

**An investigation of the effectiveness of integrating  
sound-field amplification and classroom-based  
phonological awareness intervention on the early  
reading development of young school children**

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## Abstract

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Sound-field amplification systems (SFA) have proven effective in overcoming classroom listening difficulties associated with noise, distance and reverberation. However, whether improving the classroom listening environment is sufficient to enhance young children's learning in areas critical to early reading acquisition, such as awareness of the sound structure of spoken words (phonological awareness: PA), is unclear. This study aimed to examine the effectiveness of an enhanced listening environment combined with PA intervention which aimed to specifically increase children's PA compared to an enhanced listening environment alone.

Participants were 38 children aged 5-6 years from two classes at a low-decile primary school. All children were hearing screened at baseline, pre- and post-intervention. PA, letter-sound knowledge, real and non-word decoding were measured three times over 10 weeks (Term 1) prior to SFA installation in both classrooms, as well as pre- and post-intervention. In Term 2, children in class 1 were randomly assigned to receive SFA and an eight-week class-based teacher-administered PA programme. Class 2 received SFA only.

A significant learning effect for all children occurred during the first phase of the monitoring period. Yet, a plateau was reached for most children between assessment times two and three prior to intervention. Following intervention, class 1 demonstrated a significant difference compared to class 2 in one PA assessment. Other measures failed to show any differences between classes. Visual data analyses revealed particular (non-significant) improvements for poor readers in class 1. These children outperformed poor readers in class 2 on all measures. Teacher questionnaires indicated that children's listening skills improved with SFA. The significant difference observed in one measure of PA between classes demonstrated that the combination of enhanced classroom acoustic environment and PA intervention actively improved PA development. The results of this study have implications for: (a) facilitating attention to sound structure, (b) optimal intervention for early PA development, (c) early reading acquisition in New Zealand classrooms, and, (d) the use of typical models of professional teacher development.



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## 1 Introduction

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The system of delivery for state education in New Zealand assumes that all school students perform optimally in the ordinary auditory-verbal environment in which mainstream classroom instruction in New Zealand is primarily presented (Matkin, 1996). The premise is that within these classrooms children learn by receiving clear acoustic signals from their teacher (Brackett, 1997). This principle is undermined if children are unable to hear speech clearly and reliably. There is a wide body of evidence demonstrating that children's hearing, listening and learning are compromised by poor classroom acoustics, challenging signal-to-noise ratios (SNRs) and middle ear dysfunction, often resulting in fluctuating hearing loss (Berg, Blair, & Benson, 1996). These issues may be compounded for children at risk of academic underachievement for other reasons such as socio-economic background (Goldenberg, 2001; Snow, Burns, & Griffin, 1998; Whitehurst & Lonigan, 2001). Yet, improving the acoustic signal via a sound-field amplification (SFA) system optimises the learning environment for all children regardless of such factors (Heeney, 2007).

As children mature, a clear and complete speech signal is crucial to facilitate learning of speech, language and literacy (Briscoe, Bishop, & Frazier Norbury, 2001). Research has highlighted the importance of children's ability to process phonological information in facilitating their reading development particularly in the early stages of reading acquisition (See Gillon, 2004 for a review). When children discriminate between speech sounds their ability to make the connection between the spoken and written form of a speech sound is enhanced. Facilitating children's awareness of the sound structure of spoken words, i.e. enhancing their phonological awareness (PA), is a proven and successful method to assist children in both their reading and spelling development. The need for universal classroom-based PA instruction in the early school years is becoming increasingly apparent. Yet the effects of this instruction may well be lessened if implemented in poor acoustic environments.

This study aims to investigate whether, in addition to an improved acoustic signal, PA intervention adds further benefit for young children at risk of reading difficulties. More specifically, how the administration of a class-based PA programme with the benefit of an enhanced signal through SFA in the classroom affects literacy outcomes of young school children. The outcomes of this study will inform educationalists and policy-makers of whether simple, efficacious and cost-effective intervention is able to reduce disparity and raise levels of literacy achievement in New Zealand.



