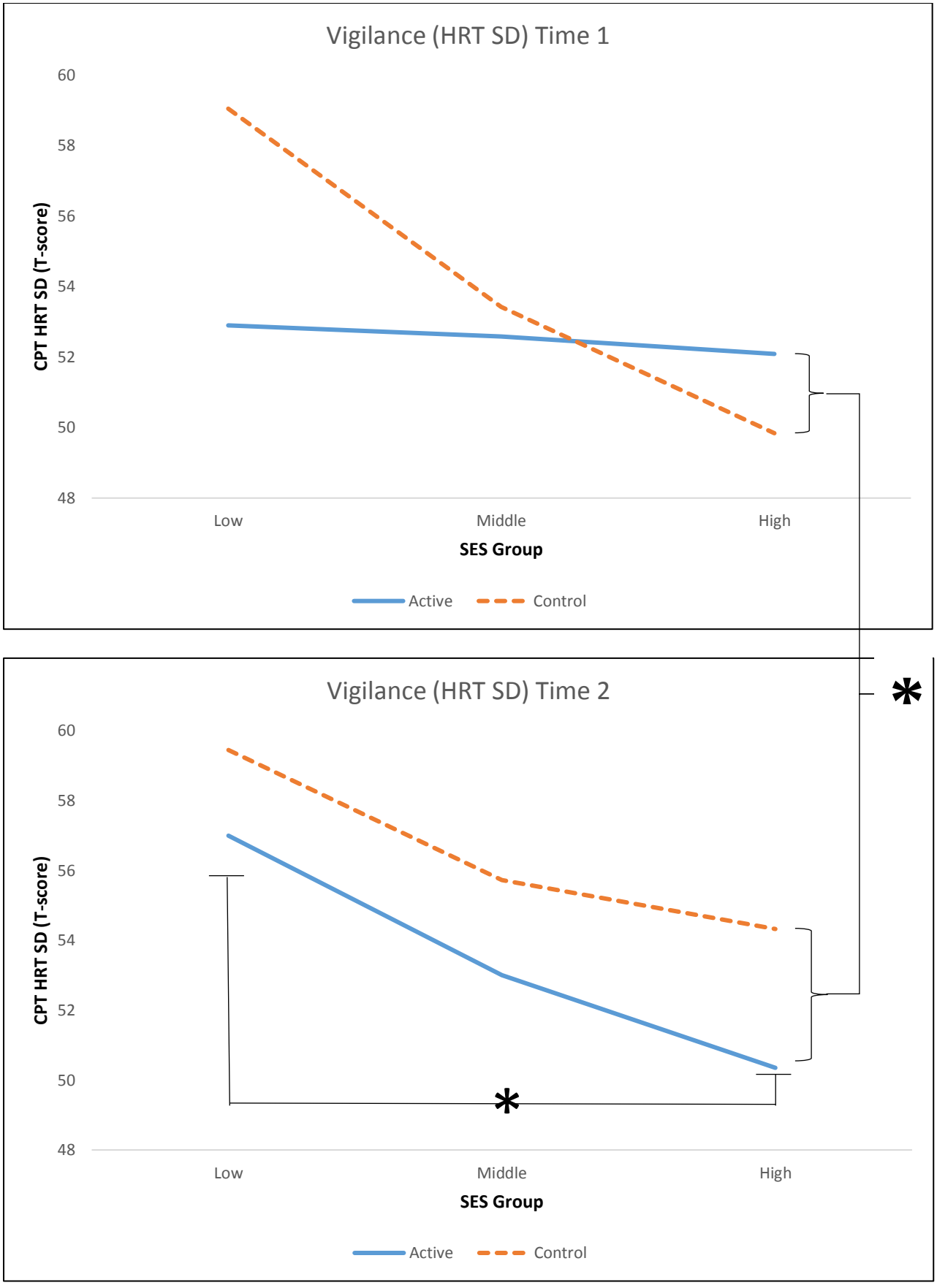


Figure 14 Graphs to illustrate the three-factor time, by condition, by SES interaction for Vigilance (HRT SD)
*significant relationship (lower score denotes better performance)

Sustained Attention (HSE ISI) Condition by SES Interaction

A significant condition by SES interaction was obtained for sustained attention (HSE ISI) ($F(2, 257) = 3.98$. $p < .05$). Overall, SES levels were aligned to performance levels with the high SES group ($M = 51.26$, $SD = 9.91$) outperforming the middle group ($M = 53.41$, $SD = 12.48$) which outperformed the low group ($M = 57.20$, $SD = 11.44$). The active low group ($M = 54.02$, $SD = 9.50$) was significantly more successful than the control low group ($M = 61.74$, $SD = 12.59$).

Main Effects

Within the three-factor analysis, five rather than six of the eight CPT subtests (as found in the two-factor analysis) and working memory resulted in a significant time main effect with errors of commission approaching significance ($F(1, 257) = 3.76$, $p = .054$) (see Table 35).

Table 35 Significant time main effect outcomes for three-factor interaction

Subtest	**Time 1**	**Time 2**	**Significance**	**Performance**
Detection (F(1, 281) = 9.12)	M = 52.60, SD = 11.68	M = 49.48, SD = 16.42	p < .01	Improved
Omission	M = 50.45, SD = 10.56	M = 50.23, SD = 9.94	NS	Not significant
Commission (F(1, 257) = 3.76)	M = 53.74, SD = 9.76	M = 52.59, SD = 9.51	p = .054	Improved
HRT	M = 46.36, SD = 8.89	M = 46.09, SD = 9.21	NS	Not significant
Vigilance (HRT SD) (F(1, 257) = 7.14)	M = 52.81, SD = 11.33	M = 54.34, SD = 12.06	p < .01	Decreased
Variability (F(1, 257) = 5.84)	M = 50.81, SD = 11.47	M = 52.37, SD = 11.23	p < .05	Decreased
Fatigue Management (HRT ISI) (F(1, 257) = 7.95)	M = 51.71, SD = 10.81	M = 53.71, SD = 11.57	p <.01	Decreased
Sustained Attention (HSE ISI) (F(1, 257) = 9.21)	M = 51.50, SD = 11.24	M = 53.47, SD = 11.46	p < .01	Decreased
Working Memory (F(1, 282) = 17.64)	M = 168.82, SD = 17.08	M = 172.64, SD = 19.59	p < .01	Improved

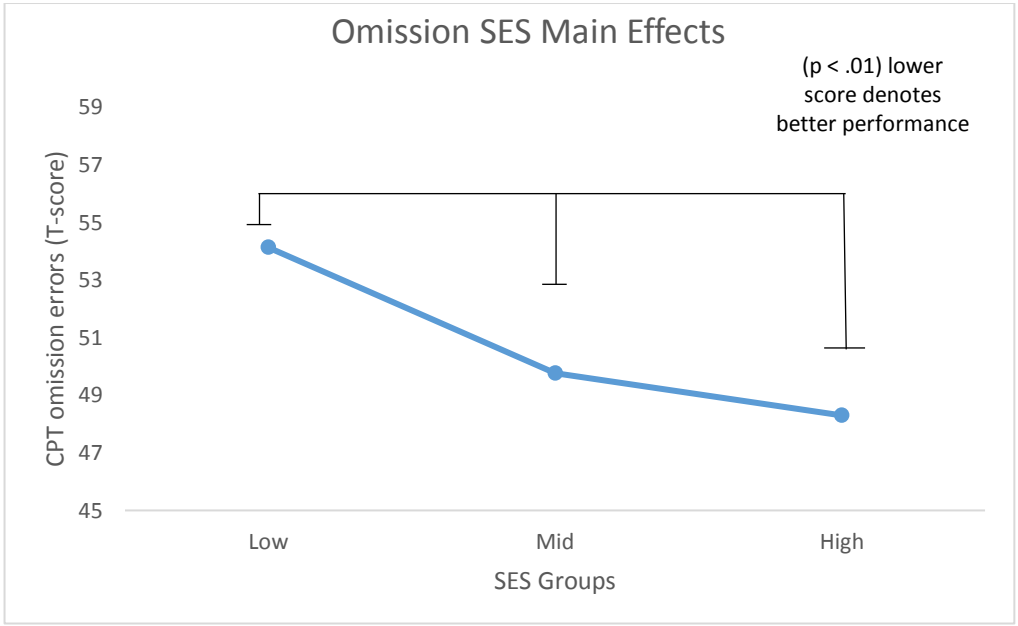
As with the two-factor analysis, variability was the only subtest to return a condition main effect (F (1, 257) = 4.59, p < .05) where the active group (M = 50.52, SD = 11.26) outperformed the control group (M = 54.61, SD = 10.82).

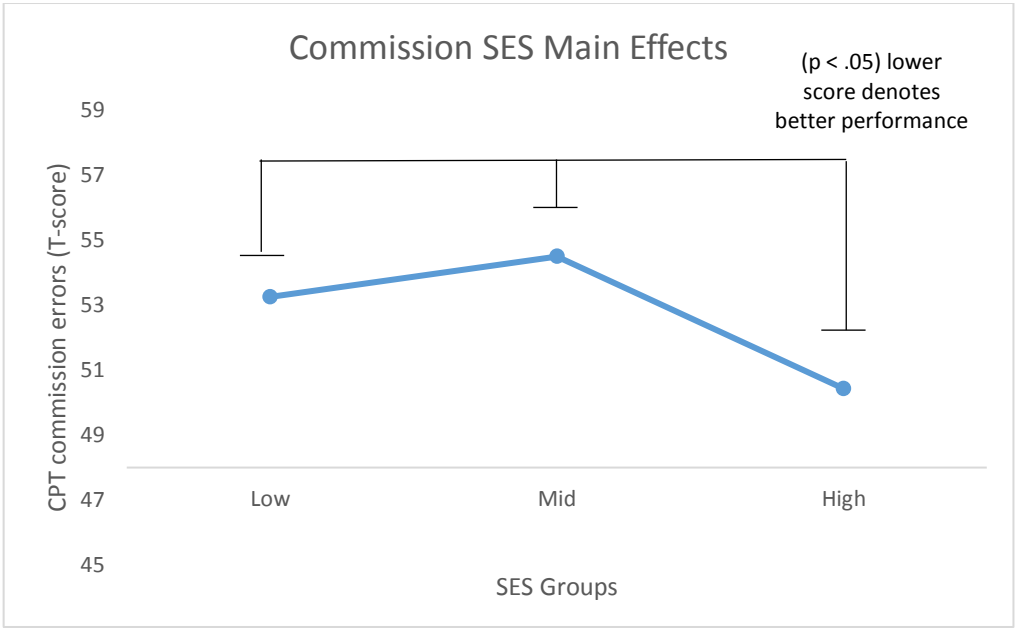
Five CPT subtests resulted in an SES main effect (see Table 36).

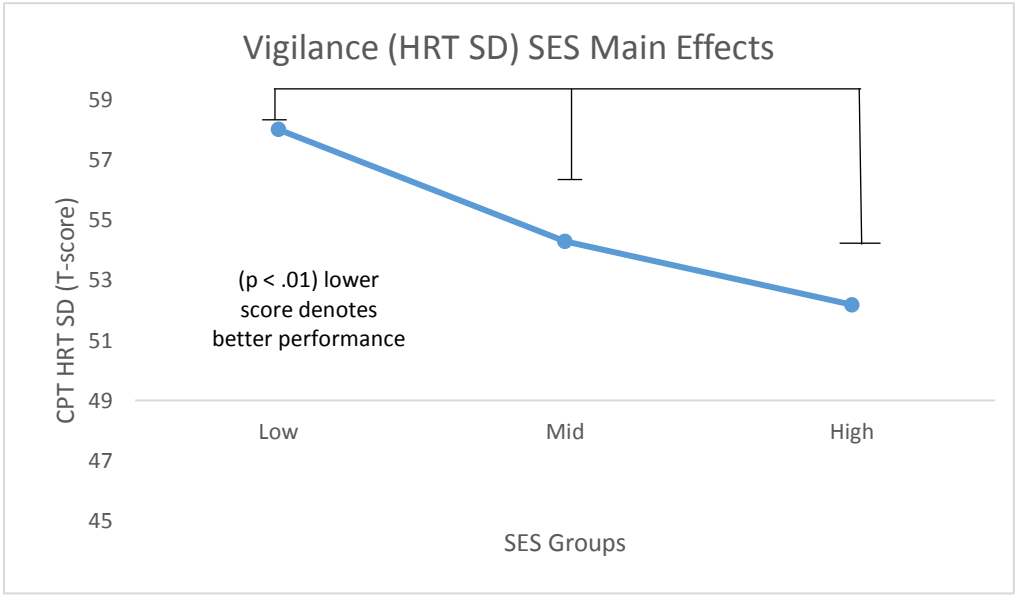
Table 36 Significant SES main effect outcomes for three-factor interaction

Subtest	**Low**	**Middle**	**High**	**Relationship**
Detection	M = 49.00, SD = 19.31	M = 48.90, SD = 18.44	M = 50.38, SD = 11.56	NS
Omission (F(2, 257) = 8.53, p < .01)	M = 54.13 SD = 12.26	M = 49.77, SD = 8.75	M = 48.30, SD = 8.77	High outperforms Middle which outperforms Low
Commission (F(2, 257) = 3.33, p < .05)	M = 53.25, SD = 8.65	M = 54.49, SD = 8.97	M = 50.43, SD = 10.13	High outperforms both Middle and Low but Low outperforms Middle
HRT (F(2, 257) = 2.85, p = .059)	M = 47.85, SD = 9.10	M = 45.35, SD = 9.18	M = 45.71, SD = 9.25	High and Middle outperform Low
Vigilance (HRT SD) (F(2, 257) = 5.22, p < .01)	M = 58.00, SD = 13.15	M = 54.28, SD = 12.46	M = 52.18, SD = 10.49	High outperforms Middle which outperforms Low
Variability	M = 54.47, SD = 13.34	M = 53.09, SD = 11.36	M = 50.44, SD = 9.36	NS
Fatigue Management (HRT ISI) (F(2,257) = 8.84, p < .01)	M = 58.27, SD = 13.33	M = 53.36, SD = 11.25	M = 51.27, SD = 9.90	High outperforms Middle which outperforms Low
Sustained Attention (HSE ISI) (F(2, 257) = 7.34, p < .01)	M = 57.20, SD = 11.44	M = 53.41, SD = 12.48	M = 51.26, SD = 9.91	High outperforms Middle which outperforms Low
Working Memory	M = 138.33, SD = 70.58	M = 148.76, SD = 57.90	M = 165.49, SD = 44.57	NS

Graphs for omission, commission, HRT SD, HRT ISI, HSE ISI and HRT follow in that order (see Figures 15-16).







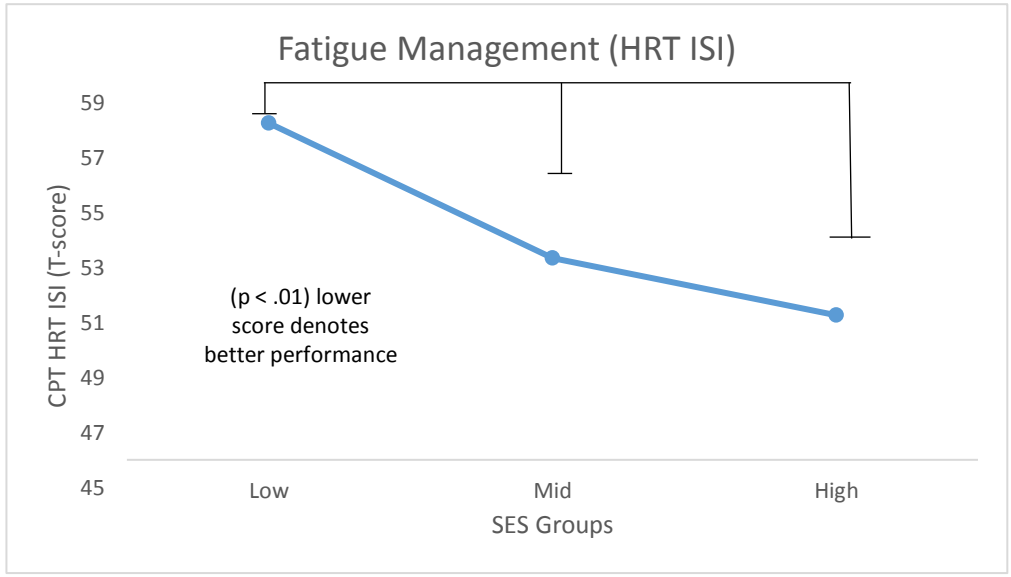
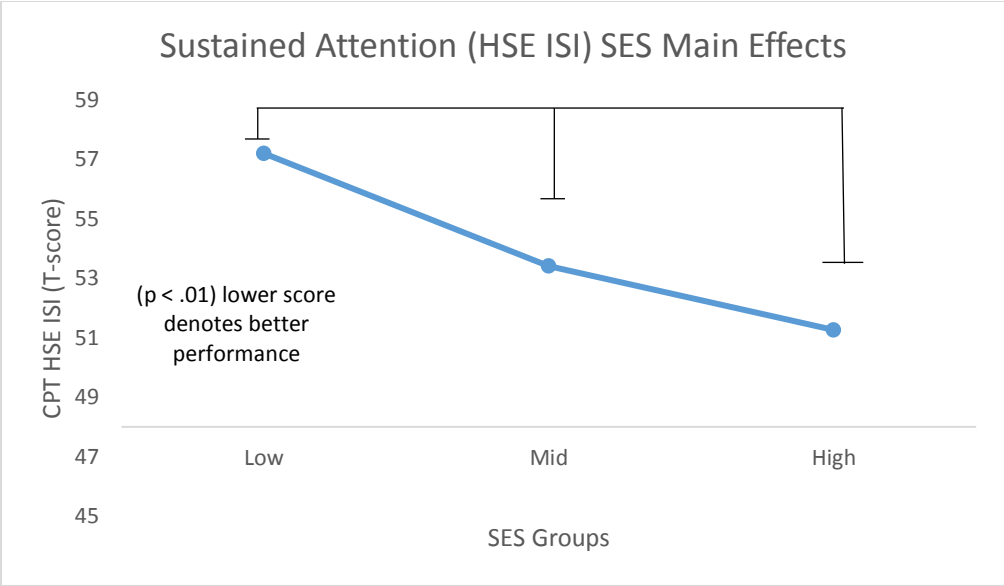


Figure 15 Graphs demonstrating SES main effects for three factor interaction



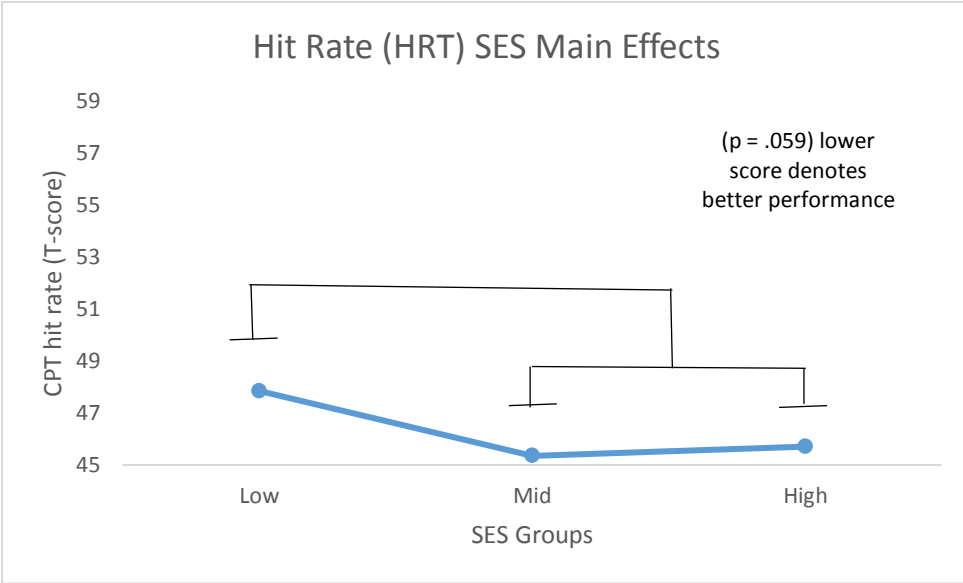


Figure 16 Graphs demonstrating SES main effects for three factor interaction (continued)

4.2.2 Secondary Measures

Motivation and Engagement Scale (MES)—Student Data

NOTE: words in italics denote MES item names.

The Motivation and Engagement Scale (MES) provided data on student attitudes to school and learning. Eleven subtests were analysed for change across time by condition. The data set was scrutinised for normal distribution, with outliers (i.e. any point falling more than 1.5 times the interquartile range above the third quartile or below the first quartile as defined by the test manual (Martin, 2012)) removed prior to analysis. Sphericity was verified, and if violated, the Greenhouse-Geisser correction was applied.

The BBL Program intervention specifically targeted aspects of *self-belief*, *learning focus*, *task management*, *planning*, *disengagement* and *failure avoidance*. It was hypothesised that data would support positive changes in the active group in relation to these factors with higher scores in positive test items (i.e. *self-belief*, *learning focus*, *task management*, and *planning*) and lower scores in negative test items (i.e. *disengagement* and *failure avoidance*).

Two-Factor Analysis with Interaction (Time by Condition)

Using a two-factor analysis with time by condition interaction only one significant interaction was observed. This was for *self-belief* ($F(1, 240) = 7.82$, $p < .01$) where the active group rated themselves higher than the control at Time 1 but lower at Time 2 (see Table 37). Overall, the cohort decreased in self-rating but this can be ascribed to the change in the active group only.

Table 37 Self-belief time by condition descriptive data

Groups	**Time 1**			**Time 2**			**Change Over Time**
	Mean	**SD**	**N**	**Mean**	**SD**	**N**	
Active	88.83	13.493	127	82.66	23.137	127	decreased
Control	83.20	18.106	113	84.32	17.228	113	increased
Total	86.18	16.048	240	83.44	20.543	240	decreased
NOTE: higher scores denote better rating							

There was one condition main effect for *learning focus* ($F(1, 231) = 3.40$, $p = .056$) where the active group rated themselves significantly higher than the control group. A time main effect resulted for *self-belief*, *time management*, *uncertain control*, and *failure avoidance* with *disengagement* approaching significance (see Table 38).

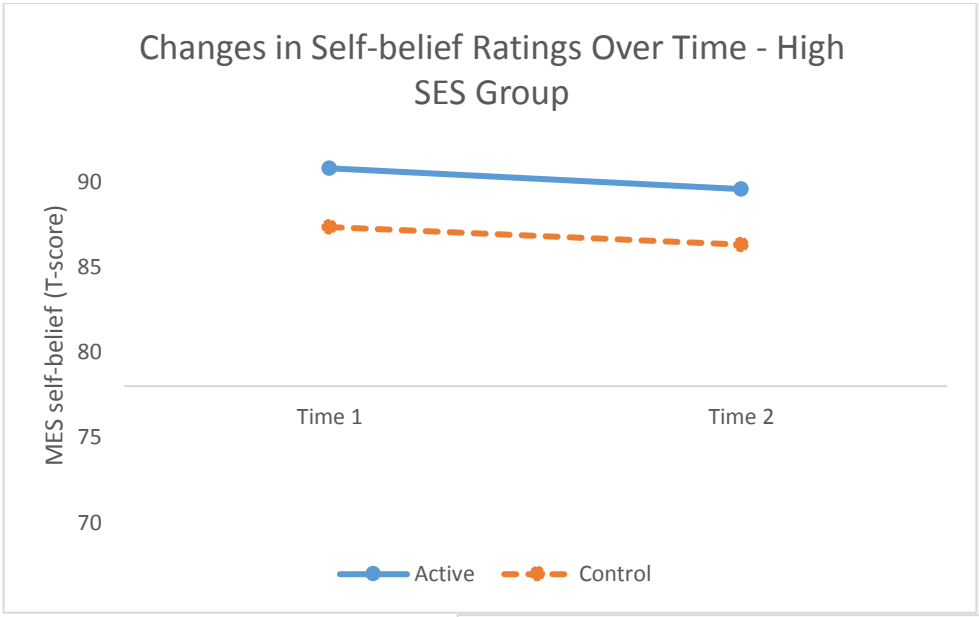
Table 38 Significant MES time main effects

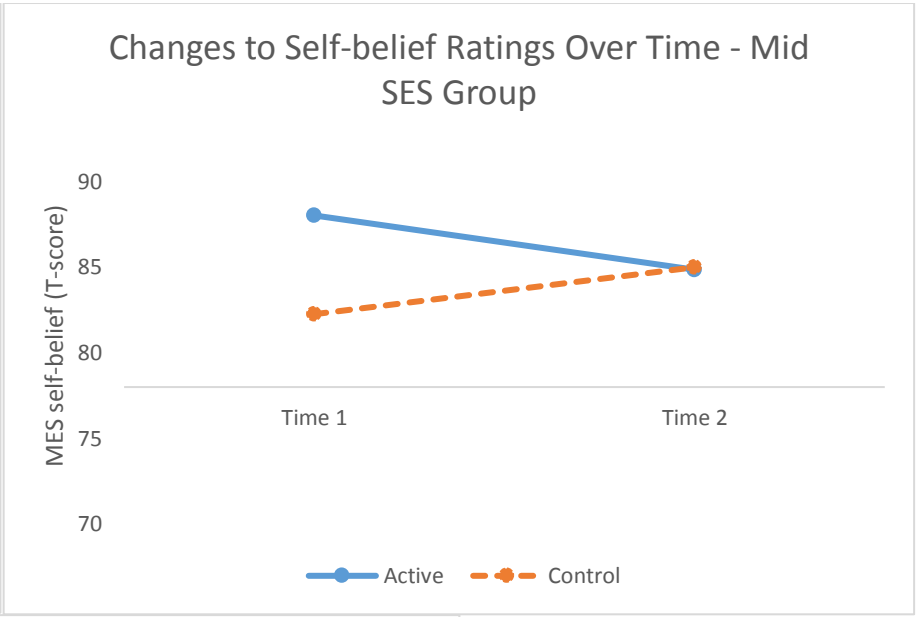
Subtest	**(Mean, SD) Time 1**	**(Mean, SD) Time 2**	**Change**
Self-belief (F(1, 238) = 3.75, p < .01	M = 86.18, SD = 16.05	M = 83.44, SD = 20.54	Negative change
Task Management (F(1, 236) = 4.63, p < .05	M = 83.16, SD = 40.99	M = 77.49, SD = 17.19	Negative change
Disengagement* (F(1, 231) = 3.68, p = .056	M = 33.56, SD = 14.94	M = 31.52, SD = 13.79	Positive change
Uncertain Control (F(1, 235) = 4.49, p <.05	M = 52.99, SD = 32.78	M = 48.48, SD = 17.46	Positive change
Failure Avoidance (F(1, 234) = 7.34, p <.01	M = 55.62, SD = 24.29	M = 51.82, SD = 23.85	Positive change
NOTE: higher score is better for items in blue, higher score is worse for items in red *** denotes approaching significance**			

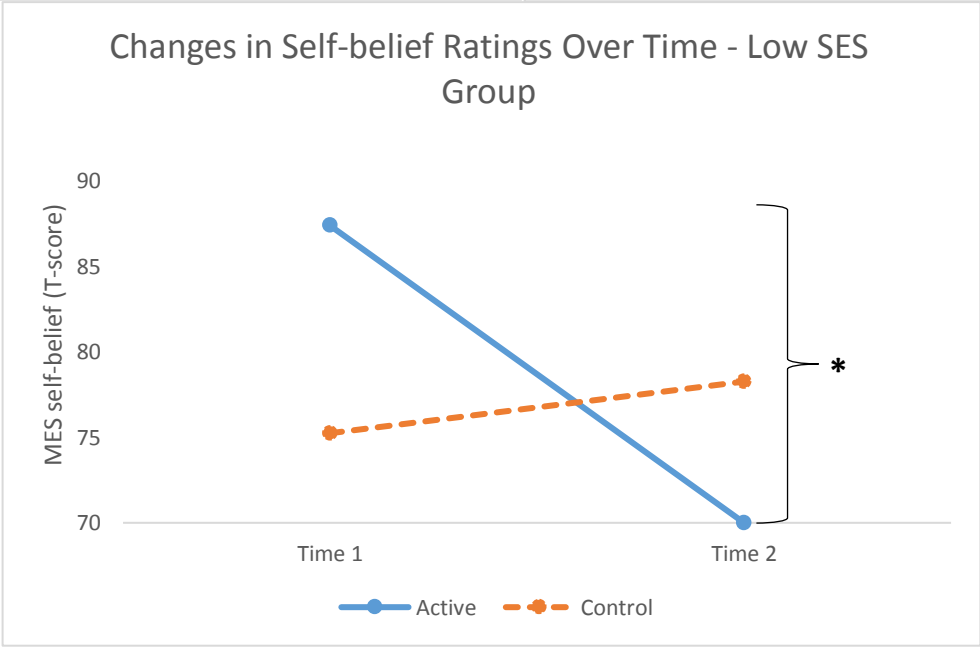
Three-Factor Analysis with Interaction (Time by Condition by SES)

There was one significant three-factor interaction, again, for *self-belief* ($F(2, 234) = 4.42$, $p < .05$) and one significant time by condition interaction, also for *self-belief* ($F(1, 234) = 11.02$, $p < 05$). Investigation revealed that the time by condition three-factor interaction, explained below, reflected the same dynamic as the two-factor interaction.