## 2 Literature review

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The following literature review firstly seeks to identify and clarify the numerous variables which can negatively affect a child's ability to listen and learn. Secondly, it focuses on two cost-effective interventions which have proven ability to counteract those variables. Those factors which research considers influential to the development of listening and learning within the classroom are:

- a) Mild fluctuating hearing impairment brought about by fluid behind the ear drum, or more specifically, otitis media.
- b) Socio-economic status.
- c) The current teaching methods practiced in New Zealand and how these approaches may influence reading achievement and outcomes for different populations.
- d) Classroom acoustics and the relationship between signal-to-noise levels within the classroom, background noise, reverberation and distance upon learning.

Research-based interventions which have effectively alleviated and restricted these detrimental influences are:

- a) SFA, in which the benefits and disadvantages from formative international and New Zealand based population studies are equally considered.
- b) PA intervention, which has demonstrated ability to enhance word decoding and reading skills. Recent research highlights the current shift in service delivery from one-on-one and small groups to whole-class teaching.

### 2.1 Mild fluctuating hearing impairment

Mainstream classrooms are typically auditory-verbal environments in which children spend 45% of their school day engaged in listening activities (Berg, 1987), and where information is presented orally by the teacher (Flexer, 1997; Simon, 1985). Children learn by receiving clear acoustic signals from their teacher (Brackett, 1997). Without full auditory access to spoken information in classrooms students do not learn at a normal rate. Flexer (1999) has suggested that the auditory neurological foundations for learning, language and reading are crucial to a child's development. However, the importance of hearing in the communicative and

educational process may be underestimated as hearing loss is invisible (Flexer, 1997). The effects of hearing loss are ambiguous and challenging to conceptualize (Davis, 1990; Ross, 1991), and as a result are often misjudged and linked to other learning or behaviour problems. Children with hearing loss may respond to instructions inappropriately, engage in off-task behaviour, be inattentive, distracted, withdrawn and may present with poor language or reading ability. These behaviours may be interpreted as slow learning or non-compliance rather than hearing-related impairment (Brackett, 1997). Accordingly, hearing difficulties are often erroneously considered inconsequential obstacles to classroom performance (Bess, 1985; Davis, 1990).

Flexer (1995) emphasised that any hearing problem for children can hinder their speech recognition abilities. Hearing impairment functions like an invisible acoustic filter that interferes with incoming sound (Ling, 2002). Besides the drop in loudness, sounds often smear or are completely filtered out (Flexer, 2004). Thus, the speech signal may be audible yet distorted. The acoustic filter effect reduces a child's ability to hear speech sounds clearly (Flexer, 2004), which in turn affects their ability to develop strong phonological representations of words in memory for use in accurate speech articulation and early reading acquisition (Sutherland & Gillon, 2007). Without adequate spoken-language abilities, reading development is disrupted (Robertson, 2000). A slight hearing loss has been shown to result in delayed acquisition of vocabulary, reduced incidental learning, significant academic delay and poor literacy skills (Ross, 1990). The primary cause of temporary fluctuating or mild hearing loss in children is due to otitis media (OM) (Finitzo-Hieber & Tillman, 1978; Flexer, 1997; S. C. Hogan, Stratford, & Moore, 1997) which may result from a simple, common cold.

### **2.1.1 Otitis media**

Conductive hearing loss results from an obstruction to the sound transmission mechanisms of the external or middle ear (Hartley & Moore, 2003). For children, the most common cause of temporary conductive hearing loss is OM (S. C. Hogan et al., 1997), characterised by inflammation and fluid in the middle ear (Bluestone & Klein, 2001). OM is a general term to describe a range of common childhood conditions involving the middle ear. Acute otitis media (AOM) is a clinically identifiable infection of the middle ear that has sudden onset and short duration often accompanied with intense pain, increased pressure in the ear and fever (Bluestone & Klein, 2001). Following acute infection, fluid may remain and accumulate in the middle ear cavity either as a corollary to the infection or due to immature Eustachian tube

drainage. Known as otitis media with effusion (OME), this condition is characterised by the accumulation of fluid which impedes sound wave transmission (Winskel, 2006).