Examination of the three-factor interaction using Bonferroni corrections located the significant relationship between the low and middle SES groups (Mean Difference = -7.21, Std Error = 2.56, $p < .05$) and the low and high SES groups (Mean Difference = -10.47, Std Error = 2.54, $p < .01$). Performances by the two high groups were in parallel at Time 1 and Time 2. The middle groups were initially widely separated but converged at Time 2, while in the low group the active students rated themselves more highly than their SES peers at Time 1 and well below their peers at Time 2. (see Figure 17).







NOTE: higher scores denote better self-rating
*shows significance

Figure 17 MES self-belief estimated marginal means ratings by time, condition and SES

Significance for condition was found between the two low SES groups only ($F(1, 52) = 5.27$, $p < .05$) with the active group decreasing in personal rating over time and the control group increasing (see Table 39).

Table 39 Self-belief three-factor interaction time by condition by SES

SES	Active Time 1		Active Time 2		Control Time 1		Control Time 2		Change Over Time
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Low	87.37	15.94	70.00	36.12	75.24	22.22	78.26	27.76	Active group decreased significantly in relation to the Control
Mid	88.03	14.35	84.86	15.57	82.26	18.64	85.00	13.11	NS
High	90.78	10.28	89.56	12.05	87.33	14.55	86.30	14.13	NS

Ratings of *self-belief* aligned with levels of SES where the high SES group showed more self-belief than the middle group which showed more self-belief than the low group. Comparison of SES levels within the active cohort resulted in significant relationships between the low and middle SES groups (Mean Difference = -7.76, Std Error = 3.19, $p = .05$) and the low and high SES groups (Mean Difference = -11.48, Std Error = 3.25, $p < .01$) (see Figure 18). Comparison of the SES levels within the control cohort resulted in a significant relationship between the low and high SES groups (Mean Difference = -10.07, Std Error = 4.07, $p < .05$) with the change between these two groups over time reaching significance (see Figure 19).



Figure 18 Self-belief <u>active</u> cohort three-factor interaction
***shows significant relationship**



Figure 19 Self-belief <u>control</u> cohort three-factor interaction
***shows significant relationship**

The MES three-factor analysis resulted in significant time (see Table 40) and SES (see Table 41) main effects. *Planning* approached a condition main effect ($F(1, 7329.04) = 3.71$, $p = .055$) where the active group ($M = 93.01$, $SD = 12.10$) outperformed the control group ($M = 73.42$, $SD = 14.32$).

Improvement over time occurred for the two items measuring negative attitudes, but decreased for *self-belief* which measures a positive attitude. This pattern was also seen in the time main effect for the two-factor analysis (see Table 38, p. 220). Significant SES main effects largely occurred between low and high groups with the SES groups rating themselves in keeping with their high, middle and low SES designation (see Table 41).

Table 40 Significant MES time main effects for time by condition by SES

Subtest	**(Mean, SD) Time 1**	**(Mean, SD) Time 2**	**Change**
Self-belief (F(1, 234) = 4.56, p < .05	M = 86.18, SD = 16.05	M = 83.44, SD = 20.54	Negative
Disengagement (F(1, 227) = 4.20, p < .05	M = 33,56, SD = 14.94	M = 31.52, SD = 13.79	Positive
Failure Avoidance (F(1, 230) = 8.25, p < .01	M = 55.62, SD = 24.29	M = 51.82, SD = 23.85	Positive
NOTE: higher score is better for items in blue, higher score is worse for items in red			

Table 41 Significant MES SES main effects for time by condition by SES

Subtest	**Low to Middle**	**Middle to High**	**Low to High**	**SES Group Relationship**
Self-belief (F(1, 234) = 4.56, p < .01	p < .05	N/S	p < .01	Self-rating = High > Middle > Low
Disengagement (F2, 227) = 4.03, p < .05	N/S	N/S	p < .05	Self-rating = High > Middle > Low
Self-sabotage (F(2, 230) = 3.65, p <.05	N/S	N/S	p < .05	Self-rating = High > Middle > Low
Uncertainty (F(2, 231) = 4.04, p <.01	N/S	p < .05	p < .05	Self-rating = High > Middle > Low
Anxiety (F(2, 223) = 7.16, p < .01	N/S	N/S	p < .01	Self-rating = High > Middle > Low
NOTE: higher score is better for items in blue, higher score is worse for items in red				

Student Behaviour Rating Scale (SBRS)—Teacher Data

NOTE: item names will be italicised for clarity.

Six items on the Student Behaviour Rating Scale (SBRS) were analysed for time by condition interaction (primary hypothesis) before examining the effects of SES (secondary hypothesis). It was expected that the BBL Program would impact on aspects of self-regulation demonstrated in the *classroom behaviour*, *getting along*, *attempting tasks* and *aggression* items.

Two-Factor Analysis with Interaction (Time by Condition)

No significant differences were observed for c*lassroom* and *social skills* items in the time by condition analysis. Results for *playground*, *getting along* and *attempting tasks* all approached significance (see Table 42). There was a significant time main effect for *playground* ($F(1, 270) = 5.03$, $p < .05$) where the cohort declined over time and *attempting tasks* ($F(1, 270) = 23.88$, $p < .01$) where the cohort improved over time. A condition main effect for *aggression* ($F(1, 269) = 6.28$, $p < .05$) was found where the active group ($M = 6.41$, $SD = 0.89$) outperformed the control group ($M = 5.99$, $SD = 1.34$).

Table 42 Significant SBRS two-factor time by condition interaction

SBRS Item	Active Time 1 & Time 2	Control Time 1 & Time 2	Change Over Time
Classroom	M = 5.61, SD = 1.18 M = 5.60, SD = 1.35	M = 5.44, SD = 1.58 M = 5.57, SD = 1.37	Not significant
Playground (F(1, 270) = 3.34, p = .069)	M = 6.18, SD = 0.88 M = 5.98, SD = 1.05	M = 6.21, SD = 1.00 M = 6.19, SD = 0.91	At Time 1, the groups were on par. The active group declined overtime with the control group remaining unchanged
Getting Along (F(1, 270) = 3.27, p = .071)	M = 5.67, SD = 1.15 M = 5.70, SD = 1.20	M = 5.53, SD = 1.38 M = 5.36, SD = 1.33	The active group was better at both Time 1 and Time 2, with the active group remaining unchanged and the control group declining over time
Social Skills	M = 6.08, SD = 1.05 M = 6.01, SD = 1.03	M = 6.03, SD 1.03 M = 5.99, SD = 1.34	Not significant
Attempting Tasks (F(1, 270) = 3.15, p = .077)	M = 4.97, SD = 1.67 M = 5.36, SD = 1.32	M = 4.87, SD = 1.74 M = 5.05, SD = 1.58	Both groups improved over time with the active group improving more relative to the control group
Aggression	M = 6.49, SD = 2.32 M = 6.41, SD = 0.89	M = 6.11, SD = 1.32 M = 5.99, SD = 1.34	Not significant
NOTE: higher scores denote better performance			

Three-Factor Analysis with Interaction (Time by Condition by SES)

Significant three-factor interaction was observed for *classroom*, *playground*, *getting along*, *social skills*, and *attempting tasks*. There was no significant three-factor interaction for *aggression*.

The interaction for time by condition was significant for *getting along* ($F(1, 3.27) = 11.16$, $P < .01$) and *attempting tasks* ($F(1, 2.32) = 5.04$, $p < .05$). A significant time by SES interaction resulted for *playground* ($F(2, 2.08) = 9.30$, $p < .01$), *getting along* ($F(2, 1.84) = 6.29$, $p < .01$), and *social skills* ($F(2, 1.81) = 5.51$, $p < .01$). Except for the *playground* item, students in the active condition outperformed the control group at Time 1 and at Time 2. Both the active and control conditions improved at *attempting tasks* over time but declined in *classroom* and *playground* behaviours. Students in the active cohort improved in their *getting along* skills over time, while the control cohort declined. In contrast, students in the control cohort improved in their *social skills* while the active group declined (See Table 43).

A significant interaction for condition by SES resulted for all items. The active group outperformed the control group on every item except *playground*. When this dynamic was examined further through the three-factor analysis, in every item except *classroom*, the active low and middle groups outperformed their control counterparts while the control high group outperformed the active high group (see Table 44).

Table 43 SBRS three-factor condition by time interaction description

Subtest	**Active (Time 1 & 2)**	**Control (Time 1 & 2)**	**Condition Relationship**	**Time Effect**
Classroom (F(2, 274) = 14.62, p < .01)	M = 5.61, SD = 1.18 M = 5.44, SD = 1.58	M = 5.60, SD = 1.35 M = 5.57, SD = 1.37	**Active** outperformed **Control** at Time 1 & Time 2	**Active:** declined **Control:** declined
Playground (F(2, 266) = 59.45, p < .01)	M = 6.18, SD = 0.88 M = 5.98, SD = 1.05	M = 6.21, SD = 1.00 M = 6.19, SD = 0.91	**Control** outperformed **Active** at Time 1 & Time 2	**Active:** declined **Control:** declined
Getting Along (F(2, 266) = 50.15, p < .01)	M = 5.67, SD = 1.26 M = 5.70, SD = 1.20	M = 5.53, SD = 1.38 M = 5.36, SD = 1.33	**Active** outperformed **Control** at Time 1 & Time 2 – significant difference at Time 2	**Active:** improved **Control:** declined
Social Skills (F(2, 266) = 52.46, p < .01)	M = 6.08, SD = 1.05 M = 6.01, SD = 1.03	M = 6.03, SD = 1.03 M = 6.04, SD = 1.15	**Active** outperformed **Control** at Time 1 & Time 2	**Active:** declined **Control:** improved
Attempting Tasks (F(2, 266) = 6.83, p < .01)	M = 4.97, SD = 1.67 M = 5.36, SD = 1.32	M = 4.87, SD = 1.74 M = 5.05, SD = 1.58	**Active** outperformed **Control** at Time 1 & Time 2	**Active:** improved **Control:** improved
Aggression	M = 6.49, SD = 2.32 M = 6.41, SD = 0.89	M = 6.11, SD = 1.32 M = 5.99, SD = 1.34	**Not Significant**	**Not Significant**

Table 44 Significant SBRS three-factor condition time by condition by SES interaction description

Subtest	**SES Group**	**Condition Relationship**	**SES Group Relationship**
Classroom ($F(2, 274) = 10.73$, $p < .01$)	Low to middle Middle to high	**Active** outperformed **Control** group	High outperformed middle which outperformed low
Playground ($F(2, 266) = 8.43$, $p < .01$)	Middle to high Low to high	**Control** outperformed **Active** group	Active low and middle SES groups outperformed counterparts. Control high SES group outperformed active
Getting Along ($F(2, 266) = 10.88$, $p < .01$)	Middle to high Low to high	**Active** outperformed **Control** group	Active low and middle SES groups outperformed counterparts. Control high SES group outperformed active
Social Skills ($F(2, 266) = 7.05$, $p < .01$)	Middle to high	**Active** outperformed **Control** group	Active low and middle SES groups outperformed counterparts. Control high SES group outperformed active
Attempting Tasks ($F(266) = 13.62$, $p < .01$)	Middle to high	**Active** outperformed **Control** group	Active low and middle SES groups outperformed counterparts. Control high SES group outperformed active
Aggression ($F(2, 265) = 8.18$, $p < .01$)	Middle to high	**Active** outperformed **Control** group	Active low and middle SES groups outperformed counterparts. Control high SES group outperformed active

Behavior Rating Inventory of Executive Function (BRIEF)—Parent Data

NOTE: questionnaire items will be italicised for ease of identification.

Six subtests and three composite scores were analysed for time by condition (main hypothesis) and then for time by condition by SES (secondary hypotheses). Data were scrutinised for normality and sphericity. Bonferroni corrections were applied as required. Higher scores indicate poorer competency ratings on all BRIEF items.

The Brief data set is smaller when compared to the data sets for the CPT, Working Memory, MES and SBRS measures as data collection depended upon parents returning forms to schools (see Table 45). Therefore, the data set was skewed towards students whose families were sufficiently organised to courier paperwork to and from school and who had proficiency in written English.

Table 45 Rate of return for mesurement questionnaires

Measure	**Data Set N**
Continuous Performance Test (CPT)	288
Visual Spatial Working Memory	249
Motivation and Engagement Scale (MES)	240
Student Behaviour Rating Scale (SBRS)	271
Behavior Rating Inventory of Executive Function (BRIEF)	178

Two-Factor Analysis with Interaction (Time by Condition)

There was no significant two-factor (time by condition) interaction for any individual item on the BRIEF. *Monitoring* approached significance ($F(1, 177) = 3.64$, $p = .058$) with change occurring through decline in the active group (Time 1 M = 48.59, SD = 11.48; Time 2 M = 50.59, SD = 10.64) and no change in the control group (Time 1 M = 48.96, SD = 11.75; time 2 M = 48.70, SD = 12.39).

A significant condition main effect was observed for *emotional control* ($F(1, 188) = 12.93$, $p < .01$) with the active group outperforming the control group. A time main effect was found for *planning* with the cohort declining over time from Time 1 ($M = 51.34$, $SD = 11.47$) to Time 2 ($M = 52.80$, $SD = 10.90$) and for *initiation* with the cohort also declining over from Time 1 ($M = 51.68$, $SD = 10.71$) to Time 2 ($M = 52.77$, $SD = 10.52$).

Composite Scores – Behaviour Regulation Index, Metacognition Index, Global Executive Composite

There was no significant two-factor (time by condition) interaction when composite scores were analysed. The Behaviour Regulation Index (BRI) and Global Executive Composite (GEI) resulted in a time main effect in which the cohort declined over time on both items (see Table 46). No main effects were found for Metacognition (MI) (see Table 46).

Table 46 Significant BRIEF time main effects for composite scores

Item	**Time 1**	**Time 2**	**Change Over Time**
Composite behaviour regulation index (BRI) ($F(1, 176) = 9.43$, $p < .01$)	M = 50.18 SD = 10.45	M = 51.64 SD = 11.47	declined
Metacognition (MI)	M = 51.55, SD = 11.65	M = 55.30, SD = 39.06	NS
Composite global executive index (GEC) ($F(1, 176) = 5.74$, $p < .05$)	M = 51.04 SD = 10.84	M = 52.17 SD = 11.08	declined
NOTE higher scores denote lower performance			

Three-Factor Analysis with Interaction (Time by Condition by SES)

When SES was included in the analysis, a significant three-factor interaction was found for *initiation* and *monitoring*. *Initiation* ($F(2, 173) = 3.71$, $p < .05$) declined across the cohort from Time 1 ($M = 51.68$, $SD = 10.71$) to Time 2 ($M = 52.77$, $SD = 10.52$) with no significance difference between active and control conditions when compared across time.

However, there were significant differences between SES groups with the middle group (M = 54.27, SD = 10.43) performing worse than the high group (M = 52.65, SD = 10.03) which was worse than the low group (M = 47.53, SD = 12.34).

Monitoring ($F(2, 173) = 3.08$, $p < .05$) also showed decline across the cohort from Time 1 (M = 48.75, SD = 11.57) to Time 2 (M = 49.74, SD = 11.46). Decline was found to be in the active condition (Time 1: M = 48.59, SD = 11.48; Time 2: M = 50.59, SD = 10.64) while the control condition remained unchanged (Time 1: M = 48.96, SD = 11.75; Time 2: M = 48.70, SD = 12.39).

The three-factor interaction for *working memory* approached significance ($F(2, 170) = 2.72$, $p = .069$) with decline across the cohort from Time 1 (M = 52.53, SD = 11.23) to Time 2 (M = 53.50, SD 10.74) but with no significance between active and control conditions when compared across time. The middle SES group (M = 55.19, SD = 11.52) was rated more poorly than the high group (M = 52.72, SD = 10.38) which was rated more poorly than the low group (M = 51.53, SD = 9.33).

Significant condition by SES interaction occurred in *mental shifting* ($F(2, 186) = 3.37$, $p < .05$) and *emotional control* ($F(2, 184) = 4.00$, $p < .05$) where the middle SES group was worse than the high group which was worse than the low group in each item (see Table 47).

A significant time by SES interaction emerged for *working memory* ($F(2, 170) = 3.45$, $p < .05$) where the cohort declined over time with the low (Time 1: M = 47.41, SD = 8.25; Time 2: M = 51.53, SD = 9.33) and middle (Time 1: M = 53.37, SD = 11.77; Time 2: M = 55.19 , SD = 11.52) SES groups both rating more poorly while the high group remained stable (Time 1: M = 52.87, SD = 11.19; Time 2: M = 52.72, SD = 10.38).

The time by condition interaction for *emotional control* approached significance ($F(1, 184) = 4.96$, $p = .07$) where there was no significant overall change over time for the cohort.

However, the active cohort (Time 1: M = 45.78, SD = 16.88; Time 2: M = 44.67, SD = 18.69) outperformed the control cohort (time 1: M = 52.50, SD = 11.84; Time 2: M = 53.62, SD = 12.12).

Three-Factor Main Effects

Main effects for SES, time and condition were observed (see Tables 47-49). Except for the *inhibition* item, where performance levels reflected levels of SES, parent data resulted in the middle SES group rating more poorly than the high group which was rated more poorly than the low group. There was a general trend to rate student skills lower over time with the control group rating lower than the active group for *mental shifting* and *emotional control*.

Table 47 Significant BRIEF SES main effects for three-factor analysis

Subtest	**Low Mean & SD**	**Middle Mean & SD**	**High Mean & SD**	**SES Group Relationship**
Inhibition ($F(2, 282) = 36.75$, $p < .01$)	M = 17.42 SD = 24.62	M = 37.61 SD = 26.77	M = 46.09 SD = 14.36	High worse than middle which was worse than low
Mental Shifting ($F(2, 186) = 6.34$, $p < .01$)	M = 30.14 SD = 27.46	M = 54.01 SD = 12.34	M = 49.38 SD = 9.30	Middle worse than high which was worse than low
Emotional control ($F(2, 184) = 13.79$, $p < .01$)	M = 28.86 SD = 26.61	M = 53.06 SD = 12.68	M = 51.19 SD = 10.21	Middle worse than high which was worse than low
Monitoring ($F(2, 173) = 3.10$, $p < .05$)	M = 47.41 SD = 13.19	M = 52.16 SD = 11.63	M = 48.45 SD =10.82	Middle worse than high which was worse than low
Behaviour Regulation Index ($F(2, 172) = 3.13$, $p < .01$)	M = 49.59 SD = 13.41	M = 54.63 SD = 13.15	M = 49.88 SD = 9.30	Middle worse than high which was worse than low
Global Executive Index ($F(2, 172) = 3.00$, $p = 05$)	M = 48.88 SD = 13.00	M = 54.48 SD = 12.33	M = 51.12 SD = 9.47	Middle worse than high which was worse than low

Table 48 Significant BRIEF time main effects for three-factor analysis

Subtest	**Time 1**	**Time 2**	**Change Over Time**
Working Memory (F(1, 170) = 6.86, p = .01)	M = 52.53, SD = 11.23	M = 53.50, SD = 10.74	Declined
Planning (F(1, 172) = 7.80, p < .01)	M = 51.34, SD = 11.47	M = 52.80, SD = 10.90	Declined
Monitoring (F(1, 173) = 4.53, p < .05)	M = 48.75, SD = 11.57	M = 49.74, SD = 11.46	Declined
Behaviour Regulation Index (F(1, 172) = 8.85, p < .01)	M = 50.18, SD = 10.45	M = 51.64, SD = 11.47	Declined
Global Executive Index (F(1, 172) = 8.81, p < .01)	M = 51.04, SD = 10.84	M = 52.17, SD = 11.08	Declined

Table 49 Significant BRIEF condition main effects for three-factor analysis

Subtest	**Active**	**Control**	**Relationship**
Mental Shifting (F(1, 186) = 3.86, p = .05)	M = 45.54, SD = 18.86	M =51.58, SD = 11.40	**Active** outperformed **Control** group
Emotional Control (F(1, 184) = 15.93, p < .01)	M = 44.67, SD = 18.69	M = 53.62, SD = 12.12	**Active** outperformed **Control** group

4.2.3 Performance and Physical Factors (Sleep, Diet and Physical Activity)

As demonstrated in the literature review, sleep habits, diet and levels of physical activity are understood to impact on attention, memory and academic performance (Chaput et al., 2016, Dishman et al., 2006, Francis and Stevenson, 2013, Gómez-Pinilla, 2008, Gomez-Tolle, 2012, Meeusen, 2014). Data were collected from all student participants at baseline for diet and physical activity and, from students in the active cohort for sleep (as part of the BBL Program intervention). Results are detailed below.

Sleep

Data were collected from the active group only, using a seven-day sleep diary which was completed prior to the commencement of the sleep unit in Week 9 of the intervention. Continuous Performance Test (CPT) subtests and working memory (the main measures for this study) were analysed against aspects of sleep— quality, quantity, and pattern (i.e. regularity of hours per night)—at Time 1 to assess whether students who performed better on the computerised testing also had better sleep hygiene (secondary research question). Subtest items at when compared to CPT and working memory outcomes at Time 2 were also analysed to explore any changes that took place in executive functioning related to sleep behaviours after the BBL Program intervention which included the four-week sleep unit.

Measurement Definitions

Sleep quality can be measured in multiple ways. For the purposes of this study, quality was measured by self-reports of feeling well rested, somewhat tired or very tired. Feelings of tiredness were ranked from 1 to 3 where 1 denoted well rested, 2 was somewhat tired and 3, very tired upon waking.

Data for sleep quantity were considered in three categories to match recommended levels for the study population as: less than 10 hours/night, 10-11 hr/night (recommended levels at

commencement of study and data analysis—see p. 79 for 2016 updated guidelines), and more than 11 hr/night. It should be acknowledged here that, although beyond the scope of this work, habits that affect sleep quantity develop from birth and vary between individuals (Galland et al., 2012).

Sleep pattern was determined by the number of nights that a student achieved the same amount of sleep as measured in hours. Highly regular (ranking 1) was assigned when five or more nights recorded the same amount of sleep, regular (ranking 2) indicated between three and four nights were the same and random (ranking 3) occurred when there were two or less nights with the same recorded sleep time.

Pre-Intervention Subtest Items by Sleep Aspects (two-factor analysis)

Analysis of sleep quality, quantity and pattern by baseline CPT subtests and working memory scores at Time 1 yielded significant sleep quality interactions for commission, detection and hit rate (HRT). There were no significant interactions for quantity or pattern (see Table 50).

Table 50 Summary of significant interaction between sleep factors and main measure subtests at Time 1 and Time 2

Sleep Factor	**Time 1**	**Dynamic**	**Time 2**	**Dynamic**
Sleep quality	Commission Detection Hit rate (HRT)	Well rested students performed best for commission and detection The most tired students performed best for hit rate	Commission Detection	Well rested students performed best for commission and detection
Sleep quantity	None	None	Variability* Vigilance (HRT SD)	Performance improved with amount of sleep
Sleep pattern	None	None	Variability Vigilance (HRT SD)*	Students with highly regular sleep patterns performed worse
NOTE: * denotes approaching significance				

Significant performance differences were observed for commission ($F(19, 121) = 1.75$, $p < .05$) between ranking 1 students (not tired at all upon waking) ($M = 52.19$, $SD = 2.33$),

ranking 2 students (a little tired) (M = 55.22, SD = 8.03) and ranking 3 (really tired) (M = 62.72, SD = 6.60) where those who felt more rested performed better.

Significant performance differences for detection (F(19, 121) = 1.68, p =.05) mirrored that of commission where more well rested students performed better: not tired (M = 51.81, SD = 7.46), a little tired (M = 53.21, SD = 7.33) and really tired (M = 61.23, SD 5.26).

With hit rate (HRT) (F(19, 121) = 1.82, p < .05), the significant differences in performance pattern appeared reversed. Students who reported being really tired (M = 39.14, SD = 3.56) performed better than students who were a little tired (M = 42.29, SD = 6.78) who performed better than students who were not tired (M = 44.97, SD = 4.60). It should be noted that hit rate, examined alone, is merely a measure of response and does not indicate accuracy.

Post-Intervention Subtest Items by Sleep Aspects Interaction

Analysis of sleep quality, quantity and pattern by Time 2 (post-intervention) CPT subtest and working memory scores resulted in two significant interactions for each sleep aspect (see Table 50 above).

A significant interaction was observed between quality of sleep and both commission (F(19, 117) = 2.09, p = .01) and detection (F(19, 117) = 1.78, p < .05) but not for hit rate (HRT)—a factor at Time 1. Tiredness remained a performance indicator for both commission and detection with students who were not tired performing better than those who were a little tired who were better than those who were really tired (see Table 51).

Table 51 Significant performance interactions for sleep quality (post)

Post-Intervention	Not Tired	A Little Tired	Really Tired	Significance
Commission	M = 51.87, SD = 9.40	M = 54.30, SD = 10.17	M = 58.61, SD = 3.49	Students in the 'not tired at all' group outperformed those who were a 'little tired', who outperformed the 'really tired' group
Detection	M = 50.28, SD = 10.27	M = 54.08, SD = 7.81	M = 59.45, SD = 1.27	Students in the 'not tired at all' group outperformed those who were a 'little tired', who outperformed the 'really tired' group

A significant interaction resulted between sleep quantity and vigilance (HRT SD) ($F(2, 119) = 2.97$, $p = .05$) with the interaction between sleep quality and impulsivity control (variability) approaching significance ($F(2, 119) = 2.72$, $p = .07$).

For sleep quantity, performance scores in relation to impulsivity control (variability) improved with increased sleep. In the vigilance (HRT SD) subtest, a significant interaction was found between the students who slept less than 10 hr/night and those who slept between 10-11 hr/night with performance improving with more sleep (see Table 52). For variability, the biggest interaction was between the students who slept less than 10/night and those who slept more than 11/night with performance improving with more sleep.

Table 52 Significant performance interactions for sleep quantity (post)

Quantity	Post-Intervention Less than 10 hr/night	10-11 hr/night	More than 11 hr/night
Variability*	M = 52.77, SD = 10.87	M = 49.11, SD = 9.11	M = 47.19, SD = 8.92
Vigilance (HRT SD)	M = 55.33, SD = 12.54	M = 50.04, SD = 10.60	M = 50.06, SD = 11.93
Note: low scores denote better performance, * denotes approaching significance			

Sleep pattern had a significant interaction with impulsivity control (variability) ($F(2, 119) = 4.56$, $p < .05$) and an interaction that approached significance with vigilance (HRT SD) ($F(2, 119) = 2.72$, $p = .07$). For variability, significance lay in the relationship between the highly

regular and random groups ($p < .05$) with the random group performing better. The relationship between the highly regular and regular groups approached significance ($p = .07$) where the regular group performed better than the highly regular group. For vigilance (HRT SD), the relationship between the highly regular and the random groups approached significance ($p = 0.69$) with the random group outperforming the highly regular group (see Table 53).

Table 53 Significant performance interactions for sleep pattern (post)

Test Item	**Post-Intervention Random**	**Regular**	**Highly Regular**
Variability	M = 47.65, SD = 8.21	M = 48.99, SD = 10.02	M = 53.86, SD = 10.45
Vigilance* (HRT SD)	M = 49.16, SD = 9.79	M = 51.56, SD = 13.62	M = 55.22 SD = 10.79
Note: low scores denote better performance, * denotes approaching significance			

SES by Aspects of Sleep

Sleep data were collected at each school site using a 7-day diary. The return rate of sleep diaries varied in keeping with SES levels as shown in Table 54.

Table 54 Breakdown of seven- day sleep diaries returned

SES Level	**Number of Students**	**Sleep Diaries Returned**	**Percentage**
Low SES	39	19	48.7%
Mid SES	56	50	89.3%
High SES	57	55	96.5%
Total	152	124	81.6%

As sleep data were only collected from students in the active cohort, it was not possible to analysis for change by condition. However, the three aspects of sleep were examined for any interaction with SES.

Sleep Quality

There was a significant interaction for sleep quality ($F(2, 119) = 4.38$, $p < .05$) along SES lines with students in the high ($M = 1.69$, $SD = 0.43$) and middle ($M = 1.80$, $SD = 0.51$) SES

groups reporting a significantly better quality of sleep than those in the low SES group (M = 2.08, SD = 0.52) (see Figure 20). NOTE: lower numbers denote more well rested students.

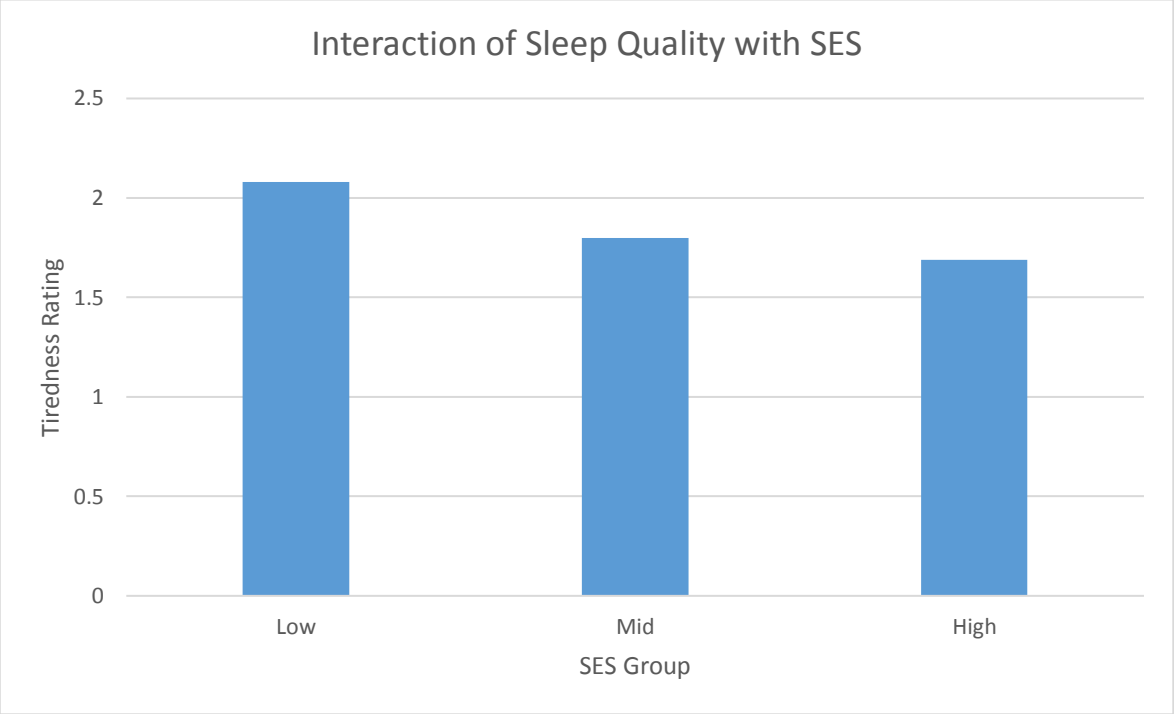


Figure 20 Illustration of sleep quality by SES interaction
NOTE: higher scores denote students felt more tired

Sleep Quantity

The relationship between sleep quantity and SES was significant ($F(2, 123) = 4.03$, $p < .05$) with significance occurring between students who slept less than 10 hr/night (M = 2.10, SD = 0.78) and those who slept more than 11 hr/night (M = 2.65, SD = 0.49) ($p < .05$) in the low SES group. There was no significant relationship with the group receiving 10-11 hr/night (M = 2.34, SD = 0.68).

Table 55 provides a breakdown of the study population in terms of average sleep quantity and SES. The highest percentage for students who failed to get the recommended amount of sleep (i.e. slept less than ten hours per night) was in the low SES group (62.3%). Both the middle and high SES groups had a large percentage of students achieving the recommended average amount of sleep, at 42.3% and 45.8% respectively.

Table 55 Sleep quantity by SES at baseline

Sleep Quantity	Low SES	Middle SES	High SES	Total % Study
< 10 hr/night average	N =12	N = 19	N = 17	N =48
(Percentage of Study)	(25%)	(39.6%)	(35.4%)	(100%)
Percentage of SES Group	63.2%	38%	30.9%	
10-11 hr/night average	N = 7	N = 25	N = 27	N = 59
(Percentage of Study)	(11.9%)	(42.3%)	(45.8%)	(100%)
Percentage of SES Group	36.8%	50%	49.1%	
> 11 hr/night average	N = 0	N = 6	N = 11	N = 17
(Percentage of Study)	(0%)	(35.3%)	(64.7%)	(100%)
Percentage of SES Group	0%	12%	20%	
Total SES Group	100%	100%	100%	

There were no study participants in the low SES group who slept more than eleven hours per night. Most study participants who slept more than eleven hours were from the high SES group (65.7%). The percentage of students who slept less than ten hours per night or who slept between ten to eleven hours per night showed little variation between the middle and high SES groups.

Sleep Pattern

The relationship between SES and sleep pattern was significant ($F(2, 123) = 4.32$, $p < .05$). Significance was found between sleepers with highly regular ($M = 2.05$, $SD = 0.78$) and regular sleep patterns ($M = 2.47$, $SD = 0.59$) with more highly regular sleep patterns occurring in the high SES group. There was no significance found in relation to sleepers with a random pattern ($M = 2.38$, $SD = 0.72$).

Sleep Summary

When the three sleep factors were analysed with elements from the Continuous Performance Test and Working Memory subtest, each factor returned a significant interaction with two subtests. Sleep quality affected commission and detection responses in both pre- and post-intervention testing and hit rate in the pre-intervention condition. In the post-intervention

analysis, sleep quantity and sleep pattern both resulted in significant interactions with vigilance (HRT SD) and variability (input change and impulsivity).

For sleep quality, performance improved with sleep, except for the interaction with hit rate where performance decreased with sleep quality at Time 1 only. For sleep quantity, sleeping the recommended amount at the time of this study's design and analysis (i.e. 10-11 hours per night) delivered better results that either sleeping less than or more than 10-11 hours. For sleep pattern, students who had highly regular sleep patterns appeared to be the worst performers on CPT subtests. Using SES as a fixed factor, a significant interaction was found for sleep quality, sleep quantity, and sleep pattern where students in the low SES group had the poorest quality, quantity and pattern of sleep coupled with poorer cognitive performance.

Descriptive Data from Diet and Physical Activity Measures

Data from diet and physical activity measures were included in this study to solely provide a descriptive picture of the cohort because of their known importance for optimal brain function (Francis and Stevenson, 2013, Meeusen, 2014). Although referenced throughout the BBL Program intervention, unlike sleep, there are no specific units of work on either diet or physical activity. As well, data on physical activity and diet were collected only at baseline since it was never the intent to explore either as change agent in the present study.

Modified Child Nutrition Questionnaire

Not all students responded to all questions on the Modified Child Nutrition Questionnaire (MCNQ). Table 56 demonstrated the total number of student responses per MCNQ item.

Table 56 Total number of student responses per MCNQ item

MCNQ Item	Total Student No
Attitude to healthy eating	266
Food environment	270
Healthy behaviour	268
Water intake	269
Non-core food intake	269
Fruit intake	269
Vegetable intake	266
Sweetened drink intake	269

Two-factor Analysis

Modified Child Nutrition Questionnaire (MCNQ) test items were analysed with items from the Continuous Performance Test (CPT), the main measure of this study. The items on the MCNQ have been divided into two categories for ease of analysis and description. The first category contains items of behaviour and includes *attitude to healthy eating*, *food environment* and the practice of *healthy eating*. The second category includes items that refer to food consumption and includes *water intake*, *non-core foods intake*, *fruit intake*, *vegetable intake*, and *sweeten drink intake*.

Category One Items

Significant interaction was found between MCNQ items and CPT subtest for *attitude to healthy eating* and *healthy behaviour* but not for *food environment* (what healthy food were readily available to students) (see Table 57). Results demonstrated that students reporting healthy attitudes and actual behaviours were better performers on the measures of attention.

Category Two Items

Significant interaction was found between MCNQ items and CPT subtests for *water intake* (i.e. the amount of water a person drinks during the day), *non-core foods intake* (i.e. foods outside the five core food groups of carbohydrate-rich, vegetables, fruits, dairy and high-protein (Johnson et al., 2011)), *fruit intake* (sweet, edible parts of plants including citrus,

melons, berries, stone fruit, tropical fruits, apples, pears, tomatoes and avocados(National Health and Medical Research Council, 2013)) and *vegetable intake* (edible plants or plant parts including legumes, marrows, allium, cruciferous, root and leafy green plants (National Health and Medical Research Council, 2013)). No significance was found for *sweetened drinks* once outliers were removed. Students with better eating habits and good levels of water intake performed better on CPT subtests (see Table 58).

Table 57 Significant interactions between MCNQ items and CPT subtests – category one items

MCNQ Item	CPT Subtests	Below Level	At Level	Description of Significance
Attitude to healthy eating	Sustained attention (HSE ISI) ($F(35, 259) = 193.05$, $p < .01$)	64	196	The group at healthy level outperformed the group below healthy level.
Food environment	None	N/A	N/A	None
Healthy behaviour	Detection* ($F(24, 267) = 215.98$, $p = .06$) Commission ($F(24, 261) = 148.14$, $p < .05$)	201 195	67 67	The group at healthy level outperformed the group below healthy level for both subtests.

Table 58 Significant interactions between MCNQ items and CPT subtests – category two items

MCNQ Item	**CPT Subtests**	**Description of Significance (Benchmark levels are verified parameters of the MCNQ test** (Wilson et al., 2008).
Water intake	Vigilance (HRT SD) (F(4, 262) = 325.13, p, .05) Variability (F(4, 262) = 307.09, p = .05)	Group 4 was the benchmark for healthy intake as defined by the Modified Child Nutrition Questionnaire manual. The dynamic was the same for the interaction between water intake with vigilance and with variability. Performance differed significantly between the group with minimal water intake levels (Group 2) and the group demonstrating healthy levels of water intake (Group 4). Subtest performance was significantly greater in Group 4.
Non-core foods intake	Sustained attention (HSE ISI) (F(26, 262) = 194.50, p < .05)	There were 15 students at healthy levels and 248 below. Significance occurred between high and low scoring students within the group below the healthy benchmark.
Fruit intake	Detection (F(5, 268) = 574.10, p < .01) Omission (F(5, 262) = 248.30, p < .05)	Group 3 was the benchmark for healthy intake. (Detection) There was a significant relationship between the group which consumed minimal amounts of fruit during the week (Group 1) and all other groups, except the group which consumed no fruit (Group 0). Group 1 outperformed all others. (Omission) Significance for omission was between minimal fruit eaters (Group 1) and those who ate no fruit (Group 0), with Group 1 outperforming Group 0.
Vegetable intake	Variability (F(6, 259) = 318.16, p < .05) Fatigue management (HRT ISI) (F(6, 259) = 248.01, p < .05)	Group 3 was the benchmark for healthy intake. (Variability) Significant performance difference was between Groups 4 & 5, with Group 4 performing better. (Fatigue) Significant performance difference was between Groups 1 and 4, with Group 4 performing better.
Sweetened drinks intake	None	None
NOTE: * denotes approaching significance		

MCNQ and SES Interaction

MCNQ test items were also analysed with items from the Continuous Performance Test (CPT) and SES, using SES as a fixed factor. Responses to the *healthy behaviour* item were significant for SES ($F(2, 267) = 5.62$, $p < .01$). Interaction approached significance for *attitude to healthy eating* ($F(2, 268) = 2.84$, $p = .06$) and for *food environment* (i.e. what healthy foods were readily available to students) ($F(2, 268) = 2.58$, $p = .07$).

Food environment and *healthy behaviour* were significant along SES lines, with the high SES group scoring higher in terms of positive healthy responses than the middle group which was higher than the low group. However, on the *attitude to healthy eating* item, significance was caused by the middle group being higher than both the low and high groups (see Table 59). There was no significant SES interaction with *water intake*, *non-core food intake*, *fruit intake*, *vegetable intake* or *sweetened drinks intake*.

Table 59 Significant MCNQ means and standard deviations for two-factor interaction with SES

Questionnaire Item	SES Group	Mean	SD	Meaning
Attitude to Healthy Eating	Low	18.79	8.45	More middle SES students responded above the test's targeted healthy values benchmark than in the other two groups.
	Middle	21.03	7.74	
	High	18.91	5.62	
Food Environment	Low	9.95	3.93	The most access to healthy foods was in the high SES group.
	Middle	10.67	3.26	
	High	11.12	2.77	
Healthy Behaviour	Low	12.36	6.44	The high SES group reported more healthy behaviours.
	Middle	13.38	4.90	
	High	14.78	2.99	
NOTE: higher scores denote healthier behaviours				

MCNQ, SES and CPT Three-factor Interaction

MCNQ test items were also analysed with items from the Continuous Performance Test (CPT) and SES. *Attitude to healthy eating* and *healthy behaviour* resulted in significant interaction for several items (see Table 60). On all items of significance, students in the middle SES group had more responses reflecting positive healthy eating attitudes than those in either the low or high groups. Attitudinal data contrasts with actual CPT test performance which followed SES lines for each test item (see Table 61).

Table 60 Significant interactions for MCNQ with CPT items

MCNQ Item	CPT Item	Significance	Percentage of Positive Healthy Eating Responses		
			Low	**Middle**	**High**
Attitude to Healthy Eating	Detection	(F(36, 265) = 1.64, p < .05)	73	80	72
	Sustained Attention (HSE ISI)	(F(35, 259) = 1.70, p < .01)	75	80	71
	Working Memory	(F(36, 264) = 1.55, p < .05)	76	80	72
Healthy Behaviour	Detection*	(F(24, 267) = 1.51, p = .06)	20	26	18
	Commission	(F(24, 261) = 1.62, p < .05)	21	26	18
	Working Memory	(F(24, 266) = 1.98, p < .01)	73	80	72
NOTE: * denotes approaching significance; higher scores denote healthier behaviours					

Table 61 Response scores for CPT items only demonstrating impact of SES on performance

Questionnaire Item	SES Group	Mean	SD
Detection (**Low** score = better performance)	Low	53.85	12.26
	Middle	52.04	13.28
	High	51.36	11.64
Commission (**Low** score = better performance)	Low	54.78	8.10
	Middle	54.08	11.29
	High	52.64	9.28
Sustained Attention (HSE ISI) (**Low** score = better performance)	Low	54.71	12.33
	Middle	51.21	11.91
	High	50.07	9.59
Working Memory (**High** score = better performance)	Low	152.33	49.26
	Middle	154.83	49.84
	High	164.09	36.41

Physical Activity Questionnaire for Older Children

Two-factor Analysis

Items from the Physical Activity Questionnaire for Older Children (PAQ-C) were analysed with subtests from the Continuous Performance Test (CPT) and working memory test, the main measures of this study. Resulting interaction between the two measures was found for the items *recess*, *lunch*, *after school*, *evening*, *weekends*, *activity last week* and the total PAQ-C score. There was no significant interaction for *physical education classes* or *frequency of activity* (see Table 62). Students were assigned to group levels as directed by the testing manual (Kowalski et al., 2004).

Table 62 Significant interaction between PAQ-C items and CPT subtests

PAQ-C Item	CPT Subtest & Significance	Group*	Mean	SD
Physical Education	Not significant			
Recess	Detection (F(5, 3261) = 308.03, p = .05)	1 2 3 4 5	54.23 45.40 54.97 52.33 52.17	6.28 20.69 11.51 9.83 10.58
Lunch	Sustained attention (HSE ISI) (F(4, 256) = 300.16, p < .05)	1 2 3 4 5	58.54 49.18 51.14 49.11 52.52	8.06 10.04 12.76 9.97 11.56
	Commission* (F(4, 256) = 213.69, p = .07	1 2 3 4 5	50.29 59.31 53.88 53.21 52.68	10.24 4.92 9.81 9.28 10.69
After School	Hit Rate (F(4, 256) = 197.60, p = .05)	1 2 3 4 5	50.58 44.54 46.76 45.67 46.02	10.79 7.97 9.33 8.29 9.37
	Sustained attention (HSE ISI) (F(5, 256) = 409.00, p < .01)	1 2 3 4 5	54.40 50.01 49.27 48.57 55.04	11.11 8.91 10.98 9.73 12.83
Evening	Fatigue management (HRT ISI) (F(5, 256) = 288.45, p < .05)	1 2 3 4 5	51.87 48.63 50.44 51.38 56.07	11.23 9.13 9.99 12.06 12.06

Weekend	Vigilance (HRT SD) (F(4, 259) =379.70, p <.05)	1	59.63	14.23
		2	53.85	12.77
		3	50.63	10.01
		4	52.89	11.05
		5	52.09	11.30
	Variability (F(4, 259) = 408.41, p < .05)	1	58.23	13.57
		2	52.10	11.50
		3	48.85	11.48
		4	50.33	11.71
		5	50.81	10.38
	Fatigue management (HRT ISI) (F(4, 259) = 281.66, p =.05)	1	54.44	10.96
		2	52.69	11.98
		3	48.96	9.98
		4	51.75	11.21
		5	53.80	11.14
	Sustained attention (HRT ISI) (F(4, 259) = 359.57, p <.05)	1	55.04	15.51
		2	52.44	11.17
		3	48.41	9.41
		4	53.77	11.63
		5	51.80	11.02
Activity Last Week	Vigilance (HTR SD) (F(4, 259) = 343.06, p < .05)	1	56.00	12.17
		2	52.79	10.91
		3	48.92	9.87
		4	53.89	13.01
		5	53.54	11.40
Frequency of Activity	Not significant			
PAQ-C Total Score	Omission (F(4, 259) = 398.53, p < .01)	1	65.83	16.73
		2	51.99	12.35
		3	49.03	9.05
		4	51.27	11.82
		5	48.54	5.21
***NOTE: Group levels indicate levels of activity with higher numbers denoting more activity. Group assignment was defined by the testing manual.**				

On each item of the PAQ-C, students were asked to rate their levels of activity on a scale of 1-5. Higher scores indicated a more physically active student. In contrast, lower scores on the CPT subtest indicated better performance.

Students reported activity levels between 32 and 139, being the number of activities they engaged in during the week. There was a trend for students who did no physical activity to score poorly in comparison to the rest of the cohort on all CPT items that resulted in significance. Students in Group 3 (i.e. those who reported physical activity across most

PAQ-C items but were neither inactive or involved in specialist athletic training such as gymnastics or distance running) tended to achieve the best scores on the CPT (see Figure 21).

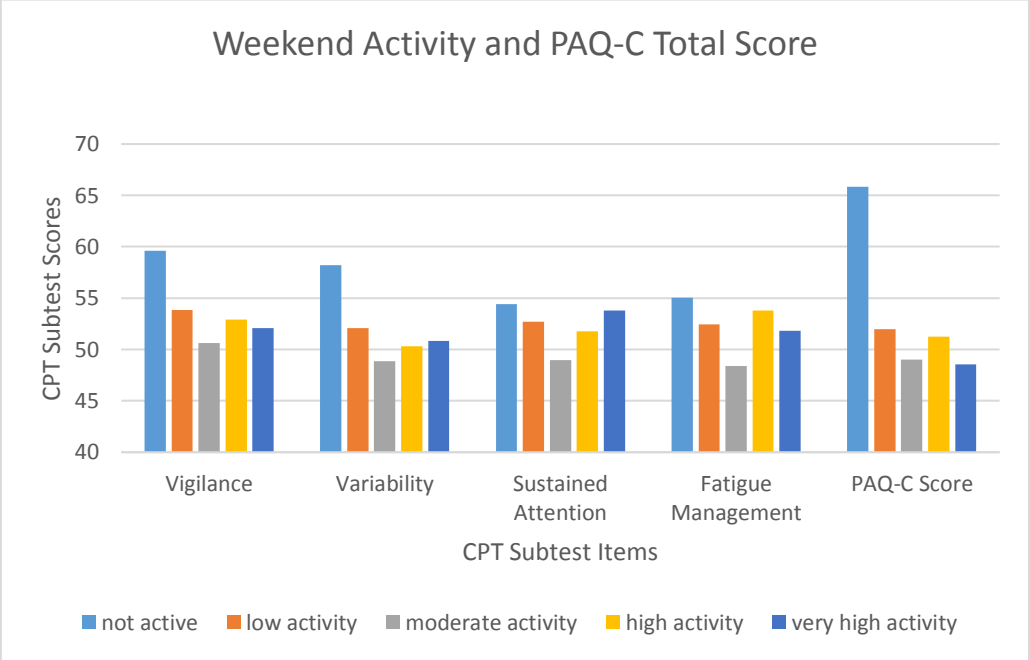


Figure 21 Sample of significant items from CPT and PAQ-C interaction
(lower score denotes better CPT performance)

PAC-Q and SES

Students reported activity levels across a wide range, between low activity levels (where little to no physical activity was undertaken) to highly active (where students were involved in multiple sporting activities and/or specialist training more than once a week), in each SES group, with students in the high group being marginally more physically active than the middle group. Both the high and middle groups were noticeably more active than the low group (see Table 63).

Table 63 PAQ-C activity levels by SES groups

SES Group	PAQ-C Activity Levels
Low	32 - 120
Middle	50 - 130
High	47 - 139
NOTE: high scores denote high levels of activity, maximum possible score = 180	

Data regarding physical activity were analysed using SES as a fixed factor. *Leisure* ($F(2, 291) = 5.44$, $p < .01$), *activity last week* ($F(2, 264) = 6.71$, $p < .01$), *frequency* ($F(2, 264) = 4.43$, $p < .01$) and total *PAQ-C score* ($F(2, 265) = 5.61$, $p < .01$) resulted in significant interaction with SES. No significance was found for *PE lessons*, *recess*, *lunch*, *after school*, or *evening* items.

Using the group mean data to determine interaction dynamics, only *frequency of physical activity* was significant along SES lines with the high SES group being the most active and the other two groups showing about the same levels of activity. For *leisure*, *activity last week* and total *PAQ-C score*, the middle SES group scored lower than the other groups and significantly lower than the high SES group on all items (see Table 64).

Table 64 Significant PAQ-C means and standard deviations

Questionnaire Item	SES Group	Mean	SD
Leisure	Low	35.15	18.48
	Middle	33.75	13.33
	High	40.00	12.42
Activity Last Week	Low	2.98	1.37
	Middle	2.72	1.38
	High	3.39	1.19
Frequency	Low	20.10	9.12
	Middle	20.43	7.05
	High	23.15	7.27
PAQ-C Score	Low	86.57	20.77
	Middle	80.86	16.34
	High	89.60	19.57

The high SES group was the most highly active overall. While the range of activity levels reflected SES levels, further exploration indicated that the number of individual students in each group who were moderately active was greater in the low SES group when compared to the middle group but not when compared to the high group.

When items for physical activity were analysed with items from the Continuous Performance Test (CPT), the main measure of this study, significant interaction was found for *leisure* with

input change/impulsivity (variability) ($F(46, 281) = 1.50$, $p < .05$), *activity last week* with vigilance (HRT SD) ($F(4, 259) = 2.66$, $p < .05$) and total *PAQ-C score* with fatigue management (HRT ISI) ($F(76, 260) = 1.44$, $p < .05$). Each interaction indicated that students who were more active managed the relevant aspect of the CPT better than those who were less active. There was nothing of significance for *PE lessons*, *recess*, *lunch*, *after school*, *evening* or *frequency of activity*.

Summary of Diet and Physical Activity Quantitative Results

With both diet and physical activity, better performance was linked to positive patterns. Students who reported healthy eating attitudes, eating behaviours, and good levels of water intake returned better scores on the CPT. Better cognitive results occurred in keeping with SES levels for food environment and healthy eating behaviours. Surprisingly, items concerning attitudes to healthy eating were found to be highest in the middle SES cohort, although this did not translate into better performance on the CPT.

In relation to physical activity, low activity was found to correlate with poorer performance on the CPT. Interestingly, students in the middle range of activities levels (i.e. not inactive but not involved in specialist athletic training, such as gymnastics or distance running) were the best performers. In terms of SES, students in the high SES cohort were the most active. However, exploration of the number of individuals in each SES group revealed a surprise. Here, the number of individuals who were inactive in the middle SES group was lower that the number in the low group and significantly lower than the high group.

4.3 Qualitative Results

> People in the programme might choose to make an intervention work or not work, and teachers' and students' motivations in, commitments to, and involvement in an intervention might be the critical factors (Morrison, 2001, p. 73).

The present research was created as a program feasibility study. Its main aim was to determine whether the BBL Program held any value to schools other than those for which it was created. In other words, was the BBL Program portable according to the characteristics outlined by Durlak and Du Pre (2008) and described in Section 2.2.6. The Quantitative Results section is divided into three parts. Section 4.3.1 explains the process used to analyse the teacher and student data and presents the collated results. Section 4.3.2 examines the themes that emerged in the data and Section 4.3.3 outlines quantitative data provided from the researcher's experience as the program presenter.

4.3.1 Collated Data

The post-intervention focus group process resulted in six teacher transcripts from eight teachers, with two transcripts containing input from two teachers participating in the same interview. This was arranged by the school sites and interviewer as a means to best manage class disruptions and accommodate the interviewer's schedule. Six student transcripts from twenty-four students were also generated. Information derived from this process was transferred to comparative tables for teachers and students. (See Table 65 BBL program teacher coded data, p. 259 and Table 66 BBL program student coded data, p. 262.)

The coding process, outlined in Chapter 3, delivered a 93% consistency level where both coders independently responded to the same pieces of text for the twelve transcripts—although code descriptor types varied. A coding meeting was held to discuss the variations.

As a result, this researcher constructed a comparative table to identify gaps or significant discrepancies in coding based on the work of Rossman and Rallis (2003) (see Appendix 11). Through this process, it became clear that coding variations were generally explained by coders switching between the types of content descriptors used in their personal interpretation of text items. That is, coders responded to individual pieces of text by variously attributing codes that summarised a concept, captured an essential point, reflected an emotional response (either from the respondents or from the coder) or highlighted a central theme—all quite acceptable coding responses within qualitative analysis (Creswell, 2013, Rossman and Rallis, 2003, Saldaña, 2012). Text was analysed under both headings where emphasis varied between coders (e.g. one coder interpreted the data as a concept summary and the other saw the text as an emotional response). No negative data were collected through the teacher interviews, despite the interviewer having no vested interest in the project and the use of an open-ended questioning format (see Appendix 10).

Table 65 BBL program teacher coded data

	Skills/Attributes	Attitudes	Feelings	Behaviour	Knowledge
Description (program)	Good quality (2) Fantastic resources (3) Variety of resources (2) Novelty Flexibility of delivery Responsive delivery Differentiation Resources easily attainable Resources accessible (2) Resources supported program Regular & weekly important Lovely resources Engaging resources Resources well pitched Consistency Sustained over time Explicit lessons Interactive Useful resources Useful discussions	Students enjoyed Impressed Students valued it Talking about 'self' is engaging Impressed with observable change in students Loved it Students loved it (3) Appropriate level Valuable to students (2) Pertinent Useful Powerful to learn from peer (teacher learning) Good Great Students loved games/activities Students liked hands-on	Fantastic (2) Engaging Students were intrigued Brilliant Enjoyment Enjoyed it Sad at end Fortunate Respect Rapport Interesting	Students responded well (2) Excitable Engaged (4) Students responded from the beginning Students eager (3) Students really positive Helped students develop focus, staying on task, self-regulation Students wanted to practise games Compliant Listening Wanting to engage	Students learned a lot Students took a lot out of it Teachers could observe students and see the engagement/deeper understanding Students understood selves as learners Student learning transferred to academics & behaviour Students developed conscious awareness of factors that make a good learner BBL language Students got it
Description (presenter)	External to school important Vibrant Exciting Excellent delivery (3) Had relationship with students (2) Good behaviour management Superb manner	Presenter attributes helped engagement	Amazing	Students rewarded presenter Students missed presenter at end of intervention Facilitation Students responsive	Facilitator content knowledge

	Stabilising influence Good presence with students Good background knowledge & specific skills Used memory strategies for learning names Good scrounger Good lateral thinker Outside authority Personalised approach Honest Truthful				
Comparison **(any noted changes ascribed to the BBL Program)**	Think Patience Persistence Observation Focus Teachers improved skills Teachers can apply Teachers given language Teacher learning re activities, engagement, student management	Suitable for all students (6) All gained (5), some more Lower skilled gained more (2) Current capacity dictated gains Student responses differed from staff expectation Student change in attitude to failure/mistakes Students with more skills gained more Gender differences in expressing learning Hard to isolate why students develop		Teachers using language (2) Teachers using management strategies Teachers using resources Teachers shared BBL resources (3) Student engagement was different-not more or less Students applying vocabulary Students controlling own behaviour Refer to posters Keep posters on display Student change Student change rapid Students remembered lessons Teachers referenced lessons	Awareness of rescuer attitude in contrast to BBL Student knowledge enable self-control Teachers developed knowledge (3) Teachers learned strategies for engagement (2) Understand attention capacities Students understood why focus, sleep, diet were important Students understood purpose Students understood difficult concepts via activities

Prediction **(including suggested changes)**		Program-No difficulties Future participation –yes (6) Delivery by others – yes (3) More staff time with Donna BBL should be a priority (2) Donna to coach Need 3 Donnas Problem with non-Donna rollout = facilitator quality, skills, resources, funding, time to learn	Donna to come back Do BBL Program for whole year	Should have videoed lessons	Need background knowledge (2) Need time to get resources together

Table 66 BBL program student coded data

NOTE: changes to headings--student responses made differentiation of skills and behaviour challenging in the comparison phase. Attempts to differentiate did not add to the overall analysis.					
	Skills and Behaviour	**Attitudes**	**Feelings**	**Games/Activities Recalled**	**Knowledge**
Description (program)	Good lessons Fun lessons Helpful (2) Helpful in real life Active Educational	Liked lessons 'really enjoyable and fun to learn.' Pretty awesome Educational Active No 'books or 'work' Brilliant Liked challenge in some activities	Good (6) Really good Fun (5) Interesting (2) Very interesting Excited	N/A	
Description (presenter)	Teaches step-by-step	More lessons with presenter Presenter would make lessons fun (like spelling) Presenter always challenging	Upset when presenter left	N/A	
Comparison (any noted changes ascribed to the BBL Program)	Patience (13) To learn from mistakes Maintaining concentration/dealing with distraction (4) Use a story as a memory aide Can recognise emotions Concentration (4) Learned to memorise/ Memory skills (8) Self-assessment '…practice to be a good person'	Student remembers being successful Uses in class Uses in school work 'Well, I reckon we all want to do it again.'		Marshmallow Test (6) Squeaky Toy Orchestra (5) Bop It (3) Squeaky Toy Listening Brain Balance Mindfulness Exercise with chocolate freckle (3) Wooden puzzles (2) Box & Bag Listening (2) Excited (emotion) Meter (6) 'It was like a stress clock.' Toy neuron Robot, Robot Game (4) Make a story memory trick (2)	Learnt a lot of stuff 'I learnt quite a lot about how your body's formed & what happens in your brain.' Learned about the body & brain Useful self-talk/reframing of situation Games helped build skills

	Learned to relax while concentrating Learned not to be distracted (2) Learned how to control ourselves over really, really hard things Learned listening classroom & home Self-control how to remember more things and to control yourself more when you're in class.' 'I learned to keep my brain good by being active and sleeping at the right time.' Useful self-talk/reframing of situation Listening to instructions Don't react to everything Trust teachers to do their job re other students' behaviour Relaxation			Chunking repetition Path Game (memory website) Nouns & Verbs Chalk Game (2) Sleep & Nightmares Emotional control by reframing situations Optical illusions (3) Sleep & blue light Two Teacher Talk (2) 3 Puppet Game Noun-Verb Ball Pass Thumb Wrestling Connect Ball Moving Memory Game Hidden Pictures Bubble Shower Sleep & learning Deep breathing Standardised CPT test Dealing with distractions (4) Mood monitor	
Prediction (including suggested changes)	More lessons More games that can be connected to one another Learn new games More games/activities More strategies for 'keeping your memory' 'even longer' (not sure if this means individual lessons longer or having the lessons over a longer period of time?)	Sitting too long (2) Movement Donna come back All students in class to listen and manage themselves 'I don't think there's much. It was that good.'	Sense of unfairness related to missing out on doing certain activities		Longer to work on things (note: varies across SES) Sometimes you need more explanation More 'science-y' things like 'put things in tubes' Taught us more about the brain – like using a giant model of the brain that we could walk into

4.3.2 Outline of Emergent Themes

Information from the transcripts provided three basic, five organisational and three global themes. The terms reported in the following analysis and in the Venn Diagram (see Figure 23, p. 265) are verbatim words and phrases used in teacher interviews and student focus groups. Information from all data was used to construct the themes as determined by the coders presented in Figure 22, following.