OME typically causes a mild hearing loss, usually between 15 and 40 decibels (dB) (Bluestone & Klein, 2001) across all frequencies, the subsequent result of reduced air pressure in the middle ear space as well as fluid retention in the middle ear cavity. The effusion decreases the mobility of the tympanic membrane thereby increasing the tension and stiffness of the middle ear mechanism (Bluestone & Klein, 2001; Rosenfeld et al., 2004). The viscosity of the effusion varies from serous to 'glue-like' (Takeuchi et al., 1989) resulting in the popular term 'glue ear'. However, hearing loss is not influenced by the quality of the fluid, rather by the extent to which the middle ear is filled with fluid (O' Klein, 2001). Hearing loss associated with effusion is also variable and may often go unnoticed in an asymptomatic child (Rosenfeld & Bluestone, 2003). Although an accumulation of fluid often clears within a month, OME may persist for up to two months in 20% of children and for three months after the initial infection in 10% of children. The hearing loss associated with OME has a fluctuating nature, alternating with phases of normal hearing and leading to an inconsistent sound stimulus to the auditory central nervous system (Winskel, 2006).

Almost all children will have at least one episode of OME by the time they have reached seven years of age and some children are more at risk for severe and recurrent OME (Teele, Klein, & Rosner, 1989). Risk factors for OME may be divided into 'host' and 'environmental' factors (Bluestone & Klein, 2001; O' Klein, 2001). Host factors associated with increased risk include: (1) Age; with the highest occurrences from six to 18 months of age (O' Klein, 2001), (2) Sex; AOM occurs more often in boys (O' Klein, 2001), (3) Race; children from certain ethnicities, including New Zealand Māori (Giles & O'Brien, 1989) demonstrate a high incidence of OME, however, this may be linked to access to medical care, (4) Early onset of OME is associated with recurrent infections. Environmental factors linked to increased risk include: (1) Exposure to tobacco smoke; smoke exposure has been linked to increased incidence of AOM and increased duration of OME (O' Klein, 2001), (2) Season; incidence of AOM corresponds to the seasonal variations of respiratory tract infections (O' Klein, 2001) (3) Socio-economic status (SES); inadequate medical care, poor sanitation and crowded living conditions have been associated with severe and recurrent AOM, (4) Childcare facilities; more working families necessitate more children in childcare facilities for longer periods. Viral infections are easily spread in these environments. Additionally, the anatomy and physiology of the immature Eustachian tube and restricted immune response of the infant and small child

is conducive to OM (O' Klein, 2001). Research suggests that OM resulting from the combination of these internal and external factors may jeopardize later academic outcomes for specific populations.

### **2.1.2 Otitis media and academic outcome**

A child who experiences mild fluctuating hearing loss as a result of OME receives an incomplete or inconsistent auditory signal. Sounds and words are not heard or are misinterpreted. Mody and colleagues (1999) suggested that the child who experiences persistent OME and hearing loss develops an inaccurate and incomplete representation of the linguistic system. Upon this inadequate base, children must attempt to develop sufficient semantic, syntactic and pragmatic knowledge of their language, as well as develop a proficient speech sound system. During critical language development periods the child is disadvantaged and consequently finds emerging literacy skills of PA, phoneme-grapheme (speech sound-to-letter) correspondence and attention challenging. The term 'phonological representation' describes the long-term storage of speech sound information and is considered necessary for PA and reading development (Sutherland & Gillon, 2005). When the level and clarity of speech sound information are reduced, achieving accurate phonological representations are threatened (Stackhouse & Wells, 1997). Children with weak phonological representations may have compromised word decoding abilities (Elbro, 1996). Extensive research has investigated what impact OM has upon children's academic skills and behaviour.

The enduring effect OM has upon language development has received widespread attention (Casby, 2001; Roberts, Rosenfeld, & Zeisel, 2004). Clear-cut correlations between the number of AOM episodes, the duration of OME, the degree of hearing loss associated with those diseases and the reading scores of children have been demonstrated (Golz et al., 2005; Kindig & Richards, 2000; Loutonen et al., 1996; Teele, Klein, Chase, Menyuk, & Rosner, 1990). Golz and colleagues (2005) reported that children with recurrent or prolonged middle ear disease and associated hearing loss during the first five years of life tended to be at greater risk for delayed reading than aged-matched controls with no previous middle ear disease. Furthermore, a history of OM in early childhood has been related to lower scores on specific PA skills, expressive vocabulary, word definitions and reading when compared with children without prior middle ear disease (Winskel, 2006).