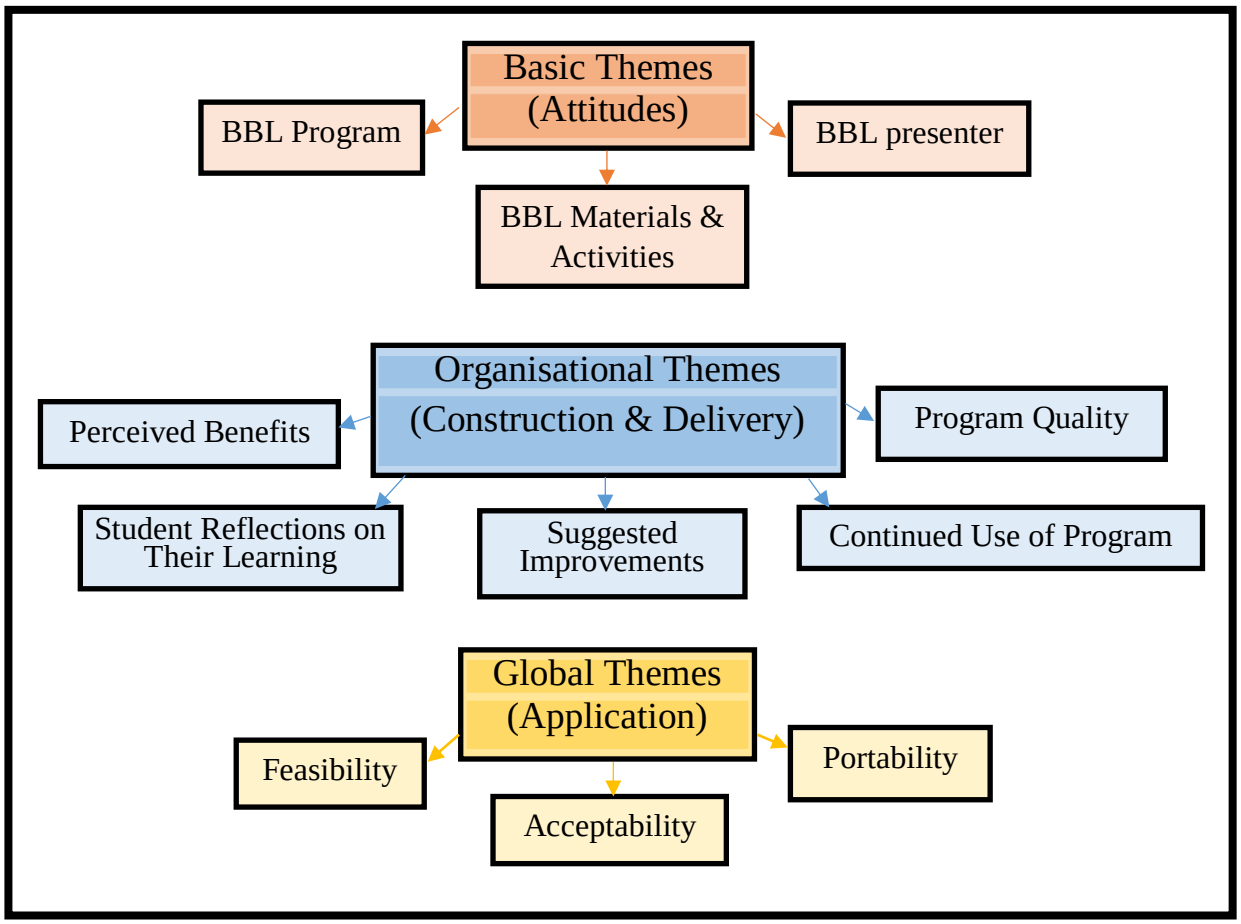


Figure 22 Emergent qualitative theme structure

Basic Themes

Data from both teacher and student interviews reflected attitudes about the BBL Program, the presenter (i.e. this researcher), and BBL Program materials. Overall, the data positively supported BBL Program delivery and contents.

Attitudes to the Program

Both teachers and students expressed positive attitudes to the BBL Program. Many comments reflected emotional reactions to the sessions, for example, "fun". However, these were balanced by comments regarding specific usage and perceived learning. When compared, teacher and student data contained quite different perspectives and overlapped on three points only (see Figure 23).

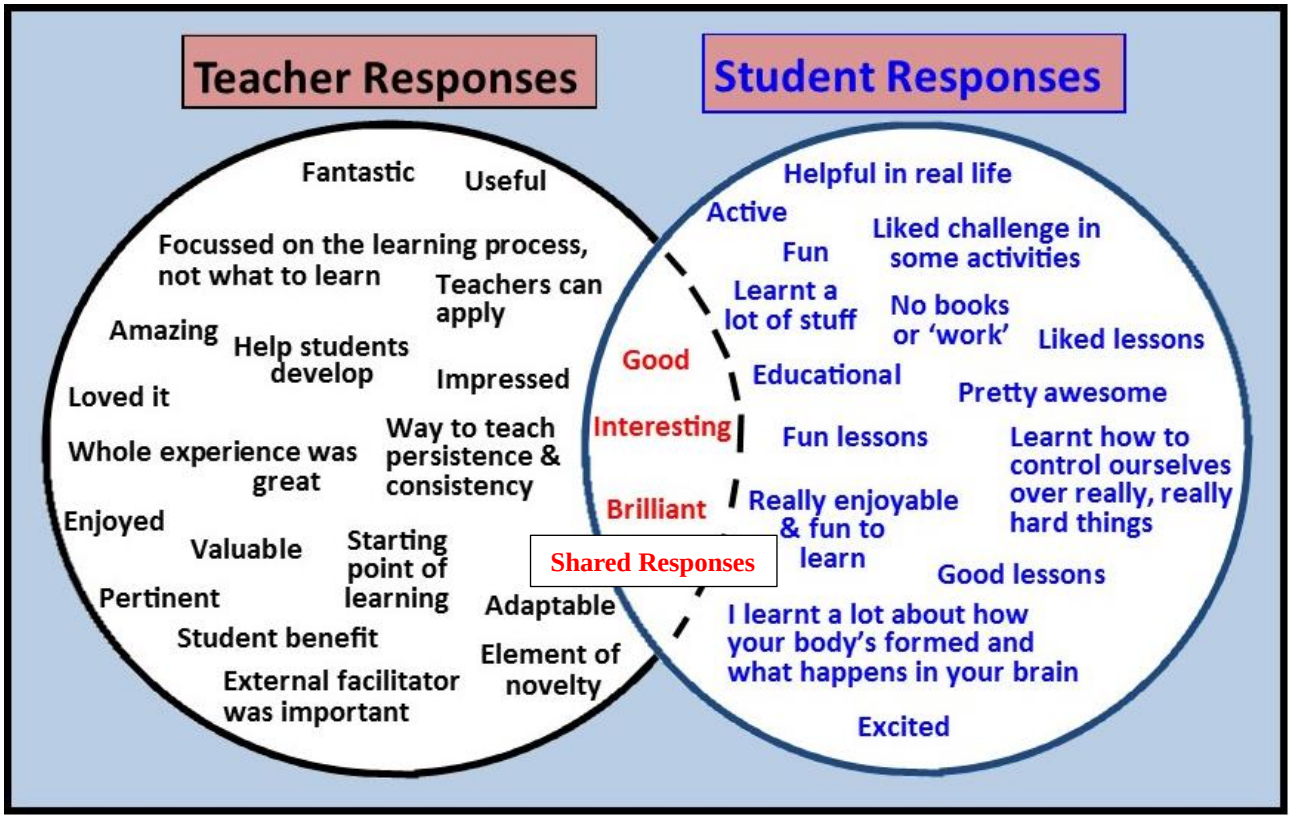


Figure 23 Venn diagram of teacher and student responses about the BBL program

Attitudes About the Presenter

Comments about the presenter concerned her expertise, teaching skills and passion for the BBL Program. Teachers noted that it was reinforcing for them to have an authority giving the same messages they tried to deliver about learning and behaviour and, also helpful for the students to have the science behind these messages. However, as will be seen later, not all participants extended this concept to mean that the program was only deliverable by the presenter. The presenter was variously described as vibrant, exciting, excellent, engaging as well as a "very

good scrounger" (i.e. scavenger) (Teacher 5, p. 2) and lateral thinker in relation to the development and accumulation of materials and activities.

Several teachers stated that the presenter had quickly developed relationships with the students who appreciated her knowledge, manner and lessons. The presenter was perceived as "truthful and honest" (Teacher 5, p. 4), consistent and a "stabilising influence" (Teacher 3, p. 2) in the classroom by the teachers. It was noted that she the technique of modelling as she demonstrated her own use of the skills she was teaching the students during sessions (e.g. memory tricks for quickly learning the names of every student). One student remarked on the presenter's teaching approach as, 'Well, she would come in every Friday and then from games she would help us like learn skills. We need to use some of the skills in the future so she would teach us by like step by step." (Student Transcript 2, p. 2). However, student comments generally focussed on the activities, general information, or their personal experiences.

Program Materials and Activities

Program materials were developed by the researcher using materials readily available in classrooms or cheaply purchased (see Appendix 10 for full list of materials used), acquired from subject experts (e.g. the ACES Sleep Program) and sourced online, including the use of interactive websites. These materials were perceived as useful, easy to use, accessible, age-appropriate, and could readily be available to students at home. Teachers appreciated the creative use of a wide range of engaging materials that were both online (e.g. Neuroscience for Kids and Exploratorium) and three dimensional objects (e.g. stress balls in the shape of a brain, animal squeaky toys, and wooden puzzles made by the presenter). As one participant said, "The students were quite regularly saying, can we do that thing, animal noise game? Or can we do this game? [The presenter] obviously has her resources on her USBs and some websites and so she could bring up interactive activities with the Smartboards, which the kids loved doing. They like hands-on things that stimulate them as well." (Teacher Transcript 5, p. 2).

Both teachers and students remarked that specific BBL Program language assisted students to manage their behaviour by using pre-rehearsed strategies for emotional regulation. Class lessons using metacognitive tools helped to clarify their thinking and enabled them to deal more effectively with their peers as demonstrated by this student quote:

> Because I normally get, like if someone pisses me off, I would not talk to them or would try and hurt them, but [the presenter] taught us, [how to] calm down. Calm down. I won't talk to them for five minutes and then I'll say…Then I'll just go up to them and say, 'Yeah, I was like—my emotions got the better of me and I just…You have to control your actions. Try not to use violence and stuff. (Student Transcript 3, p. 6)

Students appreciated the range of games and activities and several made key connections between the "fun" and the "learning". "Well, they [games] were really fun, but they also really helped you learn whatever topic we were on about" (Student Transcripts 6, p. 1).

Organisational Themes

Emergent organisational themes included viewpoints on program quality, perceived benefits from participation, suggested improvements, continued use of aspects of the BBL Program, and student reflections on their learning.

BBL Program Quality

The quality of the BBL Program was judged as "good" by participants based on the program content, the presenter's ability to consistently deliver flexible, responsive and differentiated lessons (Teacher Transcripts 2. p. 2; 3, p. 1) and the strength of the supporting resources. Novelty was also highlighted as a positive factor in eliciting student engagement (Teacher Transcript 2, p. 2). Various respondents considered that BBL lesson construction, lesson content and the range of in-class games/activities were well-received by students in part due to the

novelty of presentation, materials used and student participation opportunities. No teacher expressed a sense that the intervention was interrupting or taking up valuable teaching time. Rather, there appeared to be an understanding that explicitly building executive function skills supported their students to learn.

Teachers believed that the regular, weekly sessions were important for student uptake of information and personal skills development (Teacher Transcripts 2, p. 2). Lessons were described as explicit, interactive and able to generate useful class discussions. BBL resources were seen to support the program and be appropriate for the age and development of the students.

Perceived Benefits

The data indicated that both teachers and students perceived benefits from their participation in the BBL Program. Benefits were ascribed to students, teachers and specific student sub-groups.

Students

Teachers expressed the opinion that their students had learned a lot from the BBL Program in relation to developing a conscious awareness of the factors that make a good learner (Teacher 4, p. 2), understanding themselves as learners (Teacher 2, p. 1) and acquiring an underpinning language for thinking about thinking and learning (Teacher 5, pp. 1 and 3). The students in each focus group also stated that they had learned new skills, behaviours and information. A complete list of skills mentioned by students is detailed in Table 66, p. 262.

Staff

Teachers valued the chance to observe their students working with another teacher. Through this observation, they gained new insights into individual students by watching how students engaged and deepened their understanding. Teachers stated that they had acquired new

knowledge, skills, and resources, reflected on personal practice and noted positive change in their students.

> Well I think I was very impressed with the program and the change in the children, and also how the Learning Advisors (teachers) were noticing different things about their children in different ways during these sessions, so they have a bit deeper understanding of each child and their learning. (Teacher Transcript 2, p. 1)

It is possible that this chance for classroom teachers to reflect and learn while in their own classrooms accounted for the general positivity in their feedback.

All teachers reported referencing BBL Program lessons and materials outside of BBL Program lessons which implied a transfer of the skills and strategies modelled by the presenter. Three stated that they developed their personal knowledge about how students learn, while two noted that they had learned new strategies for student engagement. All reported positive student behavioural change in relation to attention, sleep, diet and/or making mistakes which they attributed to the students' new ability to understand the concepts and connect knowledge with behaviour change. Three mentioned that they had been sharing BBL materials, resources and knowledge with their school colleagues.

One teacher and one student (Student Transcript 2, p. 1) specifically noted that BBL activities helped students understand difficult concepts.

> Yeah, I initially thought [when first approached by the principal] neuroscience, oh my god, what are you going to teach the kids or go through with the kids but it was, it was because of the games, they loved it, they couldn't wait to have it the following week and the discussions, you know, some topics might

> have been a little bit above their heads but because they actually acted them out they had a better understanding. (Teacher Transcript 6, p. 2)

For information regarding recruitment and program information, please see Appendix 5.

Specific Groups

While all teachers indicated that the BBL Program was suitable and beneficial for all students, a number commented on specific student subgroups. Two teachers felt that students with fewer skills levels gained more (Teacher Transcripts 1, p. 1; 3, p. 1) while others stated that students with more initial skills gained more from the program (e.g. Teacher Transcripts 5, p. 3). There is no elaboration in the transcripts that help define the basis upon which individual teachers made these assessments. It is possible that different respondents varied in the way they conceptualised the question, "Do you think the program was suitable for your students? Did some benefit more or less than others?".

Differences in program response along gender lines were mentioned especially in expressing personal learning, for example, "Boys tend to not reflect on what's happening, they might have - they might use it, they might understand it but not actually verbalise it in situations..." (Teacher Transcript 6, p. 2), application of new learning (Teacher Transcripts 6, p. 1; 3, p. 1; and personal reflection (Teacher Transcripts 1, p. 1; 3, p. 2). While acknowledging that it is hard to isolate one factor that motivates student development in busy school settings, group dynamics (including peer pressure) (Teacher Transcript 2, p. 3) and changes to individual student mindset (Teacher Transcript 6, p. 3) were highlighted as factors for positive student response to the program. In the low SES settings, highly disengaged students were seen to have participated on a partial basis with some benefit.

> There were a few reluctant kids who normally don't like listening anyway but I think they're the ones that I think [the BBL Program] hit the most as in they

> may still not have reacted the way we wanted them to and there might not have been a really major change but there was a change and they were aware of what they do and why they think in that way because of everything that [the presenter] had described to them. (Teacher Transcript 6, p. 3)

Possible explanations for this change in behaviour include seeing classmates actively enjoying lessons and activities and an unexpected response from the presenter in response to disruptive behaviour. To explain, one method used at this school to engage students was a program entitled, Play is the Way. This program instructs teachers to stop activities when a student exhibits disruptive behaviour and allow the class to discuss the behaviour, their reactions to the behaviour and their feelings towards the disruptive student, relying on peer pressure to bring students into line. For some disruptive students, the ability to bring an entire game to a halt provides power over their peers, rendering the tool of peer pressure ineffective. In contrast, during BBL Program lessons, the focus is on students learning to be responsible for their own behaviour. Activities do not stop for students who are actively not engaging. Rather, they provide students who are willing to exert effort to become the best learners they can be with positive reinforcement and strategies to maintain focus (or re-engage focus), enthusiasm and persistence when interrupted.

Several teachers commented that their students had responded in ways that differed from their expectations, especially in relation to displaying positive changes in attitudes towards failure and making mistakes (Teacher Transcripts 2, p. 4; 6, p. 3). In addition, changes in behavioural responses were noted in some students with disabilities who were often disengaged or confrontational.

> …certainly with one of my aggressive Aspergers…I was really impressed with how--even earlier on in the year, I felt uncomfortable sometimes interacting in

> a way that I was worried that I might escalate that behaviour. But then watching [the presenter], and being just very clinical almost in saying, no, you need to do this and this is why you need to do this, and then watching the student actually just do it. I went, oh, okay, so as long I can justify and be very clear and clinical about it, not necessarily attach emotion to the issue, I can do that and I have done it and I feel much more comfortable after viewing that, being say, no you don't do this, and don't touch yourself like that and just being very, very consistent with the student. (Teacher Transcript 5, p. 3)

Suggested Improvements to the BBL Program

Suggested improvements were made by both students and teachers in relation to program access with students providing the most input.

Students

When asked how the BBL Program could be better several students indicated that it was fine as is; "I don't think there's much. It was that good." (Student Transcript 3, p. 9). However, students provided several thoughts on how their BBL Program experience could be improved. Improvements were suggested for individual lessons, access time to the program, and personal access to activities as follows. Suggestions for lesson content and delivery ranged from simple management issues (e.g. sitting on the floor too long and wanting more activities during a lesson) to some quite "creative" recommendations (e.g. the inclusion of more 'science-y' things like "put things in [test] tubes" (Student Transcript 5 p. 6) and the use of "a giant model of the brain that we could walk into" (Student Transcript 4, p. 12). Students in both low SES classes requested more time to work on an activity or a concept (Student Transcript 1, p. 5) because "Sometimes you need some explanation, like talking" (Student Transcript 2, p. 7). The low SES group also indicated that the behaviour of some of their peers was an issue that took time away from lessons. These students expressed a desire for their peers to listen and manage themselves

better (Student Transcript 2, p. 7). While there were disruptive students in all classes, the percentage of students whose behaviour proved disruptive to their peers was noticeably higher in the two low SES classes when compared to the rest of the active cohort. Primary-aged classes in low SES South Australian schools are capped at 25 students, whereas classes in other sites will have as many as 31 students. Whether the sentiment expressed here is a global issue or particular to these students, classes and/or school is the subject for further study.

Across the board, students wanted more—more lessons, more new games, more activities, more strategies for "keeping your memory" (Student Transcript 6, p. 4), more movement, more games that can be connected to one another and a return of the presenter. Some students were dissatisfied that they had not had a chance to personally try some of the activities, especially if this was related to having to wait for student peers to manage themselves. The negative emotion connected with missing out formed an overriding memory of the BBL Program experience, as demonstrated by this exchange:

> **Student:** Sometimes it just got a bit boring because sometimes you sit too long and you miss out on a turn. Do you get it (a turn)? Turns out you never get it, even the other day and the other day and the other day.
>
> Q: And you haven't forgotten, have you? No.
>
> **Student:** Did you bring the ball [for a requested game]? Oops, sorry. She did, but we didn't have enough time. Because people were mucking around. (Student Transcript 4, p. 14)

This quote has implications for the researcher in that emotional context so strongly influences learning. Desire to participate is a positive response to the program, but when thwarted, desire

becomes disappointment and disengagement. In a program that aims to engage and motivate, it is important to be mindful of the fine balancing act between expectation and disappointment.

Staff

The central improvement theme from staff concerned more access to the BBL Program. Two teachers suggested more time and a third asked for the delivery to be extended to a whole year and continue into the following year. Teachers also thought it would have been useful to have a chance to meet with the presenter to share observations and ask questions. It was suggested that schools would benefit from having someone with neuroeducational expertise based on site and to have the program as a school-wide focus rather than for just one class. One teacher was enthusiastic enough to state, "I'd like to see a program across every class in every school. I just see so much value…" (Teacher Transcript 5, p. 2). However, this person also acknowledged the cost involved (i.e. teacher training) in implementing this. Finally, two teachers requested a teacher resource to accompany the program (Teacher Transcripts 5, p. 5; 6, p. 4) and one regretted not videoing the sessions to keep as a personal reference (Teacher Transcript 5, p. 4). All the points suggested here are features of the BBL Program as it runs in the four original schools, including an accompanying handbook.

Researcher Reflections

In reading the transcripts, this researcher noted some conceptual confusion from some student responses. These include:

- Confusion of language/concepts from different social-emotional programs encountered. For example, one student mentioned the red beast (Student Transcript 4, p. 9) when discussing anger which is not part of the BBL Program but is part of an anger management program currently in use in many South Australian schools. A possible addition to the BBL Program could be a metacognitive tool that helps students to organise language and strategies.

- Some students didn't seem sure how certain activities connected with targeted skills development. For example, although they enjoyed the Daniel Simons gorilla clip on focussed attention, they could not articulate the reason for viewing it. More explicit connections need to be made by the presenter in relation to some of the more complex concepts, such as directed attention and the deep concentration state. It may also be necessary to re-visit information once the excitement of the activity has disappeared.

BBL Program—Post Intervention

There were three factors regarding continued use of aspects of the BBL Program post intervention. These were continued use of materials, language and activities, views regarding future participation in the BBL Program or a similar program, and views on classroom teachers as neuroscience presenters. Table 67 on p. 278 provides a breakdown of teacher responses. Ideally, a post-study follow-up would be employed to test the transition of teacher intention into practice. However, this is presently outside the scope of the current study and the resources of the researcher.

Continued Use of BBL Materials, Language and Activities

Teachers indicated that they referenced BBL materials and concepts, integrated the specific language and management strategies into their practice, and shared their learning with colleagues.

> (Personal email correspondence from classroom teacher after initial BBL Program lesson dated 28/4/14)
>
> Just want to let you know that I thought today went extremely well. You did a fantastic job. You helped to reinforce what I have been saying. I can't wait for the next session. The kids really enjoyed it. We actually talked about the session with our year six buddies. Pity we didn't have the toys to demonstrate.

> It was extremely powerful learning and we have talked about what we did all day and how it applies to what happens in the classroom.

One teacher found that the BBL concepts provided a platform for an important class presentation.

> [Learning from the BBL Program] was really pertinent with being in the Year 5 class, having to run an exhibition for the IB (International Baccalaureate] last term. A number of the Year 5 students were able to take some of those ideas [from BBL lessons] on board to help them with self-regulating and making sure it was important that they kept on track and used timelines and referred to them and things like that. (Teacher Transcript 5, p. 3)

One class became so interested in the effects of sleep that sleep became an inquiry question and resulted in a two-week unit of work.

Future Participation in Neuroeducation Programs

Respondents unanimously indicated that they would be prepared to participate in the BBL Program or a similar program in the future. Reasons for doing so included benefits for students and a chance to improve personal skills.

Teachers as Presenters

Three participants believed that others could deliver the BBL Program, with two planning to incorporate what they had learned during the intervention into their classrooms. One stated, "Obviously, I won't be able to present [neuroscience] the same that [the presenter] did, but I plan to mould some understanding that I now have of neuroscience, into what I do as a teacher." (Teacher Transcript 4, p. 2).

Most respondents felt presenting neuroeducational lessons would require coaching, time to collate resources, the development of appropriate background knowledge, practice and funding. Two respondents perceived the BBL Program to be "such an individually directed program" and [the presenter's] "baby" (Teacher Transcript 3, p. 3) that it was difficult to imagine someone else delivering it (Teacher Transcript 5, p. 5) (see Table 67). (NOTE: the BBL Program has since been successfully delivered by other teachers using the same approach as this researcher. So, this opinion has not been substantiated.)

Table 67 BBL program post intervention continued use

Transcript	Continued Use	Future Participation	Delivery by Others
Teacher 1	Keep posters on display for student reference (p. 2)	**Yes** "Absolutely." (p. 2)	**Yes** "…I would personally feel like I'd need a lot of the background knowledge behind why you're doing the activities that Donna does, because to an outsider they might just seem like games. But I think with the background knowledge you would understand the benefit and the need for them…" (p. 2)
Teacher 2 (2 teachers)	Use language, strategies, resources and ideas. Share these with colleagues. (p. 5)	**Yes** "Definitely, yeah." (p. 7)	**Yes** "…next year we would take on and start off with some of those strategies and things they've learnt." (p. 5)
Teacher 3	**Not addressed**	**Yes** "I want it next year. Thank you." (p. 4)	**Uncertain** "No. I don't know, because that (The BBL Program) was (Donna's) baby and you could see the passion as she was delivering, and it was done in such an unaffected way." (p. 3)
Teacher 4	"I plan to mould some understanding that I now have of neuroscience, into what I do as a teacher." (p. 2)	**Yes** "Yeah, and I intend to use a lot of [the BBL Program]." (p. 2)	**Yes** "I think like anything, you would get better at it, and obviously having Donna's background she will present it better. But yeah, I think with some merit, you could. I feel like, yes I could deliver it to give some benefit to students." (p. 3)
Teacher 5	"That was really pertinent with being in the Year 5 class, having to run an exhibition for the IB last term. A number of the Year 5 students were able to take some of those ideas on board to help them with self-regulating and making sure it was important that they kept on track and used timelines and referred to them and things like that. So they all benefited, but certainly some probably did benefit a bit more." (p. 3)	**Yes** "I'd go through the whole thing from start to finish again because I know there would be other things I would pick up and it would give me an opportunity to go, right, okay, I really am going to focus on this now to get down some notes about this now and jot down some possible resources for it now. Whereas I think initially, you go with the flow and you see how it goes, and then part way through you go, oh, gee I wish I'd been more proactive in gathering some information and writing some notes for myself." (p. 5)	**No** "I'm not aware of other people who have those qualities and those skills, who would have the resourcing, financial resourcing from a department or whatever, to go out and do that in schools." (p. 4)
Teacher 6 (2 teachers)	Referencing BBL Program aspects during other lessons	**Yes** "For the kids' sake yeah definitely." (p. 6)	**Not addressed**

Student Reflections on Their Learning

> [Neuroscience] was good and when the lessons ended I did what [the presenter] told us and I put that to my school work so I won't get distracted in class (Student Transcript 3, p. 1).