New Zealand research has suggested that early sequelae of OME, such as behavioural and cognitive effects are still present in the early to late teens (Bennett, Haggard, Silva, & Stewart,

2001). After adjustments for covariates such as SES, hyperactive and inattentive behaviour, problems were apparent as late as 15 years, and lower IQ associated with OME remained significant to the age of 13 years. The largest effects were observed for deficits in reading ability which persisted into late childhood and early teens. Authors reported that this study was from a slightly more advantaged SES group than the New Zealand population as a whole and was under-representative of Māori and Pacific Island children. Using the same cohort, Silva et al., (1982) considered whether children with bilateral OME differed from children who were otologically normal in background characteristics, speech articulation, language or motor development. The results demonstrated that while children with bilateral OME did not differ in terms of background factors, they were significantly disadvantaged in speech articulation ability, verbal comprehension, motor development and intelligence. They also exhibited more behavioural problems. These results taken together indicate that OME can have harmful, long-term effects on the child's language, cognition, behavioural and literacy outcomes.

Conversely, these results have not been replicated in similar studies, thus, it is controversial whether OM has any long-term impact on academic outcomes. In an early review of literature, Lous (1995) concluded that children will catch up in cognitive development when middle ear disease has resolved and hearing becomes normal at around school age. While there was a minor correlation between OME and reading, reading achievement was more closely correlated with cognitive, language and linguistic factors, and to socio-environmental and classroom related factors. More recent research seems to corroborate these early findings (Golz, Westerman, Westerman, Gilbert, & Netzer, 2006; D. L. Johnson, McCormick, & Baldwin, 2008; McCormick, Johnson, & Baldwin, 2006; Roberts, Burchinal, & Zeisel, 2002).

However, recent neuroanatomical animal studies suggests that mild to moderate conductive hearing losses increases thalamocortical synaptic depression, leading to tiny gaps in responses to the incoming signal (Xu, Kotak, & Sanes, 2007). This data demonstrated that conductive hearing loss can significantly alter the temporal properties of auditory cortex synapses and spikes which may contribute to processing deficits that attend mild to moderate hearing loss. For learning language and reading development this may help to explain, at least for some children, why hearing loss associated with OM can have such long-term detrimental impact. Shapiro et al., (2009) recently found that later onset OM children did not differ in reading and PA abilities overall from typically developing control children. But, those children with early onset OM were more likely to show poor performance persisting into early school years.

Authors suggested that time of onset may account for the disagreement in literature. A single, common thread to these studies is that when host and environmental risk factors amalgamate, the probability of poorer academic outcomes will be far greater. In New Zealand, Māori and Pacific Island children have been identified as having a high occurrence of educationally significant hearing loss (National Audiology Centre, 2004), which may be associated with a higher incidence of middle ear disease in this population (Ministry of Maori Affairs, 1989; National Audiology Centre, 2000). The above literature suggests that middle ear disease may impact on language and literacy learning. However, it is well established that literacy and academic outcomes are associated with socio-economic background (Goldenberg, 2001; Snow et al., 1998; Whitehurst & Lonigan, 2001).

## **2.2 Socio-economic status**

New Zealand studies have reported that Māori and Pacific Island children have higher rates of OME (Hamilton, McKenzie-Pollock, & Heath, 1980), higher hearing screening failure rates (National Audiology Centre, 2006), and, are often associated with low-income backgrounds (Crampton, Nelson, & Bandaranayake, 1996; Salmond, Crampton, & Atkinson, 2007). Diverse socio-economic dynamics such as living in low-income families, residing in poor communities, having parents with limited education and low levels of literacy, and attending schools in which literacy performance is continually low are also associated with reading failure (Nicholson, 2003; Snow et al., 1998). These children are more likely to exhibit delayed development of oral language skills (Longian & Whitehurst, 1998), delayed letter knowledge and phonological processing skills prior to school entry (Longian, Burgess, Anthony, & Barker, 1998; Raz & Bryant, 1990), begin school with fewer literacy experiences than their more affluent peers (Goldenberg, 2001), and depend more on their school experiences to develop literacy than middle-class children (Snow, Barnes, Chandler, Goodman, & Hemphill, 1991). SES-linked differences in phonological processing abilities are associated to later disparities in word decoding skills (Raz & Bryant, 1990). A child who begins school with poor reading-related skills is at increased risk of qualifying for special education services. Most school-age children who are assessed for these services are referred because of limited reading progress (Lentz, 1988). Without successful intervention these children may fall further behind their peers.

Two international reports of reading literacy for 10- and 15-year-old students in New Zealand link poor literacy results to ethnicity and SES (Chamberlain, 2008; Marshall, Caygill, & May, 2008). The Progress in International Reading Literacy Study (PIRLS) (Chamberlain, 2008)

reported that Year 5 (10-year-old students) Māori and Pacific Island students from low-decile schools were consistently amongst the lowest achieving students. The 2006 Programme for International Student Assessment (PISA) (Marshall et al., 2008) describes New Zealand's results for reading literacy in 15-year-old students. In these studies the largest majority of poor readers were from low-income backgrounds with an over-representation of Māori and Pacific Island students. The key findings of these reports demonstrated that socio-economic background has far-reaching effects on academic performance. These findings have not changed in the last decade (Tunmer, Chapman, & Prochnow, 2006). Such academic indicators suggest that the educational achievements of Māori and Pacific Island children may be at greater jeopardy comparatively due to overlapping risk factors of lower socio-economic backgrounds, higher incidence of middle ear infection and glue ear. Therefore, how might current teaching practice in New Zealand foster those children who are clearly at-risk?

### **2.3 Teaching practice in New Zealand**

New Zealand primary schools are internationally recognised for their innovative teaching approaches. Small group work and incidental learning is emphasised. Co-operative learning or incidental teaching is a common style of learning in classrooms in which a high level of verbal social interaction is encouraged (Nelson & Soli, 2000). As children become more proficient in language, they incidentally (albeit passively) grasp many skills by listening to or overhearing what people say (Ling, 1988). Incidental learning can foster the ability to monitor environmental events, enable access to the redundancy in instructional messages and to social cues (Flexer, 1997). Consequently, these skills facilitate language and literacy development and meaningful communication. Thereby, learning in school primarily relies on hearing and listening. Wilson et al., (2002) reported that in New Zealand primary schools 69% of teaching time was spent in mat work or group work and a further 12% in didactic blackboard teaching. These children are expected to understand the verbal instruction of their teachers through listening until strong reading skills have been established, usually in their fifth year of school (Matkin, 1996).

Although New Zealand has developed a unique teaching style it has also followed international pedagogic practice in adopting an all-inclusive approach to teaching by mainstreaming children with special needs, through early education to secondary school (New Zealand Legislation, 1989). Targeted support is allotted according to need. Despite the inclusion of children with specific learning needs New Zealand has a unified education system regulated by the national Ministry of Education in which the approach to literacy instruction

and intervention is relatively uniform (Tunmer, Chapman, & Prochnow, 2004). While New Zealand has enjoyed significant past success in international standards of literacy (Guthrie, 1981; Purves, 1973; 1979; Thorndike, 1973), considerable debate now exists regarding the increase of lower literacy rates in particular ethnic groups and the mode of teaching which best supports improving literacy for all New Zealand children and adolescents.