Student data indicated that the main messages of the BBL Program (i.e. the development of specific skills and attitudes related to attention, memory and self-regulation) had largely been received. Clearly, students could name aspects of executive function and could see personal value in their development and use. See Word Cloud below.



Figure 24 Word cloud generated from student responses (using Wordle.com)

Students were also able to recall a lengthy list of BBL activities and materials used during the 20-week program. (See Table 66, BBL Program student coded data, p. 262.)

Comments indicated that students could see improvement in their ability to remember, attend and self-regulate over time and that this was positive for them. Although students and schools are de-identified for each transcript, there is a marked difference in the articulation levels and

transcript lengths. It should be noted that, due to scheduling issues, some student data were collected up to eleven weeks after the BBL Program intervention was completed. However, the time interval between the intervention completion and interview did not impact on the amount of information received from students. For example, the final recording on the 8th December is the longest and one of the richest transcripts.

Students understood that what they did or did not do could impact their brain, behaviour and learning.

> It was really interesting how the neuroscience helps with your brain. (Student Transcript 6, p. 1)

They made the connection that executive functions learned during neuroscience lessons could transfer to other environments.

> When she taught us like games and then those games helped in real life and reality. They taught us skills like patience. (Student Transcript 2, p. 1)

Students mentioned learning information about concentration and memory as well as improving these skills through various BBL activities (Student Transcript 1, pp. 4-5; Student Transcript 4, pp.2-3, Student Transcript 1, p. 5, Student Transcript 5, p. 3). They appreciated that academic learning could also be fun, using games, to practice concepts or improve automaticity (Student Transcript 3, p. 9). Students also provided examples of how they had generalised self-regulation techniques and inhibitory skills to improve listening and social interactions (Student Transcript 3, pp. 6-9) and the following quotes:

> It helped me for listening in class and home. (Student Transcript 2, p. 3)

> I learnt to be patient…I learnt to be relaxed, don't worry about anything else while you're concentrating on something else (Student Transcript 2, p. 4).

> We have [applied skills learned in neuroscience lessons]. In PE…I had to wait some time until someone passes the ball to me in soccer. Yeah so I can't be like pass, pass, pass I can't keep saying that. I already say it like three times so then I thought my team will pass and then you've got to be patient (Student Transcript 2, p. 5).

Global Themes—The Research Questions

Three global themes, in answer to the research questions, were identified as research issues relating to the lived experience provided by the BBL Program. These were:

- Portability—was the Program effective in primary school sites for which it was not designed? Did this vary according to SES?
- Feasibility—could a 20-week intensive version BBL Program be delivered across a range of settings? Would a 20-week program be sufficient to have any measurable impact on student executive functions?
- Acceptability—did recipients see value in the Program?

From the summary of findings above, it is possible to draw the following conclusions:

- The BBL Program is portable across a range of sites. Teaching conditions vary from class to class due to factors such as school/class ethos, class dynamics, student mindsets, and not just because of SES.
- It is feasible, although logistically challenging, to deliver a 20-week program across a range of sites due to an array of competing pressures (e.g. swimming week or pupil free days) that interrupt a regular class timetable. The qualitative data confirm that

20 weeks was sufficient to positively impact student learning and behaviour. However, the issues relating to program delivery would provide an argument for a cross-curriculum approach to the teaching and learning of executive functions and brain function, rather than a stand-alone approach such as the BBL Program.

- The BBL Program was well received and valued by both teachers and students. Incidental parent input indicated that it was also valued beyond the school site.

4.3.3 Changes to Class Composition and Program Delivery

Changes to class composition were evident in low SES sites at the first data collection point with students consenting to participate but leaving their schools before the study intervention commenced (see Table 24, p. 195). Class composition changes during the intervention directly impacted program delivery as aspects of later lessons were built upon concepts that were covered previously. As mention in the Methods section, students who joined a class after the commencement of the intervention were not included in any data collection. However, their presence in the classroom did affect how well lessons could be delivered.

While there were minimal changes to class composition in the high and middle SES classes, there were considerable changes in the two low SES classes. In both BAN 1 and BAN 2, student numbers fluctuated on a weekly basis due to high absentee rates by students not subscribed to the study but part of the class and student transience which is endemic to low SES schools in metropolitan South Australian (Office of Operations Resources and Assurance, 2015). By the end of the study, BAN 1 had lost five students from the original twenty (three students within the study and two not subscribed) and gained another four. BAN 2 had lost two subscribed students and gained five. For these two classes, it became necessary to re-visit past concepts to achieve full class participation in current lessons. This was time consuming and created a difference in program delivery between low SES and other classes.

Another difference in program delivery related to classroom configuration. The high and middle SES classrooms were organised in a traditional layout with each student having their own desk space and storage facility. In the two low SES classes, classrooms were organised as more fluid learning spaces where students could work on the floor, at low tables, on a couch or at a desk. Despite it being a stipulation for participation in this study, the interactive Smartboard and internet connections in the low SES classes were not as reliable as those in the other sites which made some facets of program delivery more challenging.

4.4 Analysis of Study Results

This project was constructed to explore change to executive functioning using the BBL Program with a novel student population (i.e. students other than those for which the program was designed as explained in the Introduction). The following section will analyse all reported results before integrating the results to answer the research questions (see Section 4.5) as outlined in the mixed methods design model chosen for this work (see Section 3.2.4).

4.4.1 Improvements to Executive Functioning

The study's primary hypothesis was that implementation of a 20-week intensive form of the BBL Program would provide measurable improvement in executive functioning levels of working memory, attention (both directed and sustained) and self-regulation (especially impulsivity) for students in the active condition as compared to students in the control condition. This premise was based on available research literature that found executive functioning in children could be improved with training (Crone, 2009, Diamond et al., 2007, Diamond and Lee, 2011, Diamond and Ling, 2016 , Jolles and Crone, 2012, Klingberg, 2006, Rueda et al., 2012). Further, that improvements to executive functioning helped to improve academic outcomes (Anderson and Reidy, 2012, Baker et al., 2012, Best et al., 2011, Cartwright, 2012, Center on the Developing Child at Harvard University, 2011, Cragg and Gilmore, 2014, Diamond, 2013, Petersen and Posner, 2012). It is acknowledged that the

elements under examination here do not represent a full array of executive functions. This is a limitation to the study that will be discussed more fully in Section 5.1.

Mitigation Rather than Improvement

The primary hypothesis was tested by analysing condition (active versus control) by time (pre- and post-intervention testing) on all elements of the Conners' Continuous Performance Test (CPT) and Working Memory Battery subtest. Significant findings in favour of the active intervention over time resulted for input change/impulsivity (variability) and sustained attention (HSE ISI). Results approached significance for vigilance (HRT SD). Although all students generally declined in performance between baseline (Time 1) and post-intervention (Time 2), the active group's decline was significantly less in each of these subtests. This suggests that the BBL Program had a positive, mitigating impact on student performance.

General Performance Decline

Data collection for the randomised controlled trial took place over a 22-week period of one school year. It is reasonable to expect that all students would improve their skills with time as a function of school attendance (Finn et al., 2014) and general maturation (Conway et al., 2005b, Schul et al., 2003). Performance improvement was found for errors of detection and commission. However, for this study, results indicated a functional decline in other aspects of attention. This was a surprising outcome that elicited a return to the research literature in search of any explanation.

Taking into consideration that studies about school attendance and attainment tend to concentrate on *academic* attainment, such as improvements to mathematics scores or increased reading levels, the author searched the literature for changes in executive functioning in relation to a school year. However, search results were tangential to this query. For example, Schul and colleagues (2003) reported on declines in attention in young school-aged children but the focus of this study was that attentional effort declines with age due to

the development of more efficient attentional practice (Schul et al., 2003). Yeung and colleagues (2011) found a general decline in attentional effort at school with age, especially as students move into adolescence (Yeung, 2011). Finally, van der Vinne (2015) reported that performance is affected by the time of day a student (particularly an adolescent) is tested (van der Vinne et al., 2015). The author could find no supporting research that might explain the overall decline in executive function performance on the CPT over the course of a school year. Further research is warranted to determine if the performance decline reported here is an aberration of this study cohort or a true performance factor that would have implications for classroom pedagogy and curriculum presentation.

Other possible explanations suggested by the literature for the general decline in performance include:

- increased illness in the late winter months (Palmer et al., 2010) however, attendance records show that student attendance was not significantly affected by illness during this study
- loss of enthusiasm/motivation during post-intervention testing—the novelty had worn off, therefore, overall attention-to-task was lowered (Hughes and Graham, 2002). However, this concept was not supported by either MES data nor qualitative student data in this study.
- habituation to the testing (Hughes and Graham, 2002), unlikely in this case given the timeframe between testing.
- some difference between the data collectors or data collection process at Time 1 and at Time 2 (Creswell, 2013), also unlikely given the rigid protocol and computer-based nature of the tests.

- interruptions to students during individual school-based testing situations (Creswell, 2013), possible given the busy-ness of schools and the difficulty in quarantining quiet, isolated spaces but unreported by data collectors.

A further possible explanation is fatigue. It is known that fatigue will impact upon performance on tasks requiring executive control (Steelandt et al., 2012, Strayhorn, 2002, Vohs and Baumeister, 2011, Vohs et al., 2008) and that attentional training can improve attentional stamina (Posner, 2010, Rueda et al., 2012, Tang and Posner, 2009). Therefore, it is plausible that the significantly smaller decline in performance for the study's active group was due to specific BBL Program training. It is equally possible that the decline in overall test results was due to loss of interest and/or general fatigue during post-intervention testing and that the more favourable results for the active group were due to the positive personal relationship the students had formed with the presenter. In other words, the students in the active condition may have tried harder at the second assessment point than their peers in the control group because they liked the BBL Program and its presenter and, therefore, cared more about the testing outcome (Klem and Connell, 2004, Wang and Eccles, 2013). A relationship with the presenter was not a factor at baseline testing as she had not yet met any student participants. Whereas, at post intervention testing, students had clearly been involved in the BBL Program or they had not. Students involved in the program could well have had a personal investment in change. However, this was one reason for selecting computerised performance tests, since, when using a computerised format, just wanting to perform better does not necessarily translate to better actual performance.

Proficiency in metacognition has been found to improve other aspects of executive function (Dinsmore et al., 2008, Komarraju and Nadler, 2013, Veenman et al., 2006). For this reason, the BBL Program explicitly taught participating students some skills to improve working memory performance, monitor attentional states. Self-regulation was also a primary focus of

BBL lessons. It is conceivable that this training accounts for the mitigating effect found in the reported data. It is also conceivable, although not probable, that the students in the active group just happened to get more adept at computer-based testing between baseline and post intervention testing. Further work is required to determine if there is any verifiable connection to between the results of this study and each of the skills taught during the BBL intervention.

Student Motivation

Qualitative data provided by students in this study indicated that they were motivated by the concept of being able to actively improve their learning by improving skills such as attention and self-regulation. While student qualitative data demonstrated that students enjoyed and benefited from the BBL Program, except for *self-belief* and *learning outcomes*, quantitative data did not demonstrate a generalised change in student motivation and engagement as measured by the Motivation and Engagement Scale (MES). Results from the MES showed reduction in negative attitudes across the entire cohort over time. However, there was also a decline in *self-belief* (a positive attitude) over time in the low and middle SES active groups while the matching control groups remained stable. The high SES groups were both stable. It is possible that students had not fully integrated their BBL Program experiences into their general thinking about thoughts and feelings towards school. Available data does not provide evidence, one way or the other, about changes to student metacognition and their view of schooling. However, this finding does suggest future study on how the BBL Program changes can be more consciously integrated into change of general student attitudes towards school and schooling over a longer timeframe.

Although it could be considered *positive* to reduce negative attitudes, it is, nevertheless, interesting that positive attitudes would decline in the active group. While it is tempting to suggest that students may be inaccurate in their self-rating abilities, in this study, student

input was much more aligned to the actual performance data than either the teacher or parent input. This difference is in keeping with research demonstrating discrepancies between student and teacher rating, particularly using single-point rating tools such as questionnaires (Wagner et al., 2016) and often attributed to differences in experience and perspective between adults and children (Miller et al., 2014).

A more likely explanation for the decline in positive attitude by the middle and low active groups is that more knowledge about executive functioning and feedback gained from participation in the BBL Program activities recalibrated student understanding regarding their levels of functioning. Whereas, prior to experiencing the BBL Program, students did not know what they did not know, after taking part in the program, students had more understanding of where their personal strengths and weakness lay and, perhaps, altered their self-rating accordingly—as stated, this is an area for future study. Additionally, the decline in student positivity could align, as mentioned above, with factors related to habituation (Hughes and Graham, 2002) and general fatigue (Vohs and Baumeister, 2011, Vohs et al., 2014). This last explanation seems less likely given that the decline was found in the active group, only, and each of these factors would affect all students in the entire cohort.

4.4.2 Sleep, Diet and Physical Activity

As demonstrated in the literature review, sleep habits, diet and levels of physical activity are understood to impact on attention, memory and academic performance (Chaput et al., 2016, Francis and Stevenson, 2013, Lees, 2013). Data were collected from all student participants at baseline for diet and physical activity and, from students in the active cohort for sleep (as part of the BBL Program intervention) in Week 9 of program implementation, prior to introducing the unit on sleep. Findings for sleep, diet and physical activity levels aligned with current conceptual research frameworks.

Sleep

Performance outcomes in this study confirmed that more well-rested students were better able to manage their attending behaviours in relation to error commission and target detection. This study also found that students in low SES classes slept less than students in either the middle or high groups and performed worse on measures of attention and working memory. These findings align with current literature on sleep, attention and performance (Bub et al., 2011, Chaput et al., 2016, Dewald et al., 2010, Diamond, 2013, Könen et al., 2015, Owens et al., 2016, Sadeh et al., 2003, Shochat et al., 2014, Turnbull et al., 2013, Walker et al., 2009). A surprising outcome from the data was the finding that students who regularly slept more than the recommended hours for their age group, performed worse than those in the recommended range. A return to the literature found that too much sleep can be indicative of mental or physical disorders which in turn are detrimental to performance (Buysse, 2014, Hirshkowitz et al., 2015). Students in this study were not asked if they had mental and physical disorders other than those classified as disabilities under the Department of Education and Child Development funding categories. It is, therefore, not possible to test this supposition with current data, but the question does suggest and interest future study.

A second surprise outcome was the finding that students who were well-rested had slower reaction times than those with sleep levels under the age-based recommendations. One possible explanation is that well-rested students took more time to ensure accuracy. A second explanation is that the study sample contained a few students who naturally required less sleep than the average to function adequately. A third possibility is that students who regularly slept less than ten hours per night spent time on computer games when they should be sleeping and were, therefore, more practiced at quick responses to computerised tasks. This is an interesting point for future investigation.

Diet

Students in this study who had positive attitudes and behaviours regarding healthy eating generally performed better on the cognitive test measures, as has been found in a number of other studies (Dye, 2011, Francis and Stevenson, 2013, Gómez-Pinilla, 2008). Dietary intake reflected levels of SES with students in higher SES sites reporting a more nutritious diet. However, in this work, students in the middle SES cohort reported better attitudes and healthy eating habits but were still cognitively outperformed by students in the high SES group. This finding would seem to underline the interconnectedness of all factors which impact on individual students and their learning since, it clearly demonstrates for this group, that having a better diet does not, in and of itself, translate to better performance outcomes. Additionally, it suggests a gap between espoused dietary attitude (what children think adults want to hear) and true dietary practice (what children really do). This was a reporting issue highlighted in Section 2.2.4 which the MCNS was able to detect.

Physical Activity

Inactive students performed worse on cognitive testing than any other group, with more inactivity found in the lower SES cohort. These finding align with current literature in the field (Álvarez-Bueno et al., 2016, Chaddock-Heyman et al., 2013, Erickson et al., 2015, Gomez-Tolle, 2012, Haapala, 2012). However, in this study, students with moderate physical activity outperformed those who were highly physically active (i.e. engaged in specialist and/or intensive athletic training during the week). This result could be explained in two ways. First, students who have committed a large proportion of afterschool time to training, have less time to commit to homework. Second, re-visiting data from the 7-day sleep diaries revealed that 60% of the students who were involved in intensive, afterschool athletic training in this study reported that training was late enough for them to come home from training, have a shower, eat, and go straight to bed within less than an hour. This is an example of poor

sleep hygiene. Of the 60% of students reported here, 84% noted that they were either a little tired or really tired upon waking for at least three days in the seven of the data collection period.

4.4.3 Teacher and Parent Rated Data

Student self-rating more accurately matched computerised performance data than either teacher or parent assessments. Student performance and student attitudinal data reflected actual levels of SES. However, this was not the case for either the SBRS (teacher input) or the BRIEF (parent input) data sets which will now be discussed.

Data from Teachers

With the SBRS, there was general agreement between teacher ratings for the middle SES group across both active and control conditions (with exception of the *aggression* item where the active group was seen to manage aggression better), but a persistent polarity between the teachers in the active versus control conditions regarding both low and high SES cohorts.

In the low SES cohort, teachers in the active condition rated their students higher than those in the control condition, while in the high SES group, this was reversed. The distinction in teacher rating between the middle SES teachers and the other two SES groups was also evident in the breakdown of improvement over time by SES where the pattern for the middle SES group almost completely mirrored the other two groups (excepting the *attempting task* item) (see Table 44, p. 231). This consistent pattern raises the question of immediate context on rater perspective. That is, do teachers who work in high or low SES sites alter their perspective of *normal* such that they under- or overrate their students due to their skewed classroom context? Rater bias is a well-known psychological construct whereby one's ability to accurately rate a situation, performance or person is impeded by personal beliefs and values, be they conscious or not (David and Kistner, 2000, Goldin, 2000). Teachers are prone to perceptual bias (Park et al., 2014) as the results of this study appear to demonstrate through

the differing expectations for differing levels of SES. The possibility of bias in teacher rating for the SBRS data represents a limitation for this study that was not controlled for sufficiently. However, it is possible that another explanation for this data is that it represents a true and fundamental difference in school engagement levels and teacher-student relationships across sites. There is not corroborating data regarding teacher-student relationships nor allegiance to a school to be able to prove or disprove this premise—an additional limitation in the current study.

Data from Parents

With the BRIEF, parents rated their children more harshly between baseline (Time 1) and post intervention (Time 2) with the worst ratings given to the middle SES group, followed by the high SES group. Low SES parents in both active and control conditions rated their children more highly than the other groups. As was highlighted in Section 4.2.2, return rates for the BRIEF, particularly in the low SES group, were most likely affected by levels of parent literacy and engagement with schooling. Therefore, the results from the BRIEF were probably skewed in favour of students who had reasonable executive functioning levels, rendering this data set untrustworthy.

There are many factors that contribute to an SES rating, as discussed in Section 2.2.5. The method used to assign SES levels to students in this study was via school attendance. The choice of method here could account for the surprising parent data. For example, some students in the active low SES site were newly arrived refugees who, in their home country, would not have been in a low SES classification (based on data provided from the Student Background Questionnaire -- see Appendix 9). In contrast, most students in the control low SES cohort were Australian-born or from migrant but not refugee backgrounds and had been in the country for much of their lives. This information provides another possible explanation

for the higher rating in the low SES group is that students, who were assigned to SES groupings based on school site rather than individual circumstance.

There are two counter-arguments here. Firstly, parents in both low active and low control conditions gave their children higher ratings than those in middle or high SES groups negating the explanation offered in the preceding paragraph. Secondly, while there was no additional screening for SES in the study design, education department schools are assigned levels of SES based on the circumstances of the general population residing in the school catchment area. Data from school sites indicated that students attending each school in this study were local to the area meaning that students attending school designated as low SES were probably living in conditions of low SES. At any rate, being schooled in a low SES site produces conditions that can be identified as impacting SES factors, such as less access to financial capital (Office of Operations Resources and Assurance, 2015), restricting the extra curricula activities on offer (e.g. excursions or individual music tuition) (Office of Operations Resources and Assurance, 2015), lower levels of parental education (Office of Operations Resources and Assurance, 2015), or increased social issues (Department of Education and Child Development, 2014).

4.4.4 SES – Impact and Improvement

The consideration of SES was included in this research project to test differences in uptake to the BBL Program, given the large body of research concerning the impact of SES on brain development and, by extension, learning (Bornstein and Bradley, 2012, Brito and Noble, 2014a, Hackman, 2012, Hackman et al., 2014). It was hypothesised that research findings would show an increased improvement in student performance across the board, but particularly for students from low SES settings, as per Diamond (2013) and Diamond and Ling (2016).

SES was clearly an important element in this project, with performance on measures of executive functioning generally aligning with levels of SES. However, in this work performance improvement occurred most in the active high SES group rather than in the low or middle groups. This finding contrasts with the research literature, as summarised by Diamond (2013) and Diamond and Ling (2016), whereby executive skills training programs tend to provide the most improvement to the students with the lowest skills levels (Diamond, 2013, Diamond and Ling, 2016). One possible explanation for this research difference is the format of training delivery (although Diamond (2013) notes that format does not usually affect this dynamic) (Diamond, 2013).

The BBL Program was delivered to all students as a group in their regular classroom, as opposed to many training programs which are delivered individually, through programs outside of the classroom , or via interactive computer programs (e.g. Cogmed (Shipstead et al., 2012)). The executive functions that the BBL Program seeks to improve must also be recruited by students for full participation in classroom lessons. Thus, an explanation for this study's results could be that students who already had good classroom learning skills found it easier to access the information and skills training opportunities afforded by the BBL Program. These students were better able to integrate new information into their existing behavioural repertoire and benefit from the acquisition of new skills/skills levels more efficiently. This view is supported by the research of Raver and colleagues (2013) which was discussed in the post-2011 literature review (see p. 261).

Greater improvement in students from high SES sites could be a reflection on school conditions in which the program was delivered. As mentioned, the internet connection and interactive Smartboard facilities in the low SES classes were unreliable and inefficient when compared to these facilities in other classes. It may be that these technological restrictions

also affected program uptake and opportunities for students to practice on some of the websites highlighted from the BBL lessons (Livingstone and Helsper, 2007).

Although support from home in higher SES households is a factor often discussed in relation to student performance (Tan, 2017), it is unlikely to have had a large impact in this study as the BBL Program was delivered during class time directly to students and, with the exception of the 7-day sleep diary, did not involve homework or outside (i.e. parental) support. It is, however, possible that parents may have shown more interest in what occurred for their children during BBL lessons. Available data does not allow for speculation on parental levels of interest and support for or the effects of such involvement on the BBL initiative. This is a limitation to the current study and a consideration for future investigation.

4.4.5 Program Portability

The present research was created as a program feasibility study. Its main aim was to determine whether the BBL Program held any value to schools other than the original four for which it was created. In other words, was the BBL Program portable according to the characteristics outlined by Durlak and Du Pre (2008) and described in Section 2.2.6.

As a feasibility study, data was collected to examine:

- Fidelity—was it possible to deliver the BBL Program in novel settings without losing the program's internal structure and original intent?
- Dosage—would an intensive 20-week program be sufficient to see any changes in student performance?
- Quality—how well could individual elements be delivered?
- Participation responsiveness—how well did the program stimulate and hold the attention of participants? (Durlak and DuPre, 2008).

Fidelity and Quality

Judgements about program fidelity and quality were made based on problems encountered by the presenter in relation to physical delivery in each classroom setting and in the ability to maintain each lesson plan without variation. As noted in Section 4.3.3, transience in the low SES group created some issues with program delivery as certain aspects of the earlier lessons had to be briefly repeated to promote whole class conceptual understanding. Lack of reliable internet access and quality interactive screens in the low SES classes also made it difficult to ensure high quality delivery of the electronic aspects of the program. For this study, conditions in the SES settings was a factor that impacted both program fidelity and quality.

Dosage

Main measure results obtained in this work were sufficient to demonstrate change both over time and between the active and control conditions. It is, therefore, reasonable to conclude that a 20-week intensive BBL Program is a viable intervention option. Whether 20 weeks is the best intervention option as compared, for example, to the entire school year, is a subject for future study.

Participant Responsiveness

Surprisingly, there was no negative data collected from teachers. Student data indicated that improvements could be made in some aspects of program delivery, such as not sitting on the floor for long periods or the provision of giant, walk-in brains. Overall, qualitative data indicated that staff and students found their experience with the program to be engaging, enjoyable, informative and beneficial and were happy to participate in similar programs in the future.

4.5 Integrated Results

This mixed methods analysis has employed a convergent design to answer the research questions. Results from the quantitative and qualitative data will now be merged to answer the seven research questions.

Question 1: Improvements to Executive Functions

How and to what extent is the BBL Program more effective in increasing the specific executive functions of working memory, attention (both directed and sustained) and self-regulation (especially impulsivity) as compared to a control group receiving usual classes?

The quantitative data indicated a mitigating effect, rather than the hypothesised improved effect, from the BBL Program for input change/impulsivity (variability), sustained attention (HSE ISI) and vigilance (HRT SD) for students in the intervention. That is, although the whole student cohort displayed a performance decline between Time 1 and Time 2, the active group declined significantly less than the control group.

These results could indicate that over the course of a school year, student attentional efforts are in decline by the end of third term. It is possible that students in the active condition may not have declined as much as the control group because they participated in the BBL Program intervention. A key facet of the Program is supporting students to notice and understand aspects of directed attention, to actively monitor their levels of attention and to consciously re-direct their attention to the task at hand when a distraction has occurred. One interpretation of the data presented above is that participation in the BBL Program successfully assisted students to pay more attention to their attending behaviours and, that more attention to attending resulted in the lack of decline across the active cohort demonstrated in this study.

Quantitative data from parents regarding executive functioning changes in the study population also showed a general decline over time. Once again, the decline in the active group was significantly less than in the control group for the test items of emotional control and mental shifting—an aspect of attention control and cognitive flexibility (Gioia et al., 2000a). Emotional control and mental shifting are also key aspects of the BBL Program. Here again, it is possible to suggest that participation in the BBL Program mitigated against performance decline because students had additional input about and practise in managing attentional control.

Quantitative data from teachers, who reported on student behaviours within the school context, showed a decline in playground skills and an improvement in attempting tasks across the whole cohort over time. This would indicate that participation in the BBL Program did not affect these two aspects of school life as the same pattern was seen in both active and control conditions. However, there was a significant change over time in relation to aggressive behaviours with the active group outperforming the control group. While it is difficult to claim that the BBL Program was the reason for this, it is possible to suggest the program may have been a contributing factor. This is because the importance of emotional regulation in one's self and with others is given high priority with the BBL intervention. Additionally, the BBL Program explicitly teaches methods to improve emotional regulation skills and practices these strategies using generic school-based situations. That is, students get both knowledge and experience in emotional regulation in controlled situations.

Qualitative responses from both students and teachers independently indicated that students in the active group were better able to manage impulse control, memory and attention in the classroom after their participation in the BBL Program. During focus groups, students volunteered examples of how they had applied what they had learned about emotional regulation, delayed gratification, memory and attention outside of BBL lessons. Teachers

commented that students had gained more insight into their own behaviours which, in turn, helped these students to better self-manage. Teachers reported that students, with varying skills levels, could participate in the lessons and derive benefits.

Therefore, it is reasonable to conclude that the main hypothesis is supported to a degree by this study. Although the BBL Program did not produce outright improvements in student executive functioning, it did appear to mitigate against midyear performance decline exhibited in the student, parent and teacher data sets.

Question 2: Student Motivation and Attitude

How and to what extent does student attitude towards school and learning reflect executive function levels as measured by the test battery?

Quantitative results from the Motivation and Engagement Scale (MES) indicated a decline over time in task management across the whole cohort. This continues the pattern of decline seen in Question 1. Conversely, there was a positive change over time in how students conceptualised their disengagement, uncertainty control and failure avoidance. This was also across the whole cohort. At face value, one could theorise that, as the school year progresses, students begin to feel overwhelmed by the tasks they are required to deal with. However, as they become more familiar and comfortable with their teachers and classmates, they engage more and find it less necessary to be emotionally self-protective. As these patterns are seen across both the active and control groups, it would appear that the BBL Program had little impact on student attitude as measured by quantitative instruments. However, the data showed two areas of difference between the active and control groups. There were in the self-belief item, where the level of self-belief when up over time for the control group but down for the active group and, in learning focus where the active group outperformed the control group over time in terms of positive change to motivation and engagement.

Therefore, it could be argued that the BBL Program may have impacted student self-belief in a negative way but, learning focus in a positive way. One possible explanation for this finding is that students in the active group initially had little insight into their skills as a learner. However, after participating in the BBL Program, students could identify a range of executive functions as well as how they personally managed attention, employed working memory and self-regulated behaviours, emotions and thoughts. In short, they had a better understanding of how to measure themselves against the key executive functions that underpin effective learning. With this knowledge and improved skill set, they became more focused on learning. There is insufficient data to test this explanation but it presents a line of future enquiry. Another possible explanation is that participation in the BBL Program made students feel bad about themselves and they, therefore, put more energy into focusing on learning in a bid to improve their self-belief. This explanation seems less likely given that the study population is comprised of students between the ages of 9-11 years, but it should not be discounted without further investigation. A final possibility here involves the score of the MES tool and its fit with the study aims. The MES examines behaviours and attitudes across the whole school environment, whereas, the BBL Program focused more intently on classroom learning. A tool which focuses solely on classroom behaviours may have been a better fit for this work.