### **2.3.1 Reading achievement and outcomes in New Zealand**

New Zealand has fostered a ‘whole language’ approach to reading instruction and intervention for the past two decades. The whole language learning method includes use of a literature-based approach, emphasis on child-centred instruction, integration of reading and writing, and emphasis on meaning construction (Tunmer & Chapman, 1999). Attention is given to learning to read by reading, with little attention given to the development of word-level skills. Strategies include: utilising preceding passage content, sentence context cues and picture cues as the primary strategies for identifying novel words. The whole language approach might be described as a top-down process, referring to the engagement of metacognitive and language strategies. Top-down approaches attempt to provide a framework with which to buttress higher-order cerebral processes such as language, memory, attention and motivation. However, the whole language framework receives censure for two significant assumptions, both of which fail to be supported by research (Lieberman & Lieberman, 1992; Pressley, 2002). First of all, reading instruction is focused on encouraging children to use sentence context cues as the main stratagem for identifying novel words in text. Secondly, learning to read is considered essentially the same as learning to speak, that is, they both develop ‘naturally’. These same methods are largely utilised by Reading Recovery, a nationally-implemented early intervention programme for struggling readers (Clay, 1985). Tunmer et al., (2004; 2006) note that following the implementation of this programme in the mid-1980s, the large gap in reading performance between good and poor readers consistently observed in international surveys should have diminished. Yet, there continues to be increasing evidence of significant disparity in literacy skills between students. This is considered the principle challenge facing literacy education in New Zealand (Wilkinson, Freebody, & Elkins, 2000). Further, Tunmer et al., (2004; 2006) suggested that the disparities seen in New Zealand’s scores in international studies of literacy performance results from “Matthew effects” generated by a whole language approach to teaching reading. This approach is unable to meet base-skill variations at school entry deriving from social class differences in home literacy environments. The “Matthew effect” is a phenomenon in which children with poor reading skills fall further and further behind peers with subsequent effects in other academic areas (Stanovich, 1986).

International reports of reading performance have continued to show discrepancies in the reading scores of New Zealand school children. The most recent PIRLS (Chamberlain, 2008) revealed that New Zealand Year 5 students (10-year-olds) scored significantly lower than the average score for students in 17 countries including England, Hong Kong, and the United States. Notably, New Zealand had a wide range of scores among students, from those who were very advanced to those who had difficulties with understanding what they read. The range of scores was wider than for many other higher-performing countries. These findings suggested that, despite educationalists and policy-makers' best efforts, critical disparities in literacy skills persists. Greaney (2002) commented that these outcomes are hardly surprising given that the perspectives published by the Ministry of Education regarding teaching reading are not supported by the international research literature.

However, code-emphasis approaches to teaching reading have demonstrated benefits for children from low-income backgrounds with minimal literacy related skill and knowledge at school entry (Foorman, Francis, Fletcher, Schatschneider, & Mehta, 1998; Xue & Meisels, 2004). Such code-emphasis methods focus on increasing sensitivity to speech sounds (phonemes) thereby enhancing appreciation of sounds related to language, known as PA. When PA is linked to letters, i.e. letter-sound knowledge, this enables a child to decode words more accurately thereby accessing meaning. Such strategies influence bottom-up processing which refers to the acoustic signal and specific training in the perception and recognition of phonemes and their relationship to letters and letter groups (graphemes). Bottom-up approaches are designed to train specific auditory perception skills. While whole-language teaching predominates in New Zealand, some schools have recognised that code-emphasis approaches or bottom-up strategies may be more appropriate for children who do not possess adequate levels of critical literacy-related skills and experiences at school entry level and during initial reading instruction. Phonics and PA programmes appear to be gaining in popularity as New Zealand researchers, teachers and parents demand better reading performances following the results of international studies.

To summarise, co-existing risk factors likely to influence literacy and later academic achievement include: ethnicity, fluctuating or mild hearing impairment, SES and the teaching method for reading. The children most at-risk of poor academic outcomes are therefore those children that exist in any or all of these groups, that is, children of Māori or Pacific Island ethnicity, with OME, from a low-income background, and are taught with an emphasis on whole-language learning. Māori and Pacific Island children have been identified as having a

higher incidence of middle ear disease, educationally significant hearing loss, as well as over-representation in figures of low SES and low-literacy levels. When these factors amalgamate with poor classroom acoustics, literacy, language and learning development is critically influenced.

## **2.4 Classroom acoustics**

The classroom is an auditory-verbal environment. Therefore, the context of learning is defined by the success of listening and understanding, or more specifically, by speech recognition (Hodgson & Nosal, 2002). In the last decade, mounting research has appraised the acoustical conditions in classrooms focusing on optimising classroom acoustics (Bradley, 1986; Nelson & Soli, 2000; Sato & Bradley, 2008; Siebein, Gold, Siebein, & Ermann, 2000; Whitlock & Dodd, 2008; Wilson et al., 2002) and building design (Crandell & Smaldino, 1995; Whitlock & Dodd, 2008; Wilson et al., 2002). Speech recognition may be compromised by the acoustic design of the classroom, distance, reverberation, noise and the resulting SNR. These acoustical parameters are critical variables and may detrimentally impact the ability for children to understand speech (Crandell, Smaldino, & Flexer, 1995; Finitzo-Hieber & Tillman, 1978).