Turning to the qualitative data, both student and teacher data sets demonstrated a range of engagement levels from students in each class. Teacher data within the low and high SES levels did not align, with the low active student groups being rated higher than the low control student groups. In the high SES cohort, the active group was rated lower than the control. While this would indicate that there could be unique teacher-student relationships in each site, the quantitative performance data demonstrated proficiency along SES lines. Thus,

it cannot be claimed that teacher data supports a relationship between performance and student attitude.

Question 3: Sleep

How and to what extent does an individual student's sleep profile influence levels of executive function?

Qualitative data indicated that students were interested in learning about sleep and its impact on their brains. As reflected in larger sleep studies, trouble going to sleep and nightmares were reported as issues (Hirshkowitz et al., 2015). Students also reported having electronic devices in their bedrooms which they used when they were supposed to be sleeping or because they had trouble falling asleep. Students in this study had not previously known that lack of sleep could affect memory consolidation or aspects of physical health such as obesity.

Quantitative analysis on performance and sleep found a significant, positive relationship between sleep quality (how tired a student felt) and commission of errors which underpins attention and impulsivity inhibition. Students who reported feeling well-rested outperformed the rest of the cohort on the computer-based measures of executive function (i.e. on the Continuous Performance Test). A significant, positive relationship was also found between sleep quantity and detection of information targets for attention as measured on the Continuous Performance Test. Students who regularly slept between 10-12 hours performed the best on the Continuous Performance Test measures. Contrary to expectation, speed of response got slower for well-rested students and increased in those who slept less than ten hours per night. This is a surprising finding that warrants further investigation.

Student sleep reflected their level of SES in terms of quality and quantity. When SES was considered along with aspects of sleep, test performance showed a significant interaction with sleep pattern (regularity) for errors of commission and with sleep amount for vigilance (HRT

SD) and fatigue management (HRT ISI). In this interaction, students from the low SES group had the poorest sleep quality, quantity and regularity coupled with poorer outcomes on the measures of executive function (i.e. CPT items).

Data from the study showed that students with poorer sleep quality and quantity also performed more poorly on executive function tasks. Therefore, it is reasonable to conclude that there is an important relationship between an individual's sleep profile and levels of executive function which aligns with reported trends in sleep research as demonstrated in the literature review above (Bub et al., 2011, Czeisler, 2013, Könen et al., 2015, Meltzer, 2016, Owens et al., 2016, Turnbull et al., 2013).

Question 4: Consistency Between Mindset/Views and Performance

How and to what extent do student mindset (i.e. perception about his/herself as a learner) and teacher/parent views of student ability align with objective executive function performance, especially in relation to SES?

The Motivation and Engagement Scale (MES) measured student perceptions regarding themselves as learners and the process of learning. Data collected from parents and teachers also provided a view of student learning behaviours. These findings, along with quantitative data, will be examined to respond to this question.

Qualitative data outcomes indicated that student self-rating aligned with results from computerised testing, especially when SES was a consideration. However, parent and teacher ratings did not align with either SES or with each other, except for students in the middle SES group. Overall, responses to the MES reflected levels of SES with the high group reporting higher positive overall views than the middle group who were, in turn, more positive than the low group. On the self-belief item, attitude change over time also differed according to SES levels. As reported in Question 2 above, students in the active group decreased in self-belief

and increased in learning focus as compared to the control group in the baseline to post intervention period. When SES was introduced into the analysis, SES was found to have a strong impact on the data with the decrease in self-belief ratings almost entirely attributable to the low SES group. When comparing active and control groups, scores in the high SES cohort remained in parallel from baseline to post intervention, while the middle groups converged. However, the active low SES group went from a score higher than their control counterparts at baseline to significantly below at the post intervention point. (See Figure 15, p. 216.) This would indicate that something unique to the active group, such as the BBL intervention, influenced attitude, particularly in the low SES contingent. Thus, SES conditions do not necessarily create an immutable mindset.

Data provided by teachers using the Student Behaviour Rating Scale (SBRS) found three significant interactions over time regarding playground behaviour, getting along skills and willingness to attempt tasks. The active group declined in proficiency over time compared to the control group in playground behaviour but improved over time with getting along skills. Both groups improved in their willingness to attempt tasks, however, the active group improved significantly more than the control. It is possible that the BBL Program had some effect on this change of attitude as the Program specifically focuses on the identifying and improving specific learning skills. It is equally possible that other factors not relevant to this study, such as new students in a class or changes in home life, came into play. The available data cannot provide these sorts of distinctions, indicating a study limitation.

Information provided by the inclusion of SES as an analysis factor for the SBRS data showed significant interactions for classroom, playground getting along, social skills and attempting tasks but not for aggression on the SBRS. Both active and control groups reflected the same pattern for improvement or decline over time for classroom (both declined), playground (both declined) and attempting tasks (both improved) but showed opposite patterns for getting

along (active group improved with decline in control group) and socials skills (active group declined but improvement in control group). The performance breakdown of the six SBRS categories showed a consistent pattern in all but classroom behaviours. Successful classroom behaviours followed SES lines, with the high group outperforming the middle group which outperformed the low group at both testing points. However, in each of the other five categories, there was a distinction between the SES dynamics in the low and middle groups and that of the high group. Here the active low and middle groups consistently outperformed their control counterparts, while in the high group the control cohort was rated more highly than the active cohort on all items. This could be taken as a positive social impact of the BBL Program as improvement which does align with research literature indicating that most improvement from interventions which target executive functioning occurs in students with the lowest skills levels at baseline (Diamond, 2013) but this supposition would require more investigation to eliminate any other environmental factor at play.

Using behavioural data as an overall measure of improvement to executive functioning in students appears to be defensible based on research literature (Toplak et al., 2013). However, the SBRS data set raises more questions than it answers, in that there are many other factors that affect how well individuals practically apply their skills, such as how well students emotionally regulate in the school playground. In hindsight, it is difficult to assume data from this measure is a pure reflection of student improvement in personal skills or skills implementation. This represents a poor choice of measurement tool and a limitation to this study.

As reported in Section 4.4 3, the parent data set from the BRIEF was skewed towards middle and high SES levels and, therefore, does not fully represent the study population. Data from the parents, like that of the teachers, did not follow SES lines, with the middle group being

rated most harshly. This is not in keeping with performance data which reflected levels of SES.

From this information, it is reasonable to conclude that relative bias is a central factor in the use of self-rating instruments underscoring the importance of collecting performance data as well as perception data in field-based research. It is also reasonable to conclude that the student population in this study had a better sense of their personal skills and abilities in relation to performance data than either their parents or teachers.

Question 5: Impact of Socioeconomic Status (SES)

How and to what extent do study outcome measures relate to socioeconomic status (SES) as defined by a school's Index of Educational Disadvantage rating?

Socioeconomic status had a main effect in six of the eight subtests of the CPT. Apart from errors of commission (where students in the low SES group outperformed students in the middle group), performance generally matched SES levels with students from low SES sites performing more poorly than those from middle SES sites, who in turn, performed more poorly than students in high SES schools. Greater overall performance improvement occurred between Time 1 and Time 2 in the active, high SES group.

Executive function performance outcomes mirrored SES levels and this trend was also seen in the motivation and engagement data. Quantitative student data from the MES resulted in significant attitudinal change interaction across the research timeframe for the positive *self-belief* item only with the interaction located between the active and control low SES groups. Self-rating of positive attributes, such as *self-belief* tended to decrease over the school year for the active group, with ratings on negative attributes becoming less harsh over time (see Significant time main effects Tables 40 and 41, p. 226). In this study, the active group was more positive in *self-belief* than the control group at baseline (Time 1), but declined in

positivity by Time 2. There was no significant change for the control group. Once again, this would indicate that SES does not doom a student to fixed outcomes.

Data from the physical inputs of sleep, physical activity and diet all reinforced the concept that SES levels impacted strongly on behaviours. Students from low SES sites had poorer sleep quality, quantity and patterns. Dietary habits were less healthy and rate of physical activity lower in the low SES cohort.

In the qualitative data, student ability to detail and articulate responses to the BBL Program were in keeping with SES levels. Students from high SES sites reported more and made more detailed connections between aspects of the BBL Program and their learning. The qualitative data also demonstrated that students were willing to engage with something they found interesting regardless of the levels of their executive functioning, although the degree to which individuals engaged varied. Qualitative data also indicate that students across all the active sites, regardless of SES level, were interested in what the BBL Program could teach them about learning and self-improvement.

Therefore, it is reasonable to conclude that SES is a high impact factor in relation to both the development and improvement of executive functions. This finding is supported by much current research literature (Brito and Noble, 2014b, Fernald et al., 2013). However, these findings also demonstrate that SES does not fix attitudes to or interests in learning and self-improvement.

Question 6: Impact of Socioeconomic Status (SES) on Performance Improvement

How and to what extent were SES levels reflected in student improvement data?

Quantitatively, significant student improvement occurred most in the active high SES group rather than the low SES group (see Section 4.4.1). Qualitative feedback from students in the

low SES groups suggested that they required more time and exposure to concepts to adequately incorporate new learning. Feedback from teachers in low SES sites indicated that teachers believed their students had benefited and improved from interaction with the BBL Program but were firstly, less able to articulate their learning and secondly, operating from a poor academic and/or behavioural position at baseline so that improvement only helped these students to move closer to standard expectations.

Students in the active lower SES group did make improvements. However, improvement occurred to a lesser degree than students in the active high SES group. Therefore, it is reasonable to conclude that, in this study, SES was reflected in outcomes from performance testing.

Question 7: Program Portability

How and to what extent did the BBL Program demonstrate positive outcomes (i.e. feasibility in delivery and acceptability to teachers and/or students) for the study population?

Implementation of the BBL Program over a 20-week period, in six novel classrooms across the range of SES levels returned meaningful quantitative and qualitative data despite the complicating issues of student attendance, student transience, and fluctuating school timetables discussed in Section 4.3.3. All content was delivered as planned, although it was necessary to re-visit some key concepts in the low SES classes. Materials and lessons translated into each setting, but with some technical challenges in the low SES classes. Qualitative data indicated that the BBL Program was highly valued. Data from the primary measure, the CPT, found a mitigating effect on performance decline across time that can be attributed to participation in the BBL Program.

Therefore, it is reasonable to conclude that the BBL Program is transferrable to educational settings other than those for which it was designed.

Chapter 5 Discussion and Conclusion

This chapter is presented in three parts. Section 5.1 reports study limitations encountered in conducting this field-based research. Section 5.2 provides recommendations for future research and for the education field. Finally, conclusions are detailed in Section 5.3.

5.1 Study Limitations

Providing ecological validity through field-based research is typically harder to implement than laboratory-based projects (Blakemore and Bunge, 2012, Lemons et al., 2014, Morrison, 2001, Rossman and Rallis, 2003, Yeung et al., 2017). To answer the research questions in this work by the most robust means possible, a mixed-methods randomised controlled trial with qualitative investigations was selected. The inclusion of the qualitative element was important because educational research provides a moving target. For example, it is possible for successful interventions to become less successful over time because the control population consciously or unconsciously changes its behaviour as successful concepts filter into the educational landscape (Lemons et al., 2014). However, it remains true that in order to prove the worth of a new intervention to educational policy makers, many of whom are politicians, statistics have greater sway than personal stories (Lemons et al., 2014, Morrison, 2001).

In applying a randomised controlled trial methodology, the current study was complicated by problems that emerged during data collection and program delivery. Data collection problems involved method short-comings, complications with selected instruments and unexpected issues at some of the sites. These will now be discussed.

5.1.2 Methodological Issues

> It is a truism to say that naturalistic settings such as schools and classrooms are not the antiseptic, reductionist, analysed-out or

> analysable-out world of the laboratory (Slavin, 1986), and that the degree of control required for experimental conditions to be met renders classrooms unnatural settings… (Morrison, 2001, p. 72).

In 2001, Morrison argued that the use of randomised controlled trials (RTCs) in education should not automatically be seen as the gold standard by which evidence-based practice was judged (Morrison, 2001). Morrison reasoned that school environments are often better understood through the lens of chaos and complexity theories, rather than causality and prediction which characterise RTCs (Morrison, 2001). Further, Morrison felt that it was impossible to provide exactly the same protocols and procedures across differing social conditions (e.g. school classrooms) because "…sentient people tailor their behaviour to each other" (Morrison, 2001, p. 73). As reported, this problem was encountered during the present study in the low SES classes due to large changes in class composition over the 20-week intervention period (see Section 4.3.3) and has been identified as a limitation to the study which requires further exploration.

Range of Executive Functions Examined

There are three core dimensions of executive function—working memory, inhibition control and cognitive flexibility. This study addressed the first two dimensions but did not measure cognitive flexibility. This represents a limitation to any study on improvements to executive function. However, it could be argued that, as Diamond (2013) has suggested, the development of cognitive flexibility is reliant on the first two dimensions (Diamond, 2013), hence, the measurement of cognitive flexibility could be seen as a secondary consideration. It could also be argued that many studies which examine executive function specifically focus on aspects of functioning, such as working memory or sustained attention, rather than the entire gamut. Therefore, the lack of measured change to cognitive flexibility in this study represents a minor limitation that does not compromise the validity of the overall project.

Computerised Testing

Licencing costs for computerised tests necessitated individualised testing and made test administration at a class level prohibitive. Limited laptops containing the tests also meant that the timeline for data collection exceeded the one-week period just prior to and following the intervention period. As well, individual test administration across a study population of 287 students, meant that students sat the tests at differing times during the day and on differing days of the week—both factors that can affect performance outcome (Creswell, 2013). However, as data in this work considered improvement from baseline to post intervention on an *individual* student level, and every effort was (barring student absence) successfully made to ensure that students were tested at the same time of day and on the same day of the week for both collection periods, the method of computerised data collection does not present a limitation to the study.

Apparent Rater Bias

Evidence for rater bias was apparent in some of the data. Results from the teacher questionnaire (the SBRS) appear to reflect rater bias in relation to student behaviour within different SES levels. As another example, one teacher commented on the differences between boys and girls in learning up-take and metacognition (Teacher Transcript 6). General teacher attitudes to stereotypes for gender, age, ethnicity or SES were not canvassed in this work. Therefore, it is impossible to tell for the available data whether this comment was a personal bias or a valid comment on this class cohort. As rater bias cannot be discounted, this must be noted as a limitation to the study design.

Study Controls

In this study, the active group was randomly selected from a group of Year 4/5 classes and matched for SES levels with the control group. Active classes were at separate school sites from those in the control group, with the active group receiving the BBL Program

intervention. This meant that the control spent more time on regular classroom activities than the active group because time was not given to an additional intervention (i.e. the BBL Program). Although this is a standard design for a randomised controlled trial, this method of organisation also had the potential to account for some improvements in the control group that were not present in the active group, such as improvements in playground behaviours using the SBRS. Improvement in the control group may also reflect the effects of other programs in operation at the school. Both more time on normal activities and the possibility of other interventions at schools are noted confounders for randomised controlled trials within school settings (Lemons et al., 2014).

Intervention Follow-up

Intervention studies that aim to improve specific outcomes usually have an additional post intervention follow-up test period to explore the maintenance of any measured change. Such a test would have been instructive in this case but was not possible due to the configuration of a school year (i.e. post intervention data was collected in Term 4 meaning that follow-up would have occurred at the start of a new school year) and the resources available for the project. Any future examination of the BBL Program will hopefully be designed to measure maintenance of change.

5.1.2 Choice of Instruments

Most measures selected for this study employed a Likert scale. While all outcome measures had high test validity, it must be acknowledged that Likert scales tend to bias rater response towards the middle of the scale (Kulas and Stachowski, 2009). A review of parent and teacher data did not reflect this tendency. Teacher data was more skewed to extremes rather than towards the middle, especially in the high and low SES sites. The author has suggested that this skewing of data is more related to teacher bias and the use of school site, rather than individual circumstance, to assign SES levels. Therefore, it is argued that the use of Likert

scales has not compromised the study results. However, there were issues with each of the measures which will not be examined.

Continuous Performance Test (CPT)

Variations to the CPT II and CPT III were unexpected at the time of design. Although advertised as primarily providing updated software, the CPT III had functional differences in test presentation in relation to font colour and length of practice session. To mitigate against these differences, each student was given the same version of the CPT at baseline and post intervention. As this study examined individual change over time, it is suggested that this protocol has resulted in a nil impact to the data collected.

Motivation and Engagement Scale (MES)

Printing of the MES questionnaire was done at each school site as part of in-kind support from the Department of Education and Child Development (DECD) for this project. Although, the directions for printing the MES specified a single-sided format, some schools did not follow this direction and produced a double-sided document. This resulted in some loss of data in the middle section of the questionnaire when students overlooked six or the forty-four questions. Missing data affected the subtests of *values*, *persistence* and *self-sabotage*. Data for these three items was analysed by the same process as other MES items, but with a smaller overall participant group (reduced by eight students in each case). A check of power calculations for the interactions analysed found that there was no significant difference between all MES items examined.

Student Behaviour Rating Scale (SBRS)

The SBRS was developed primarily to assess student difficulties in relation to behaviour. It was selected for this study to provide insight into how teachers viewed student abilities in the general school environment to assess whether performance on computer-based tests of executive function held any relationship to functional performance in school. As there was no

data collection concerning teacher attitudes to their students nor teacher-student relationship data, it is impossible to determine how much teacher bias has affected this data set. This is a large limitation in gaining a complete ecological picture that includes student, parent and teacher views. However, this problem does not affect the findings for the primary hypothesis and only impacts on the response for Question 4.

Behavior Rating Inventory of Executive Function (BRIEF)

As explained, data from parents via the BRIEF was unreliable given the poor return rate from the low SES group. As with the SBRS, this presents a large limitation in gaining a complete ecological picture that includes student, parent and teacher views. However, this problem does not affect the findings for the primary hypothesis and only impacts on the response for Question 4.

Operation of the Working Memory Test Battery

Prior to study commencement, there were significant problems in rendering the Working Memory Test Battery operational due to software system upgrades in both MATLAB and the Psychophysics Toolbox. These problems were eventually rectified through personal correspondence with the test's author who advised the use of an earlier version for the software underlying the test's operation. However, problems recurred as MATLAB automatically updated when in contact with the university network and the program pathway again had to be re-routed to the earlier version. No data were lost or damaged in this process as back-ups proved. However, there were enough systemic operational issues to seriously question selecting this outcome measure in future.

5.1.3 Unexpected Site Issues

Program Delivery

Although the presence of an interactive smartboard and internet connectivity were written criteria for acceptance into the study (which the researcher verbally confirmed during initial

site interviews with principals and teachers), both classes in the low SES active group had substandard equipment. In both classes, the teacher's computer projected on to a solid whiteboard. This meant that interactive games were operated with a mouse from the teacher's computer rather than at the screen in full view of the class. In addition, the resolution provided by a flat whiteboard was poor. It was a weakness in the study's implementation that the researcher did not personally inspect each classroom before acceptance into the study.

Data Collection

Several factors impacted on data collection and included aspects of:

- Maintaining controlled school-based environments for individualised computer-based testing in some sites where space was at a premium, for example, a musical instrument lesson started in the class next to the testing room during the attention session because the music teacher had negotiated a change of work day.
- Reliable student attendance at some schools or student unavailability during both intervention sessions and pre/post testing, for example, in GP and ET schools, test facilitators returned up to four times due to class excursions, dentist appointments and a science show that was organised, apparently unbeknownst to the teacher involved in this study.
- Parent and student response rates at recruitment and data collection points which saw a dissimilarity in questionnaire return rates along SES lines (discussed further below).
- Timely teacher administration of all paper-based BBL Program tasks where some teachers took two weeks longer than others to return testing materials (discussed further below).

Recruitment of student participants varied across school sites. Of the twelve classes, seven were fully subscribed at commencement of the intervention protocol (see Table 25 p. 195). None of the low SES classes was fully subscribed despite sustained follow-up efforts by the

researcher and school staff, including the use of class-based incentives in one site as well as direct parent encouragement by the school's leadership team. This would tend to indicate a need to have greater contact between low SES parents and researcher in future studies, rather than just rely upon the school to facilitate data collection.

Staff in low SES schools reported ongoing difficulties with parents returning any school-based paperwork due to:

- poor parent literacy skills
- problems with the English language and understanding what was required
- low engagement with schooling due to traumatic parental school history, poor organisational skills (i.e. paperwork lost) and/or energy remaining after meeting basic family survival needs.

However, it should be noted that there is no corroborating evidence for these statements, except the difficulties experienced recruiting and collecting data for this study.

Subscription to this study required parents to return a signed consent form to their child's school. All classes in middle and high SES schools were fully subscribed except for class CRA1. This class was shared between two teachers, but the researcher was only able to meet with one face-to-face to form a positive personal relationship. Whenever the researcher contacted teachers in the study regarding paperwork, teachers who had formed a personal relationship with the presenter appeared (from conversations) to have put more effort into encouraging parents and students to subscribe or complete the questionnaires.

Overall data collection was impacted by SES levels and location of collection (i.e. questionnaires answered at school or sent home and returned later). The data sets reflect differences in return rates along SES lines, despite classes in higher SES schools having up to ten additional students as compared to those in low socioeconomic sites. Return rates were

also much higher when data was collected at the school rather than when materials were sent home to families (see Table 26, p. 197).

Completion and return rates varied from class to class and were complicated by:

- teachers who shared a class (three classes—ET, HAM and CRA1) finding time to collaborate on their responses on the SBRS
- extended teacher illness in the latter part of the intervention period (three teachers—GP, SD and HG)
- poor literacy skills of some parents who reportedly found the BRIEF too difficult/long and therefore did not return it
- poor organisational skills of students and/or parents (and/or between teachers in three classes where the class was shared)
- student absence during lessons allocated to the MES, MCNQ (diet) and PAQ-C (activity) questionnaires where some teachers did not follow up, affecting ten students
- time conflicts caused by the many other assessment and data collection tasks that are currently required of South Australian schools.

Timetable Interruptions

The initial concern by some classroom teachers that Monday morning and Friday afternoon timeslots for the BBL Program might pose difficulties for student engagement did not eventuate. However, interruptions to the 20-week lesson schedule occurred due to several factors including a long weekend in June making the Monday a public holiday, some individual school-based pupil free days and, the allocation of swimming week during the intervention period in one site. Lessons were rescheduled so that each class missed only one lesson in the 20-week program (i.e. each class received 19 or the 20 sessions). Australian National mandatory NAPLAN (National Assessment Program—Literacy and Numeracy) testing took place on Tuesday-Thursday and, therefore, did not impact on program delivery to

any Year 5 students. The presenter re-scheduled the lesson timetable so that Session 19 (higher order thinking and problem solving) and 20 (bringing it all together) were combined.

Teacher Absences

Program delivery was also impacted by the multiple absences of class teachers due to personal illness, and days out of the classroom for administrative purposes or professional development commitments. Although teacher absence did not directly affect BBL Program delivery in class, it did cause some difficulty in collecting the course work and data samples. For example, with one class in the intervention group (STR), the post sleep knowledge test data were lost between the teacher and his relievers (i.e. substitute teachers) sometime during the last six weeks of the intervention period.

Teacher absence often has an effect on class behaviour with some students typically becoming less emotionally settled and self-regulating (Kidd et al., 2015). However, in this study, by the time multiple teacher absences were occurring the researcher has become a familiar face and student behaviour was largely not an issue during the BBL lesson. As part of the program, students were encouraged to practice skills and activities learned. It is possible that teacher absence impacted on the amount of practice students undertook in class. A monitoring device for practice undertaken outside of BBL lessons could provide insight into the impact of teacher absence in any future study.

5.2 RECOMMENDATIONS

5.2.1 Recommendations for Future Research

The current work is an attempt to increase available research on training executive functions to improve student learning outcomes within a regular school setting. It represents a phase one feasibility study to test BBL Program effectiveness and portability in a small population of South Australian primary school students.

The results of this project are encouraging but require follow-up testing in relation to sustained change and replication. Recommendations for future research based on both the literature review and the study outcomes in this work include the following:

Recommendations Specific to the BBL Program:

> …we can only know whether something works by 'trying it out'; practice precedes policy and is superior to theory or political will (Morrison, 2001, p. 70).

- The replication of this study in further novel school environments is recommended. The present work found a mitigating effect of the BBL Program along with indications that modifications to program delivery are need in low SES settings. Returning to the points made by Durlak and Du Pre (2008), program modifications often become evident during the implementation process. However, modifications made then require further research to ensure program fidelity and ongoing effectiveness (Durlak and DuPre, 2008). Therefore, further research is required to test the mitigating effect and to trial program delivery modifications in low SES settings. The SES-related dynamic of transience and absence demonstrated in this study lends even more urgency to further investigating the effects of the BBL Program on executive function improvement in low SES sites.
- Further research is warranted to determine if the performance decline reported here is an aberration of this study cohort or a true performance factor that would have implications for classroom pedagogy and curriculum presentation.
- Further work is required to determine to what extend direct, definable connections exist between the results of this study and individual skills taught during the BBL intervention. Examples questions here are, do improvements in metacognition about attention lead to

better performance on tests of executive function, or how much and in what ways does the BBL Program affect students views on themselves as learners?

- This study targeted students between the ages of 9-11 years. In its original sites, BBL Program is also offered to younger students, including children in preschool and older students to the age of 13 years. Investigation into the program's effectiveness at other age levels is a suggested topic for future research.
- This research tested a 20-week intervention but it is unknown if 20 weeks is the optimum intervention level for the BBL Program. This is an additional point for future enquiry.
- A monitoring device for practice undertaken outside of BBL lessons could provide insight into the impact of teacher absence in any future study, as well as, additional data about student improvement through effort expended.
- Similarly, a longitudinal study or study with a post-intervention follow-up design could increase understanding of the program's effectiveness. However, school-based follow-up studies are complicated by the loss of defined class populations at the end of each school year and would need a design that could accommodate this factor.
- As noted by Blunden & Rigney (2015), sleep programs appear to have more impact on school students when the presenter is engaging and perceived as an outside expert (Blunden and Rigney, 2015). This view (that the presenter was perceived as an outside expert) was expressed in the qualitative data by more than one teacher participant. It would be interesting to further investigate different models of BBL Program delivery (e.g. by the regular classroom teacher or by a staff member within the school who is well known to students).
- Recommended guidelines for paediatric sleep were amended and published in 2016 by the American Academy of Pediatrics. New recommendations for children between the ages of 6-12 are between 9 and 12 hours (see p. 79). This change represents an increase of

two hours, with an increase of one hour on each side of the previous range. As Sadeh and colleagues (2003) demonstrated, an increase or decrease of only one hour in sleep duration can have measurable impacts upon cognitive functioning. It would be of interest to re-analyse the study data using the updated sleep guidelines.

General Neuroeducational Research Questions and Recommendations:

- In this study, functional performance on attention tasks decreased between the beginning of Term 2 and the end of Term 3 across the entire cohort. It would be informative to the education community to investigate whether this dynamic was an anomaly in the current study population or a feature of attentional fatigue in relation to different parts of the school year.
- Does program delivery impact student outcomes? For example, is there a difference to student improvement levels when the same intervention is delivered in a regular classroom setting as opposed to using an individual, computer-based or clinical method?
- How is the impact of a novel intervention, such as the BBL Program, integrated by students into their espoused and demonstrated thinking and behavioural repertoire?
- The effects of parental interest and support levels for classroom-based initiatives such as the BBL Program across the range of SES could be of interest in further exploring factors that contribute to student success.
- In this study, the low SES cohort appeared to be affected by classes with large populations of refugees who may not have experienced low SES conditions prior to arriving in Australia. Further investigation into socioeconomic disadvantage between students who have experienced low SES conditions for most of their lives as compared to those who experienced a change in social condition, for example, due to becoming refugees is recommended.

- Would increasing amounts of sleep in the low SES group improve attentional performance as a standalone factor or is the inclusion of skills-based intervention(s) necessary to achieve significant performance improvement?
- Sleep data also raised the question, does too much sleep negatively impact executive functioning?
- Does a high level of media use in the early years impact the development of directed attention in a similar way to social neglect or trauma? If so, does the same type of targeted attention training equally benefit students with high levels of media use and corresponding low levels of physical activity in their early years and those with trauma-related hypervigilance?

5.2.2 Recommendations for Educational Practice

- Given the feedback from the active student cohort, should learning about the brain and the explicit teaching of executive function skills be incorporated into the Australian curriculum across the primary school year levels?
- If explicit teaching of executive function skills is to be incorporated into the Australian curriculum, this will require significant upskilling of classroom teachers, as per findings by (Alekno, 2012, Dekker et al., 2012, Gleichgerrcht et al., 2015, Pasquinelli, 2012).

5.2.3 Recommendations for Improvement to the BBL Program

The updated literature review highlighted some possible additions to BBL Program content while supporting the soundness of the program's basic structure. Although the present study is not an analysis of BBL Program content, it is worth considering how more recent research impacts the program's construction. Possible content/pedagogical additions include:

- Increased emphasis on acquisition of a large *working* vocabulary (i.e. vocabulary is used spontaneously by students and not just when elicited by teachers), especially in

relation to emotion. The emotional literacy component of the BBL Program already teaches emotional vocabulary in relation to differing emotions and differing levels of feeling within an emotion (e.g. one can be irritated or furious rather than angry or very angry). However, the research of working vocabulary underscores the need to give students more contextual opportunities to practise emotional vocabulary as reported in the literature (Clément et al., 2013, Fernald et al., 2013, Marulis and Neuman, 2013, Weisleder and Fernald, 2013). Going forward, the BBL Program will provide more contextual opportunities, such as role plays, and develop specific activities that require an extended emotional vocabulary to participate. The program already encourages the use of emotional check-in walls in classrooms which helps students recognise and monitor their emotional state at key points throughout the day but which has also encouraged students to request more vocabulary as they seek to better define their personal feelings.

- Understanding that the application of an emotional vocabulary must go beyond the recognition of facial expressions to incorporate an ability to connect appropriate emotions with context – the application of knowledge stage (Lugo-Candelas et al., 2016). Going forward, the BBL Program will provide more contextual opportunities, such as role plays, and develop specific activities that require an extended emotional vocabulary to participate.
- Inclusion of aspects of boredom research as it impacts academic progress into information provided to students and teachers which may clarify aspects of motivation and metacognition identified in this study (Eastwood et al., 2012, Krannich et al., 2016, Malkovsky et al., 2012, Martin et al., 2012b, Mercer-Lynn et al., 2014, Pekrun et al., 2014, Shechtman et al., 2013). This would be incorporated into work on mindfulness, creativity and daydreaming.

- Updated information regarding the influence of digital media on cognitive development, including positive social aspects provided by this technology and apparent pitfalls of too much reliance on technology as an educational motivator for students with poor executive function/independent learning skills (Choudhury and McKinney, 2013, Hill et al., 2016, Mills, 2016, Shechtman et al., 2013). The BBL Program needs to position personal use of technology alongside sleep, diet and physical activity as modifiable influences on brain development within its contents structure.
- An expanded use of embodied learning with and without digital technology (Thorburn and Stolz, 2015). The BBL Program already has activities that emphasise embodied learning. However, to date, this area has not been spotlighted for classroom teachers during planning/feedback or professional development sessions. Embodied learning will be given a more prominent profile in future sessions.
- Dealing with emotional advantage (vantage sensitivity) as well as disadvantage (resilience) (Pluess and Belsky, 2013). This information will be incorporated into the emotional development syllabus.

5.3 CONCLUSION

5.3.1 Development of Executive Function as an Educational Imperative

Executive functions are the skills required to set and then achieve a goal (Dawson and Guare, 2004). Executive functioning underpins learning, especially in formal settings such as schools (Dawson and Guare, 2004). As the research literature indicates, and this study supports, executive functions can be improved through targeted intervention (Diamond and Lee, 2011, Diamond and Ling, 2016 , Klingberg, 2016, Piquero et al., 2016, Rueda et al., 2012). Further, proficiency in subject matter, such as mathematics, can be improved by training executive

functions (Center on the Developing Child at Harvard University, 2011, Cragg and Gilmore, 2014).

How the brain learns is core business for any educator and it would seem both important and wise that classroom teachers receive specific training in the development of executive functioning as well as the supporting classroom pedagogy (Gilmore and Cragg, 2014). Specifically, the underlying foundational quality of self-regulation (see p, 253) for cognitive flexibility would indicate the need to encourage less teacher regulation and more student self-regulation in classrooms as a matter of basic pedagogy. This, however, should be tempered with an understanding that executive functions develop over time and with appropriate practice (Center on the Developing Child at Harvard University, 2011). That is, it is necessary to scaffold the development of EF skills and not just expect all students to acquire these skills without adult assistance. Further, specific skills require specific training (Simons et al., 2016).

Directed attention is learned, or not, depending upon personal experience (Posner, 2010). Research on the development of attending and digital media is particularly important for educators in that the types of directed attention required to function within the classroom and as part of a social team are not present at birth but must be developed (Fan et al., 2005, Hammond et al., 2011, Napier, 2014). Sleep habits, diet, physical activity and access to digital media, especially from an early age, are factors that influence how a brain will develop attentional capacity (Becker et al., 2016, Born, 2012, Gómez-Pinilla, 2008, Gomez-Tolle, 2012, Napier, 2014). As more young children come to school, with high levels of digital media experience at the expense of both physical and social experience (Abramson et al., 2009, Bittman et al., 2011, Brown et al., 2011, Busso and Pollack, 2015, Cain and Gradisar, 2010, Choudhury and McKinney, 2013, Cooper, 2009), educators may have to include the remediation of directed attentional deficits into regular classroom practice.

5.2.2 Conclusions from this Study

Many of the techniques and beliefs that have formed educational pedagogy are underpinned by academic theories about teaching and learning that are now being methodically tested through the application of cognitive neuroscience and cognitive psychology research. Properly understood and applied, educational neuroscience has much to offer the modern educator. However, neuroscientists are, generally, not classroom primary (elementary) or secondary (high school) teachers. Neither are classroom teachers, generally, neuroscientists. Yet, as proponents of the nascent Mind, Brain and Education discipline advocate, if there is to be a meeting of the minds or an interdisciplinary forum, individuals or groups on both sides will need to make forays into unknown territory. This work represents one such foray.

This study demonstrated that the BBL Program can have a positive impact on student functioning and engagement. However, contrary to expectations, the students in the low SES settings did not appear to benefit as much as those in the high SES settings. Students with less well developed learning skills in this work reported needing a more intensive classroom intervention than those with better skills sets. It should be noted that this finding is out of step with much international research that shows interventions deliver more improvement in students with larger deficits (Diamond, 2013, Diamond and Lee, 2011). However, it is postulated that the finding in this study reflects the need for a student to recruit executive functions to be successful as a classroom learner. Therefore, students with poor executive functions will have more difficulty accessing interventions presented to a class group than those who can manage their attention, employ sufficient working memory and regulate thoughts, emotions and behaviour.

Moreover, aspects of the researcher's experience in running this study lead her to believe that educators need to acknowledge that the learning gap between low and high SES students is not just a function of knowledge acquisition. Rather, as was stated in the initial literature

review, what an individual knows impacts upon what he/she can come to know. It seems plausible that teaching the same curriculum in classes across SES levels continues the disadvantage accorded to students with lower levels of executive functioning—especially in relation to self-regulation. In short, if educators are serious about closing the gap between high and low SES students, solely targeting academic curriculum delivery will not be sufficient. The literature on how the brain learns clearly indicates that basic learning skills should be explicitly taught and practiced as a core function of curriculum delivery (Center on the Developing Child at Harvard University, 2011) and that better levels of executive functioning deliver better educational outcomes (as has been shown throughout this work) (Best et al., 2011, Cartwright, 2012).

The research currently emerging from the cognitive arenas of neuroscience and psychology has the potential to greatly improve both student and teacher outcomes by allowing students to understand and consciously develop their executive functions as the underpinning skills for learning, as well as their social and emotional literacy skills. This knowledge, accurately translated into classroom pedagogy, will allow teachers to more accurately target teaching as well as to assess and support the learning processes. For example, the BBL Program employs a games-based format to encourage students to practise various executive functions. The reasoning behind this approach is that student skills improve with practice and if practice is both fun and visible, then students will more readily engage. In short, to produce the best equipped and most motivated students, the basic tools of learning, including working memory, self-regulation and attention skills, should firstly, be well understood by teachers and secondly, explicitly taught.

In the past, much educational research has focussed on improving student learning outcomes through measures such as improving teacher quality (Dinham, 2007, Kennedy, 2008, Yeh, 2009) and, curriculum or physical conditions (e.g. class size) (Cook et al., 2006, Gottfredson

and DiPietro, 2011, Mayor, 1991, Muennig and Woolf, 2007)—all things provided to and/or around students. In contrast, the BBL Program seeks to improve student learning outcomes by teaching students the underpinning tools that allow them to engage with learning, monitor their own progress and, thus, successfully navigate the school environment. This work has demonstrated a positive impact on student performance and behaviour for the BBL Program approach—representing a phase one investigation into program effectiveness, feasibility and portability.

Such a finding is considered important for four reasons. Firstly, the BBL Program is inexpensive to implement (as discussed in Section 1.1). Secondly, the program underpins teaching/learning (perception/practise based) rather than further crowding the curriculum (knowledge based). Thirdly, the new science of learning (i.e. neuroeducation) appears to have much to offer to the field of education. However, it is the translation of research into classroom practice that provides the real challenge for educators. This program now offers a research-backed example of such a translation. Finally, this study's outcomes reinforce the notion that SES plays a crucial role on any individual's personal experience, how that person's brain will develop and, therefore, what methods might promote the best learning outcomes. In short, not all students make sense of input in the same way. Logically, it would follow that consideration of SES must always be central to constructs of policy, pedagogy selection and professional practice.

As mentioned, the finding of this study that students in the high SES cohort benefited more from the BBL Program than those in the low SES sites is contrary to general research findings on executive function training. This raises questions about functional differences between program delivery within a regular classroom context as opposed to controlled laboratory training or individualised training programs. However, if improvement (or mitigation against decreased performance) in executive functions of attention and working

memory is possible for all students, then it is even more imperative that schools incorporate explicit training into the general curriculum to assist all children to become the best learners they can be and, thereby, the best future citizens.

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Appendix 1 *Being the Best Learner You Can Be* Program

In 2009, at the request of four north eastern metropolitan Adelaide (South Australia) schools, this author developed a school-based program entitled, *'Being the Best Learner You Can Be'* Program (BBL Program) for children from preschool to Year 7 (ages 4 to 13 years). This program was expressly created to improve executive functioning in the students and was shaped in direct response to the specific needs of participating schools.

The overriding concept of the program is student-focussed. The BBL Program sees learning as that which the student does or does not do in response to input. This contrasts with the usual emphasis on curricula, or what a teacher delivers to a student. The BBL Program focuses on helping students to improve attention, memory, emotional literacy, and higher order thinking skills (HOTS) so that academic and social outcomes are maximised. Aspects of general health such as sleep, diet and exercise are included in the program as these directly contribute to brain function and, therefore, learning.

The program has three main goals. Firstly, it seeks to improve student learning outcomes by providing students with the underpinning tools that allow them to engage with learning, monitor their own progress and, thus, successfully navigate the school environment. It differs from other brain-based educational packages by providing a range of cognitive, emotional and conceptual tools for improvement directly to students thereby placing the onus for training their brains' (i.e. learning) primarily where it belongs—on the students. Secondly, the Program provides teachers with a means to improve professional practice through current information on how the maturing brain best learns. This point is important in that a teacher's core business is the structure, assessment and development of student learning. Thirdly, the BBL Program acknowledges the mutually dependent relationship of emotional and intellectual development in promoting strong learning outcomes. Rather than single out a unit

of study on attention or emotional development, this program synthesises all the factors that contribute to learning (including attending capacities and emotional development) within the same package—a package which aspires to instil positive, lifelong, cognitive, emotional and behavioural patterns as well as academic excellence.

In constructing the program, it was important to determine the most relevant research areas. When including concepts and activities in the program, choice was guided by the following two questions:

- Has the research been well-constructed and verified or replicated?
- Does this information or approach serve to develop/improve executive functions and if so, how?

To define what constitutes 'well-constructed' and 'verified' research, the author referred to work from the Johns Hopkins University's Center for Research and Reform in Education and the University of York's Institute for Effective Education as outlined in their online resource, Best Evidence Encyclopaedia.

Given that the term 'executive function' can refer to an array of skills and abilities, it was decided to adopt the definition and approach put forward by Dawson and Guare in their book, *Executive skills in children and adolescents: a practical guide to assessment and intervention* (Dawson and Guare, 2004). This decision was made based on both face validity and general transferability into a primary (i.e. elementary) school setting.

As framed by Dawson and Guare, the set of abilities that are necessary for goal-directed behaviour include all skills that allow individuals to anticipate outcomes, adapt to changing situations, form concepts and think abstractly. Specifically, the BBL Program has targeted and expanded Dawson's and Guare's set of executive functions to include:

- Planning (ability to create a roadmap to reach a goal)
    - Organise
    - Time manage
- Working memory (both verbal and non-verbal)
- Metacognition (self-knowledge & higher order thinking)
- Response inhibition
    - Delay gratification
    - Stop unsuccessful behaviours
    - Manage distractions or interruptions
- Self-regulation for affect (ability to manage emotions)
- Task initiation
- Flexibility (revise, problem solve, error correction)
- Goal-directed persistence [adapted from (Dawson and Guare, 2004)]

BBL class lessons provide both information and opportunities to practice specific executive functions through a range of games adapted and/or developed by the author. All classroom games have been designed to improve one or more aspects of executive functioning using a minimum of materials that are easily found in, or created within, regular school environments.

In developing the BBL Program, it quickly became clear that simply listing a range of executive functions would not provide adequate direction for classroom teachers or their students. Accordingly, a set of key principles (see Appendix 2) was developed, along with a range of support materials (teacher and student versions of executive function rubrics, concept posters, fridge magnets with concept posters and explanations for parents, a games handbook and resource cards). The key principles were intentionally framed in student-friendly language and with a view to reminding educators of key concepts that arise from an understanding of the roles that plasticity, perception, experience (especially targeted practice) and emotion play in learning.

Appendix 2 BBL Program Key Principles

Being the Best Learner You Can Be Key Principles

1. Executive functions develop over time AND with training/practice.
2. The brain loves patterns and actively seeks them out.
3. Making mistakes is part of learning. We all make mistakes. It's what you do after the mistake that is important for a learning outcome.
4. Attention—just because we 'look/hear' does not mean we 'see/listen'. The information that gets to the brain is related to our focus and our perceptual filters.
5. Attention and Emotion—we may look at the same thing but see things quite differently depending upon how we feel (emotions) and what we know (experience).
6. The brain is shaped by both nature and nurture. How we use our brains makes an enormous difference to whether we become the best learners we can be.
7. The more you practice, the better you get at WHATEVER you practice. So, give the brain the best patterns possible from the start.
8. Just the right amount of emotion makes for strong learning.
9. No two brains are exactly the same, but they all have the same basic needs. Neural networks need to learn to work together. For example, it is important for a brain to learn to align the emotion (limbic) and cognitive (frontal lobes/executive function) networks.
10. If the focus is on learning, it is the learner who needs to take responsibility for training his/her brain.
11. Movement can consolidate learning.
12. Maintaining attention and self-regulation require high levels of energy expenditure. 'Focus fitness' and emotional literacy are as important as physical fitness and academic literacy skills.
13. As in any process, reflection and assessment are necessary. Assessment Modes-self-reflection checklists, formative and summative formal assessment tools, standardised testing.

Appendix 3 Educational Uses for Neuroscience Research - Examples and Citations

1. **Providing increased knowledge** (e.g. scientific information usually absorbed into the science-health curriculum). Examples include:
    - Neuroscience for Kids website http://faculty.washington.edu/chudler/index1.html
    - Life Sciences Education websites http://www.lifescied.org/search?fulltext=neuroscience+websites&submit=yes&x=0&y=0 and http://www.lifescied.org/search?fulltext=neuroscience+videos&submit=yes&x=0&y=0
    - Various Dana Foundation materials http://dana.org/downloads/kids/

2. **Providing increased direction for special educators through enhanced diagnostic and supportive capacity**
    - support for special education practice (Blakemore and Frith, 2005, Doidge, 2007, Ferrari, 2011, Graham et al., 2007b, Karmiloff-Smith, 1998, Muller, 2011)
    - autism spectrum disorders (ASD) (Ahmed and Stephen Miller, 2011, Chawarska and Shic, 2009)
    - dyslexia and related reading difficulties (Alptekin and Erçetin, 2009b, Goswami, 2008, Graham and Bellert, 2005, Graham and Bellert, 2007, Graham et al., 2007b, Hruby and Goswami, 2011, LeCaptain et al., 2009, McCandliss and Noble, 2003, Meltzoff et al., 2009, OECD, 2002b)
    - dyscalculia and related maths difficulties (Bellert, 2009, Cragg and Gilmore, 2014, De Smedt et al., 2010, Goswami, 2004, Graham et al., 2007a, Kaufmann, 2008, Kiefer and Sekaquaptewa, 2007, Pegg et al., 2005, Primi, 2010, Raghubar et al., 2010)

- trauma and abuse/attachment disorder (Anda et al., 2006, Downey, 2007, Perry and Szalavitz, 2007, Perry and Pollard, 1998, Perry et al., 1995)
- problems with language acquisition (Bodrova and Leong, 2003, Boroditsky, 2011, Kuhl, 2011b, Kuhl, 2007, Kuhl, 2011a, Meltzoff et al., 2009)
- working memory deficits (Andersson and Lyxell, 2007, Gathercole and Alloway, 2010, Lewandowsky, 2011)
- attention deficit hyperactivity disorder (ADHD) (Epstein et al., 2003, Halperin and Healey, 2011, Klingberg et al., 2002)

3. **Improving policy and practice (pedagogy)**
   - guidelines for educators in framing and presenting the curriculum (Geake and Cooper, 2003, Greenwood, 2002, Hornbeck et al., 2008, Howard-Jones, 2008b, Howard-Jones, 2009, Howard-Jones, 2008a, Howard-Jones, 2007, Howard-Jones, 2008c, Howard-Jones et al., 2010, Howard-Jones et al., 2002, Muller, 2011, OECD, 2002b, OECD, 2007, OECD, 2002c, Purdy and Morrison, 2009)
   - a basis for improving individual learning skills across the entire student population (Gathercole and Alloway, 2010, Klingberg, 2010, Klingberg, 2006, Olesen et al., 2004, Posner and Rothbart, 2005, Raghubar et al., 2010, Strand et al., 2008, Westerberg and Klingberg, 2007).

Appendix 4 Recruitment Article in DECD Xtra

WANTED: Schools to participate in a Neuroscience in the Classroom research project in 2014.

Donna Nitschke, Coordinator Neuroscience in the Classroom for the Neuroscience Cluster of Schools, is running a research project into the effectiveness of the 'Being the Best Learner You Can Be' Program (BBL Program). Donna has designed and run this program in four metropolitan schools since 2009 and is now seeking to trial core elements of the program in other settings. This project has Ethics approval from both DECD and UniSA

PARTICIPATION CRITERIA

Twelve Year 4-5 classes, with a minimum of 25 students each, are needed to participate in the project. Once identified, half of the classes will receive the test battery with a special emphasis on measuring attention and working memory skills and the BBL Program on a weekly basis during Terms 2 & 3 by Donna. The other half (the control group) will receive the test battery for executive function skills but will continue with their normal school program.

Participating schools must have no previous experience with the BBL Program. Participating classes must be able to commit one regular 45-minute session per week for 20 weeks during Terms 2 & 3, 2014. In addition, students will be individually assessed for attention and working memory skills using a computer program designed for this purpose. This testing will take place in the latter part of Term 1 and again in Term 4. Schools will need to provide a testing venue that is quiet and free from distractions and interruptions. (NB a corner in the classroom is not appropriate for this)

If you are interested in this project, please contact Donna for more information and an Expression of Interest Form. Email: donna.nitschke838@schools.sa.edu.au

Appendix 5 Information Sheets and Consent Forms



University of South Australia | School of Health Sciences

Researcher: Donna Nitschke

Ph D candidate

nitdl001@mymail.unisa.edu.au or 8302 1769

Supervisor: Associate Professor Susan Hillier

University of South Australia

Co-Supervisor: Associate Professor Gaynor Parfitt

INFORMATION SHEET FOR PRINCIPALS

Dear (name)

Donna Nitschke is the Coordinator Neuroscience in the Classroom in four DECD schools. As Neuroscience Coordinator, she has developed a program to improve student learning. Currently, Donna is working on her Ph D at the University of South Australia (UniSA) and is conducting research regarding her program, *'Being the Best Learner You Can Be'* in some primary schools in South Australia. Your school has expressed an interest in taking part in this research. Please read the information below and sign the School Consent Form attached so that the research can proceed in your site.

Aim of the Study

The aim of this study is to evaluate a 20-week short version of a classroom program developed to improve student learning. This program is called '*Being the Best Learner You Can Be'* and has been running in four Adelaide primary schools since February 2009. Students, teachers and parents from these four schools have told us that they value the program and believe that students have improved in their attitudes and interest in school, in their general behaviour and in academic performance as a result of this program.

What is the *'Being the Best Learner You Can Be'* Program?

The *'Being the Best Learner You Can Be'* Program (which will be called the BBL Program after this) aims to help every student improve all the skills that people need to be able to learn well, manage emotions/behaviour and have great relationships with other people. To do this, the BBL Program focuses on helping students to improve attention, memory, emotional

literacy, and higher order thinking skills (HOTS). The BBL Program also teaches the importance of looking after general health through good patterns of sleep, diet and exercise. These three things are included in class work because sleep, diet and exercise make a huge difference to how well our brains work and, therefore, to how well we can learn.

The BBL Program is student-focussed. It is designed to help students build an awareness and understanding of how their brains work and what they can do to make learning easier. As well, the BBL Program teaches students to test, practise, review, and take responsibility for their personal skills development. There is a parent flier with this information sheet that gives more detail about the skills that we will work on in the classroom. Please note: This flier was developed for the four original schools. It is the information that is important so we have removed all names and contact details from these schools.

How will the study be carried out?

Twelve metropolitan DECD Year 4/5 classes will be recruited for this study. Six classes will be randomised to the Intervention Group and six to the Control Group. Donna Nitschke will run the 20-week version (that is two school terms) of the BBL Program in the Intervention Group schools. We will measure how well each student can focus their attention, ignore distractions, manage their impulsiveness, remember, and problem solve in the 12 classes (both Intervention and Control) before we start the Program. This will be done using two computerised assessment programs while at school. We will also ask students to fill out a questionnaire that measures their attitudes to school, school work and personal ability. We will ask teachers and parents/carers to fill out a questionnaire that measures how well they think each child is doing in these areas. Questionnaires and a basic background information sheet will be sent home to parents/carers and should be returned to the school office. A specially marked envelope will be provided for this. Teachers will be asked to fill out the questionnaires during school time. Teacher release time will be negotiated with each school. We will also look at each child's school grades and progress reports at the beginning of Term 2 (before the program starts) and at the end of Term 3 (when the program finishes) to check for improvement. We will not copy or record student reports. Parents/carers will be informed of this in the Parent/Carer Information Sheet.

For classes in the Intervention Group, the BBL Program will be taught to students once a week for 45 minutes as part of their school day. There will be some 'homework' that will be part of the program. This will include a 7-day sleep diary during Weeks 1 and 19 of the program and practising the computer games that are part of their individual improvement plan. This plan will be determined by information students provide during the sessions in Weeks 1 & 2. As part of your agreed participation, you are asked to ensure that any classes receiving the intervention program allot the required 45 minutes/week in their timetable on the day agreed with Donna. Should there be any interruptions to the schedule due to special school events, such as Pupil Free Days, please let Donna know well in advance so that alternate arrangements can be made to deliver that lesson.

Who will benefit?

Although we cannot guarantee that every student will benefit from the BBL Program, our previous work in schools from 2009 to the present indicates that all students will improve their individual learning skills. We should see improvements in all areas included in the

program. Staff and parents should also benefit from having students/children with improved skills.

Are there any risks?

There are no risks to the staff, students or parents who participate in this study beyond what happens as part of everyday life in schools.

How will privacy be protected?

This project will follow all standard ethical procedures required by DECD and the Human Research Ethics Committee of UniSA. No individual student, principal, teacher or school will be identified in any published material. We will 'de-identify' the data when we work with it. This means that we will give each student an identifying number and will take away all names so that we are not thinking about any specific individual. We are only concentrating on what patterns we are finding in the questionnaires, computer assessments and class work. All information that we get from parents, students and schools will be kept in a locked filing cabinet at UniSA. Only Donna Nitschke and the university staff who are working with her will have access to this information.

Who to contact with further questions

If you have any questions, please contact one of these people:

1. Donna Nitschke (who is the person teaching your child and the key person running this study)
   Email: donna.nitschke@mymail.unisa.edu.au Phone: 8302 1769 Please note that you may need to leave a voice message as Donna is only at the uni part time. Donna will return your call as soon as possible.

You may also contact Donna's supervisors:

2. Associate Professor Susan Hillier (Donna's primary supervisor from UniSA)
   Email: susan.hillier@unisa.edu.au Phone: 8302 2544

3. Associate Professor Gaynor Parfitt (Donna's other supervisor from UniSA)
   Email: gaynor.parfitt@unisa.edu.au Phone: 8302 2121

This study has been approved by the Department of Education and Child Development (DECD). It has also been approved by the University of South Australia's Human Research Ethics Committee. Should you wish to discuss the project with someone not directly involved, in particular in relation to matters concerning policies, information about the conduct of the study, or your rights as a participant, please contact the UniSA Ethics Officer, Ms Vicki Allen on 8302 3118; fax 8302 3921; email: vicki.allen@unisa.edu.au.

As part of your participate in this study, we ask that you ensure that the classroom teacher(s) of the participating class and the parents/carers of each child in the participating class receive copies of the Parent Information Sheet and Consent Form. We ask that teachers read the Parent Information Sheet and sign the Teacher Consent Form. You will note that parents are consenting to completing relevant questionnaires and background information and to access to their child's school assessments at the beginning and end of the intervention period (Terms 2 & 3). As part of the requirements of human research, parents have been provided with the

opportunity to ‘opt out’ of the data collection aspects of the research. Consent to participate in the research has already been provided by the school.

Thank you for considering this project.

Donna Nitschke

Date: _____



Researcher: Donna Nitschke
Ph D candidate
nitdl001@mymail.unisa.edu.au **or 8302 1769**

Supervisor: Associate Professor Susan Hillier
University of South Australia

Co-Supervisor: Associate Professor Gaynor Parfitt
University of South Australia

TEACHER CONSENT FORM

I, _____, *(please print your name)* am a teacher at _____ *(school name)*. I understand that my school has agreed to take part in the research entitled *"Assessment of the Program 'Being the Best Learner You Can Be': A randomised controlled trial of a neuroscience-based primary school program."*

I have read and understood the Information Sheet provided for parents which outlines this project and understand that my Year 4/5 class has been nominated to participate. I understand that the class will be randomised to either an Intervention or a Control Group. If my class is in the Intervention Group, we will receive a 20-week program aimed at improving individual student learning skills. Students will take individual computerised assessments for attention and memory and fill out a standardised questionnaire on social and emotional wellbeing at school.

I understand that I will be asked to respond to a questionnaire on each student in the class at the beginning of the intervention period and again, at the conclusion. Release time may be negotiated for this purpose. I may also be randomly chosen to provide input about any significant changes that occur as a result of this intervention program. I further understand that parents will be asked to allow researchers to view their child's academic records (grades and progress reports) at the beginning of Term 2 and at the end of Term 3. These records will be summarised regarding improvement and will not be copied or recorded by the research team.

I agree, along with the Principal, to ensure that relevant parents have received all necessary information, consent forms have been signed, and that provisions have been made to schedule weekly 45 minute lessons (if our site is randomised to the Intervention Group). It will be assumed that parents/cares consent to their child's participation unless they exercise the 'opt out' option and return the appropriate signed form to indicate this.

I understand that my school and I may not directly benefit by taking part in this research.

I understand that while information gained in the study may be published, my school and I will not be identified and all individual information will remain confidential.

I understand that delivery of the program, "*Being the Best Learner You Can Be"*, forms part of the class's curriculum. However, individual students and their parents/carers retain the right to withdraw from data collection (questionnaires and computerised assessment) at any stage.

I understand that there will be no payment to the school for taking part in this study.

I am aware that I should retain a copy of the Information Sheet and this Consent Form for future reference.

Signature:

_____

Date: _____



Researcher: Donna Nitschke

Ph D candidate

nitdl001@mymail.unisa.edu.au or 8302 1769

Supervisor: Associate Professor Susan Hillier

University of South Australia

Co-Supervisor: Associate Professor Gaynor Parfitt

PARENT/CARER INFORMATION SHEET

Dear (name of parent/carer)

Donna Nitschke is the Coordinator Neuroscience in the Classroom in four DECD schools. As Neuroscience Coordinator, she has developed a program to improve student learning. Currently, Donna is working on her Ph D at the University of South Australia (UniSA) and is conducting research regarding her program, *'Being the Best Learner You Can Be'* in some primary schools in South Australia. Our school has agreed to take part in this research and your child's class will be involved. Please read the information below.

Aim of the Study

The aim of this study is to evaluate a 20-week short version of a classroom program developed to improve student learning. This program is called '*Being the Best Learner You Can Be'* and has been running in four Adelaide primary schools since February 2009. Students, teachers and parents from these four schools have told us that they value the program and believe that students have improved in their attitudes and interest in school, in their general behaviour and in academic performance as a result of this program.

What is the *'Being the Best Learner You Can Be'* Program?

The *'Being the Best Learner You Can Be'* Program (which will be called the BBL Program after this) aims to help every student improve all the skills that people need to be able to learn well, manage emotions/behaviour and have great relationships with other people. To do this, the BBL Program focuses on helping students to improve attention, memory, emotional

literacy, and higher order thinking skills (HOTS). The BBL Program also teaches the importance of looking after general health through good patterns of sleep, diet and exercise. These three things are included in class work because sleep, diet and exercise make a huge difference to how well our brains work and, therefore, to how well we can learn.

The BBL Program is student-focussed. It is designed to help students build an awareness and understanding of how their brains work and what they can do to make learning easier. As well, the BBL Program teaches students to test, practise, review, and take responsibility for their personal skills development. There is a parent flier with this information sheet that gives more detail about the skills that we will work on in the classroom. Please note: This flier was developed for the four original schools. It is the information that is important so we have removed all names and contact details from these schools.

How will the study be carried out?

Donna Nitschke will run the 20-week version (that is two school terms) of the BBL Program for a number of Year 4/5 students in several different schools. We will measure how well each student can focus their attention, ignore distractions, manage their impulsiveness, remember, and problem solve before we start the Program. This will be done using two computerised assessment programs while at school. We will also ask students to fill out a questionnaire that measures their attitudes to school, school work and personal ability. We will ask teachers and parents/carers (you) to fill out a questionnaire that measures how well they think each child is doing in these areas. Questionnaires and a basic background information sheet will be sent home to parents/carers and should be returned to the school office. A specially marked envelope will be provided for this. Teachers will be asked to fill out the questionnaires during school time. Teacher release time will be negotiated with each school. We will also look at your child's school grades and progress reports at the beginning of Term 2 (before the program starts) and at the end of Term 3 (when the program finishes) to check for improvement. We will not copy or record your child's reports.

The BBL Program will be taught to students once a week for 45 minutes as part of their school day. There will be some 'homework' that will be part of the program. This will include a 7-day sleep diary during Weeks 1 and 19 of the program and practising the computer games that are part of their individual improvement plan. This plan will be determined by information students provide during the sessions in Weeks 1 & 2.

Who will benefit?

Although we cannot guarantee that every student will benefit from the BBL Program, our previous work in schools from 2009 to the present indicates that all students will improve their individual learning skills. We should see improvements in all areas included in the program. Staff and parents should also benefit from having students/children with improved skills.

Are there any risks?

There are no risks to the staff, students or parents who participate in this study beyond what happens as part of everyday life in schools.

How will my privacy be protected?

This project will follow all standard ethical procedures required by DECD and the Human Research Ethics Committee of UniSA. No individual student, principal, teacher or school will be identified in any published material. We will 'de-identify' the data when we work with it. This means that we will give each student an identifying number and will take away all names so that we are not thinking about any specific individual. We are only concentrating on what patterns we are finding in the questionnaires, computer assessments and class work. All information that we get from parents, students and schools will be kept in a locked filing cabinet at UniSA. Only Donna Nitschke and the university staff who are working with her will have access to this information.

Who to contact with further questions

If you have any questions, please contact one of these people:

1. Donna Nitschke (who is the person teaching your child and the key person running this study)
   Email: donna.nitschke@mymail.unisa.edu.au Phone: 8302 1769 Please note that you may need to leave a voice message as Donna is only at the uni part time. Donna will return your call as soon as possible.

You may also contact Donna's supervisors:

2. Associate Professor Susan Hillier (Donna's primary supervisor from UniSA)
   Email: susan.hillier@unisa.edu.au Phone: 8302 2544

3. Associate Professor Gaynor Parfitt (Donna's other supervisor from UniSA)
   Email: gaynor.parfitt@unisa.edu.au Phone: 8302 2121

This study has been approved by the Department of Education and Child Development (DECD). It has also been approved by the University of South Australia's Human Research Ethics Committee. Should you wish to discuss the project with someone not directly involved, in particular in relation to matters concerning policies, information about the conduct of the study, or your rights as a participant, please contact the UniSA Ethics Officer, Ms Vicki Allen on 8302 3118; fax 8302 3921; email: vicki.allen@unisa.edu.au.

Your school has agreed to participate in this study and you are receiving this letter because the BBL Program will be run in your child's class during Terms 2 and 3. If you are happy for your child to participate in the 'Being the Best Learner You Can Be' Program, you do not have to do anything further to make sure he/she participates. If you do not wish your child to take part in these lessons, you must fill out and return the slip at the bottom of this page.

Thank you for considering this request.

Donna Nitschke

Date: _____



I **do not** give consent for my child to participate in this classroom project. I understand my child will be given other tasks in a separate classroom whilst the class project activities are occurring

Signatures of Parents/Legal Guardians

Your child's Name:

…… .

Your Name

……

Signature: ……Date:

……

Give this signed form to your child's teacher.

(Information appended to the Information Sheet for Principals, Teachers and Parents)

Sleeping, Eating, and Fitness

We do our best learning when we are fit, healthy and alert. Our sleep patterns directly affect our learning and memory. Diet and exercise are also important if we want to learn and develop as well as we can. Students at [school name] learn about the importance of sleep, how much sleep they should get for their age and the patterns that help them sleep well. They also look at what happens when we eat well and exercise. For example, exercise helps the brain make stronger memory connections.



Higher Order Thinking Skills

Having a good memory and being the boss of your attention are the foundations for learning. Students at [school name] are encouraged to use the information that they have learned to be creative, to solve problems, to be analytical and to recognise patterns of thinking, behaviour, science, maths, art and movement to give them the broadest learning base possible.



[School Name
School Address
School Suburb]

Government of South Australia
Department of Education and Children's Services

For more information about our school
or to arrange a tour
with the Principal
phone 8xxx xxxx
or email
info@xxxxxxxxxxxxxx

Neuroscience Cluster Schools:

- School 1
- School 2
- School 3
- School 4



[SCHOOL NAME]
Pre School-Seven

INSERT SCHOOL LOGO HERE

Excellence
Equity
Community

Neuroscience

Being the Best Learner I Can Be!



What is Neuroscience?

Neuroscience is the study of how we learn and develop. In neuroscience lessons, we look at how we can help our brains, minds, and bodies to work together so that we can *'be the best learners we can be!'*

Attention

Your brain comes already set up to pay immediate attention to certain things. Your attention is automatically *caught* by such things as loud noises, movement, flashing lights, music and being touched. But that is just one type of attention. We must also learn to directly focus our attention and to keep focussed until we finish what we are trying to do. This type of attention is something we all need to learn.

We need to teach our brains how to look and listen and what to look and listen to. We also have to learn to ignore or avoid distractions.





Students practice different ways to pay attention and concentrate. They are shown games and websites that will help them train their brains to be great learners. They learn to recognise what distracts them and learn better ways to stay focussed on work.

Memory

You need to use many different kinds of memory when you learn. Your mind needs to remember facts and information. Your body needs to remember how to move and do things. Even if you think you have a poor memory, there are many things you can do to make your memory work better. At [school name] we practice developing our memories so we can improve our learning.





Plasticity

Our brains are able to keep learning and making new connections throughout our lives. However, brains are a bit like bodies. If you don't work to stay fit, you get flab. With your brain, if you don't keep trying new things, your brain gets lazy. With your brain, it's a case of:

USE IT OR LOSE IT.

It's about getting in the habit of learning.

Patterns and Practice

Your brain seeks out patterns to help it choose where to put attention. (When we talk about behaviour we call these habits.) Learning is easier when we are aware of patterns and when we rehearse, repeat and practice. There are patterns all around us and in every subject including music, maths, art, reading, spelling, society and environment, and sport.

Emotional Literacy

School is a very social place. To be the best learner possible, students need to be able to wait, take turns, and to generally have control over their feelings. They need to learn to feel and show empathy and respect for others. These things develop over time for all of us but only if your experiences and environment help you to build an understanding of yourself and others. Learning to understand and control emotions is an important part of becoming a great learner. It is a main focus of our neuroscience program.

Logo for Our School Website



Appendix 6 ACES 7-Day Sleep Diary/Knowledge Test

Australian Centre for Education in Sleep - junior school ACES Copyright: # 91-09: 4/5

ACES ONE WEEK
Sleep Diary and Bedtime Activities



Sleep Diary	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Into bed at..... Lights out at.....							
Waking up time next day							
Number of hours I slept							
Which number are you? When I got up I felt: 1 = not tired at all 2 = a little tired 3 = Really tired							

Check off any of these activities that you did ONE HOUR before bed

Bedtime Activity	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Read a book							
Used the computer							
Play with toys/games							
Did exercise/sport							
Watched TV							
Played video games							
Listened to music							
Had a snack							
Had a shower/bath							
Did my homework							

8

Developed by Professor Sarah Blunden, founder and director of the Australian Centre for Sleep Education (ACES) and Professorial Research Fellow and Head of Paediatric Sleep Research at the Central Queensland University. Used with permission.

Please answer the following questions by ticking either true or false

	True or False?	**True**	**False**	**Don't Know**
1	Tired students do worse at school and get grumpy	X		
2	You can make up for lost sleep by drinking tea or coffee. or soft drinks containing caffeine		X	
3	People who worry sleep better		X	
4	Staying up late studying before an exam is good for remembering things.		X	
5	Students need more sleep than their parents.	X		
6	In school students, a full sleep cycles goes for about 30 minutes.		X	
7	NREM sleep has four stages.	X		
8	When you are tired your reactions are faster		X	
9	Not enough sleep can make you fat.	X		
10	Kids with 7 hours sleep do better at sports than teenagers with 9 hours sleep.		X	
11	Hormones for growing (Growth hormone) are released in REM sleep		X	
12.	When we first fall asleep we usually go into REM sleep.		X	
13	If you are tired from the school week, it is good for you to sleep in a lot on the weekend		X	
14	Snoring is an indicator of sleep apnea.	X		
15	Dreams occur in NREM sleep.		X	

Appendix 7 Physical Activity Questionnaire for Older Children (PAC-Q) (Kowalski et al., 2004)

Physical Activity Questionnaire (Elementary School)

Name:_____ Age:_____

Sex: M_____ F_____ Grade:_____

Teacher:_____

We are trying to find out about your level of physical activity from ***the last 7 days*** (in the last week). This includes sports or dance that make you sweat or make your legs feel tired, or games that make you breathe hard, like tag, skipping, running, climbing, and others.

Remember:

1. There are no right and wrong answers — this is not a test.
2. Please answer all the questions as honestly and accurately as you can — this is very important.

---

1. Physical activity in your spare time: Have you done any of the following activities in the past 7 days (last week)? If yes, how many times? (Mark only one circle per row.)

	No	1-2	3-4	5-6	7 times or more
Skipping	○	○	○	○	○
Rowing/canoeing	○	○	○	○	○
In-line skating	○	○	○	○	○
Tag	○	○	○	○	○
Walking for exercise	○	○	○	○	○
Bicycling	○	○	○	○	○
Jogging or running	○	○	○	○	○
Aerobics	○	○	○	○	○
Swimming	○	○	○	○	○
Baseball, softball	○	○	○	○	○
Dance	○	○	○	○	○
Football	○	○	○	○	○
Badminton	○	○	○	○	○
Skateboarding	○	○	○	○	○
Soccer	○	○	○	○	○
Street hockey	○	○	○	○	○
Volleyball	○	○	○	○	○
Floor hockey	○	○	○	○	○
Basketball	○	○	○	○	○
Ice skating	○	○	○	○	○
Cross-country skiing	○	○	○	○	○
Ice hockey/ringette	○	○	○	○	○
Other:					
_____	○	○	○	○	○
_____	○	○	○	○	○

2. In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? (Check one only.)

I don't do PE ..... O
Hardly ever ..... O
Sometimes ..... O
Quite often ..... O
Always ..... O

3. In the last 7 days, what did you do most of the time *at recess*? (Check one only.)

Sat down (talking, reading, doing schoolwork)..... O
Stood around or walked around ..... O
Ran or played a little bit ..... O
Ran around and played quite a bit ..... O
Ran and played hard most of the time ..... O

4. In the last 7 days, what did you normally do *at lunch* (besides eating lunch)? (Check one only.)

Sat down (talking, reading, doing schoolwork)..... O
Stood around or walked around ..... O
Ran or played a little bit ..... O
Ran around and played quite a bit ..... O
Ran and played hard most of the time ..... O

5. In the last 7 days, on how many days *right after school*, did you do sports, dance, or play games in which you were very active? (Check one only.)

None ..... O
1 time last week ..... O
2 or 3 times last week ..... O
4 times last week ..... O
5 times last week ..... O

6. In the last 7 days, on how many *evenings* did you do sports, dance, or play games in which you were very active? (Check one only.)

None ..... O
1 time last week ..... O
2 or 3 times last week ..... O
4 or 5 last week ..... O
6 or 7 times last week ..... O

7. *On the last weekend*, how many times did you do sports, dance, or play games in which you were very active? (Check one only.)

None ..... ○
1 time ..... ○
2 — 3 times ..... ○
4 — 5 times ..... ○
6 or more times ..... ○

8. Which *one* of the following describes you best for the last 7 days? Read *all five* statements before deciding on the *one* answer that describes you.

A. All or most of my free time was spent doing things that involve little physical effort ..... ○

B. I sometimes (1 — 2 times last week) did physical things in my free time (e.g. played sports, went running, swimming, bike riding, did aerobics) ..... ○

C. I often (3 — 4 times last week) did physical things in my free time ..... ○

D. I quite often (5 — 6 times last week) did physical things in my free time ..... ○

E. I very often (7 or more times last week) did physical things in my free time ..... ○

9. Mark how often you did physical activity (like playing sports, games, doing dance, or any other physical activity) for each day last week.

	None	Little bit	Medium	Often	Very often
Monday	○	○	○	○	○
Tuesday	○	○	○	○	○
Wednesday	○	○	○	○	○
Thursday	○	○	○	○	○
Friday	○	○	○	○	○
Saturday	○	○	○	○	○
Sunday	○	○	○	○	○

10. Were you sick last week, or did anything prevent you from doing your normal physical activities? (Check one.)

Yes ..... ○
No ..... ○

If Yes, what prevented you? _____

Appendix 8 Modified Child Nutrition Questionnaire



Nutrition Questionnaire for students (Upper Primary)

This questionnaire asks about what you eat and drink. It starts with some general questions about what you think about fruit and vegetables and then about what you eat and drink at different times.

The teacher and classroom helpers will help you fill out this questionnaire.

The information will be used to describe all of the children in the study. Your individual information will be kept private and confidential.

Your Name_____

Reference Number
☐☐☐☐☐☐-☐

Year level (for example yr 6)
_____

What you usually eat and drink

1. Think about <u>today</u>. Describe what you drink at each time?

Tick as many boxes as apply

Drinks you will have/have had today at:	**Recess** 1	**Lunch** 2	**After school** ***(not including dinner)*** 3
a. Nothing to drink	☐	☐	☐
b. Cordial (fruit-flavoured concentrated syrup)	☐	☐	☐
c. Fruit Juice or fruit juice drink	☐	☐	☐
d. Regular Soft Drink or Energy/Sports Drink (e.g.. *Powerade*)	☐	☐	☐
e. Diet Soft Drink (e.g. Coke Zero, Diet Fanta)	☐	☐	☐
f. Water	☐	☐	☐
g. Milk/flavoured milk	☐	☐	☐

2. Think about today. Describe what you eat at each time?

Tick as many boxes as apply

Foods you will have/have eaten today at:	**Recess**	**Lunch**	**After school** ***(not including dinner)***
a. Nothing to eat	☐	☐	☐
b. Potato crisps or similar snack (e.g. twisties)	☐	☐	☐
c. Chocolate/Chocolate bar	☐	☐	☐
d. Lollies	☐	☐	☐
e. Muesli bar/ fruit bar	☐	☐	☐

f. Yoghurt / custard	☐	☐	☐
g. Savoury biscuits (e.g. saladas, jatz & dip)	☐	☐	☐
h. Sweet biscuits/Cake/Muffin/Doughnut	☐	☐	☐
i. Icecream/Iceblock	☐	☐	☐
j. Vegetables or salad	☐	☐	☐
k. Fruit (fresh or canned)	☐	☐	☐
l. Dried fruit (e.g. sultanas)	☐	☐	☐
m. Hot chips/French fries/wedges	☐	☐	☐
n. Pie/Pastie/Sausage roll	☐	☐	☐
o. Hot dog	☐	☐	☐
p. Pizza	☐	☐	☐
q. Sandwich/roll	☐	☐	☐
r. Bread/toast	☐	☐	☐
s. Spaghetti/pasta/noodles/rice	☐	☐	☐
t. Soup	☐	☐	☐

3. In the class room, how often do you have a 'fruit and/or vegetable break'?

Tick one box

Never/rarely	Once/week	Most days/week	Every day
1 ☐	2 ☐	3 ☐	4 ☐

4. In class time, do you usually have a drink on your desk?

Tick one box

1. ☐ Not allowed
2. ☐ No, even though it is allowed
3. ☐ Yes - If yes, what do you usually drink? _____

5. How often do you usually do the following?

Tick one box in each row

	Never/rarely OR Less than once/week 1	About 1-3 times/week 2	About 4-6 times/week 3	Every day 4
a. Drink water	☐	☐	☐	☐
b. Drink fruit juice or fruit juice drink	☐	☐	☐	☐
c. Drink softdrink (not including *diet* softdrink)	☐	☐	☐	☐
d. Carry a water bottle	☐	☐	☐	☐
e. Eat chocolate or lollies	☐	☐	☐	☐
f. Eat hot chips/French fries/wedges	☐	☐	☐	☐
g. Eat potato crisps or similar snack (e.g. twisties)	☐	☐	☐	☐
i. Help choose or buy groceries for the family	☐	☐	☐	☐
j. Help prepare your dinner	☐	☐	☐	☐
k. Eat dinner with most of the family	☐	☐	☐	☐
l. Eat dinner in front of the television	☐	☐	☐	☐
m. Eat snacks in front of the television	☐	☐	☐	☐

What do you think about?

6. How strongly do you agree or disagree with the following statements?
Tick one box in each row

	Strongly agree 1	Agree 2	Not sure 3	Disagree 4	Strongly disagree 5
a. Eating vegetables makes me feel healthy	☐	☐	☐	☐	☐
b. I like the taste of many vegetables	☐	☐	☐	☐	☐

c. In my home, vegetables are served at dinner most nights	☐	☐	☐	☐	☐
d. I like tasting new vegetables that I haven't tried before	☐	☐	☐	☐	☐
e. It is easy to prepare vegetables to eat e.g. make a salad	☐	☐	☐	☐	☐
f. Eating fruit makes me feel healthy	☐	☐	☐	☐	☐
g. I like the taste of most fruit	☐	☐	☐	☐	☐
h. Fruit is an easy snack	☐	☐	☐	☐	☐
i. I like tasting new fruits that I haven't tried before	☐	☐	☐	☐	☐
j. In my home fruit is available to eat at any time	☐	☐	☐	☐	☐
l. I like to drink water	☐	☐	☐	☐	☐
m. I ask my parents to buy foods or drinks that I see advertised on television	☐	☐	☐	☐	☐
n. My parents encourage me to eat fruit and vegetables	☐	☐	☐	☐	☐
o. Most of my teachers encourage the students to eat fruit and vegetables	☐	☐	☐	☐	☐

7. Where did you/will you get your <u>recess</u> from today?

Tick one box

Home today	Canteen	Shop outside of school	Friends	No recess
1	2	3	4	5
☐	☐	☐	☐	☐

8. Where did you/will you get your <u>lunch</u> from today?

Tick one box

Home today	Canteen	Shop outside of school	Friends	No lunch
1	2	3	4	5
☐	☐	☐	☐	☐

About fruit and vegetables you eat

9. How many serves of vegetables do you <u>usually</u> eat each day?
(1 serve = 1 cup of salad vegetables, OR ½ a cup of cooked vegetables, OR 1 medium potato)

Tick one box

1. ☐ I don't eat vegetables
2. ☐ Less than 1 serve a day
3. ☐ 1-2 serves a day
4. ☐ 3-5 serves a day
5. ☐ More than 5 serves a day

10. How many serves of fruit do you <u>usually</u> eat each day?
(1 serve = 1 medium piece, OR 2 small pieces of fruit e.g. mandarins or apricots, OR 1 cup of diced pieces)

Tick one box

1. ☐ I don't eat fruit
2. ☐ Less than 1 serve a day
3. ☐ 1-2 serves a day
4. ☐ 3-5 serves a day
5. ☐ More than 5 serves a day

11. Below is a list of different types of fruits (fresh, canned or dried). For each fruit please indicate answer PART A and PART B.

PART A: Please indicate if you ate this fruit yesterday, by ticking the box that applies to you, for each fruit

PART B: Please indicate if you like this fruit by ticking the box that applies to you, for each fruit

Tick one box in each row

Type of fruit	PART A		PART B		
	I ate this fruit yesterday	I didn't eat this fruit yesterday	Never had it or don't know what it is	Yes I like this fruit	No I don't like this fruit
	1	2	3	4	5
a. Apple	☐	☐	☐	☐	☐
b. Apricot	☐	☐	☐	☐	☐
c. Banana	☐	☐	☐	☐	☐
d. Grapes	☐	☐	☐	☐	☐
e. Kiwi fruit	☐	☐	☐	☐	☐
f. Mandarin	☐	☐	☐	☐	☐
g. Nectarine	☐	☐	☐	☐	☐
h. Orange	☐	☐	☐	☐	☐
i. Peach	☐	☐	☐	☐	☐
j. Pear	☐	☐	☐	☐	☐
k. Pineapple	☐	☐	☐	☐	☐
l. Plum	☐	☐	☐	☐	☐
m. Rockmelon	☐	☐	☐	☐	☐
n. Strawberries	☐	☐	☐	☐	☐
o. Watermelon	☐	☐	☐	☐	☐

12. Below is a list of different types of vegetables (fresh, canned or frozen). Please indicate if you ate this vegetable yesterday, by ticking the box that applies to you, for each vegetable.

Tick one box in each row

Type of vegetable	I ate this vegetable yesterday 1	I NEVER eat this vegetable 2
a. Beans (green)	☐	☐
b. Beetroot	☐	☐
c. Broccoli	☐	☐
d. Brussel sprouts	☐	☐
e. Cabbage	☐	☐
f. Capsicum	☐	☐
g. Carrot	☐	☐
h. Cauliflower	☐	☐
i. Celery	☐	☐
j. Chinese greens	☐	☐
k. Corn	☐	☐
l. Cucumber	☐	☐
m. Eggplant	☐	☐
n. Legumes (baked beans, chickpeas, lentils, kidney beans)	☐	☐
o. Lettuce	☐	☐
p. Mushroom	☐	☐
q. Peas	☐	☐
r. Potato (not hot chips)	☐	☐
s. Potato fried e.g. hot chips/ french fries/wedges	☐	☐
t. Pumpkin	☐	☐

u. Spinach	☐	☐
v. Sweet potato	☐	☐
w. Tomato	☐	☐
x. Zucchini	☐	☐
y. Squash	☐	☐

☺ Fantastic, you've finished

THANK YOU

Appendix 9 Student Background Questionnaire



University of South Australia | School of Health Sciences

Researcher: Donna Nitschke

Ph D candidate

nitdl001@mymail.unisa.edu.au or 8302 1769

Supervisor: Associate Professor Susan Hillier

University of South Australia

Co-Supervisor: Associate Professor Gaynor Parfitt

University of South Australia

STUDENT BACKGROUND QUESTIONNAIRE for PARENTS

CONFIDENTIAL

Child's Study ID No. _____

Please complete this questionnaire and return in the envelope provided. Note that all references to 'your child' refer to the child participating in the above study.

If you have any questions please contact Donna Nitschke by phone on (08) 8302 1769 or e-mail donna.nitschke838@schools.sa.edu.au.

Thank you for taking part in this study. We are grateful for the time that you take to complete this questionnaire.

1. Does your child have any current medical conditions (please tick one) Yes ❑ No ❑
2. If yes, please specify: ……..
……..……

3. Has your child received a diagnosis of ADHD? Yes ❑ No ❑
Year of diagnosis: ……

4. Does your child have a formal individual education plan such as an NEP or IEP? Yes ❑ No ❑

5. Does your child receive school card concession? Yes ❑ No ❑

6. Is your child currently taking any medications on a regular basis? (please tick one) Yes ❑No ❑
If yes, please specify which medications your child is currently taking:
……
……

7. Is your child taking any nutritional supplements? Yes ❑ No ❑
If yes, please specify which supplements your child is currently taking:
……
……

8. What language is spoken at home? Please indicate if more than one language is used.
……

9. Who is the child's <u>primary</u> caregiver:
(the person who spends the most time with the child)

Mother ❑
Father ❑
Grandparent ❑
Other ……

10. What is the primary caregiver's highest level of education achieved:

Grade 10, high school ❑
SACE/Matriculation ❑
TAFE certificate or equivalent ❑
University diploma ❑
University degree ❑
Postgraduate degree ❑

11. What is the primary caregiver's usual occupation ……

12. Who is the child's <u>secondary</u> caregiver:
(the person who spends the 2nd most time with the child)

Mother ❑
Father ❑
Grandparent ❑
Other ……

13. What is the secondary caregiver's highest level of education achieved:

Grade 10, high school ❑
SACE/Matriculation ❑
TAFE certificate or equivalent ❑
University diploma ❑
University degree ❑
Postgraduate degree ❑

14. What is the secondary caregiver's usual occupation ……

Appendix 10 Background for Qualitative Interviews and Focus Groups

Purpose:

These data are being collected as part of a randomised controlled trial. It is one of several outcome evaluation measurements. Although every effort to standardise the program delivery has been made across the six active classroom in the study, it is acknowledged that there will always be inherent differences due to the uniqueness of every student and teacher within any given class and any given school. Hence, the use of qualitative outcome measures for students and teachers. The purpose is to probe whether or not participants:

- Found general value in the program
- Considered that the students' attitude to learning improved as a direct result
- Considered that the students' attention, memory, and self-regulation skills improved as a direct result
- Considered that any skills improvement impacted positively on general academic learning.

Sites:

School	Teacher(s)
Blair Athol North	MH, (KM-leader)
Blair Athol North	AI, (KC-leader)
Burton	BK, DD
Highgate	PP
Hillcrest	CM, VC
Stradbroke	PH

Suggested Interview Questions (Teachers) [NOTE: there are six classes across five school sites. Two of these classes had two teachers present during lessons. One site had two school leaders present for many of the lessons. These leaders have requested that they be able to provide feedback on the project.]

1. Can you tell me your opinion of the neuroscience program that Donna ran in your class during Terms 2 & 3 this year? (tease out if they thought it was effective, high quality delivery, high quality resources)
2. Do you think the program was suitable for your students? Did some benefit more or less than others?
3. How do you think the students responded to the program?
4. Could you describe any direct benefit to the students from their participation in the program?
5. Did you observe or experience any difficulties associated with the program?
6. Do you have any suggestions for enhancing the program?

7. Based on this experience, would you be willing to participate in a similar project in the future?

Suggested Focus Group Questions (Students) [NOTE: suggested group size is 4 students who have been randomly selected from the class-including 2 students for 'back-up' in case of absence or participation refusal]

1. What did you think of the neuroscience lessons that you had with Donna?
2. What are some of the activities that you liked the most? (box of prompts) What can you tell me about the activity that used _____visual prompt)?
3. How do you use what you learned in the neuroscience lessons at other times in the classroom? [prompts: how do you deal with distractions when you are working? Do you use any memory tricks when you have lots to learn? Do you notice if your emotions are in the orange or red (ie high)]?
4. What would make neuroscience lessons better for you?

List of Visual Prompts Available to Stimulate Discussion

- Coloured floor dot
- Bubble wand
- Marshmallow & chocolate freckle in protective plastic bag
- Small rubber brain
- Soft toy model of a neuron
- Wooden puzzle pieces
- One squeaky toy pig
- One small jewellery bag
- A4 copies of executive function poster and emotion meter
- A4 prints of some websites games, including Sheep Dash and Short Term Memory Checker

Full List of Materials Used During the BBL Program Intervention

- Set of 12 coloured floor dots, approximately 20 cm in diameter
- Bubble wand
- Marshmallows for delayed gratification
- Bag of chocolate freckles for mindfulness session
- 5 small rubber brains
- 3 plush toy neurons, approximately 12 cm long
- 3 D Wooden puzzles
- Selection of squeaky toys in various animal shapes
- Collection of jewellery bags and boxes
- 24 posters (see program overview, p. 149)
- A3 emotion meters (excited, sad, angry and scared)
-
- Soft soccer ball, approximately 10 cm in diameter
- ACES Sleep Program

- Unifix cubes (plastic stacking cubes in various colours, approximately 3 x 3 cm
- Bop It (commercial toy)
- 30 emotion word flashcards
- Various websites

Appendix 11 Framework for Assessing BBL Program Qualitative Data

Table 68 Qualitative framework for assessing BBL program merit (example only)

	Skills	Attitudes	Feelings	Behaviour	Knowledge
Description (program)					
Description (presenter)					
Comparison (any noted changes ascribed to the BBL Program)					
Prediction (including suggested changes)					