### **2.4.1 Building design and construction**

In New Zealand, current didactic practices, building design and construction, and ventilation methods have all been identified as contributors to poor speech recognition within the classroom. Moreover, the building design and construction methods of New Zealand classrooms vary widely and accordingly, acoustic parameters also vary (Wilson et al., 2002). Standards for building design in New Zealand have only recently recognised acoustic effects upon learning and listening (Wilson et al., 2002). The Ministry of Education (Ministry of Education, 2008) now recommends that schools meet the design standards in the Australian and New Zealand Standard (Australian and New Zealand Standard, 2000) which provides recommended design sound levels and reverberation times (RTs) for primary school teaching spaces. A satisfactory unoccupied noise level (35 dBA) is the level of noise which is not intrusive and is most acceptable by the majority of people within that environment. A maximum level (45 dBA) is the level of noise which exceeds most people's tolerance. The recommended RT is 0.4 to 0.5 seconds. Furthermore, the standard notes that for teaching spaces intended for students with learning difficulties and with English as a second language, RT should be at the lower end of the specified range. Despite building design or acoustic standards the principal consideration for accurate speech recognition is the relationship

between the intensity of the signal of interest and the intensity of the background noise at the child's ear (Crandell & Smaldino, 2000).

#### **2.4.2 Signal-to-noise ratio**

The relationship between an incoming signal and background noise is specified as the SNR. Evidence suggests that adults comprehend familiar spoken material when the signal and noise are of the same strength, i.e. when the SNR level approximates 0 dB (Nilsson, Soli, & Sullivan, 1994). Young children, children learning a second language, children with hearing loss and children in highly reverberant environments require higher SNRs (Nelson & Soli, 2000).

Chermak and Musiek (1997) comment that the detection of fine acoustic features precedes higher levels of auditory processing skills. Therefore, a child has a greater opportunity to develop and expand language and literacy skill when he or she can successfully detect word/sound distinctions. For this reason, it is important to determine levels of SNRs that provide children with the best learning opportunity. As speech perception is greatest at favourable SNRs and decreased at reduced SNRs (Finitzo-Hieber & Tillman, 1978), providing a stronger signal would maximally benefit children in an educational setting. Therefore, to preserve fine acoustic information provided by the target signal, a higher SNR is required (Carhart, Tillman, & Greetis, 1969). However, within a typical classroom, background noise, reverberation and variations in teacher position all contribute to an unstable and inconsistent SNR which influences the learning ability of all children (Berg et al., 1996). Yet, research has demonstrated that a +15 dB SNR enables all students regardless of age, hearing acuity or second language learners to recognise speech (Nelson & Soli, 2000). Furthermore, because short-term speech level varies over a wide range, full audibility of the acoustic signal requires a SNR of at least +15 dB (Boothroyd, 2004).

In a small sample of classrooms in Auckland, New Zealand, Coddington (1980) reported classroom acoustics and their relationship to children with hearing impairment in typical schools. The author commented that for children with impaired hearing the SNR ratio should be +10 dB. Blake and Busby (1994) measured SNRs in Wellington, (New Zealand) classrooms documenting +6 dB as the median SNR. In addition, this study revealed that only 4% of junior classrooms were quiet enough for normal hearing children, sitting at a distance of three metres from the teacher, to hear clearly. In an active classroom, background noise level will interfere with and potentially impede the transmission of speech to the child.

### 2.4.3 Background noise

Noise commonly refers to any sound that hinders what the listener wants to hear (Boothroyd, 2004). Modern teaching methods in New Zealand encourage 'cooperative instruction' environments in which students work together cooperatively in small groups, (D. W. Johnson & Johnson, 1994) thus promoting incidental learning (Flexer, 1999; Ling, 1988). In a document reporting the acoustic characteristics of New Zealand primary school classrooms, background noise was an acknowledged concern of both teachers and students (Wilson et al., 2002). Background classroom noise levels vary substantially as a function of time. Internal sources of noise, excluding noise generated by the children within the class itself, may comprise computer generated noise, fluorescent lighting 'hum' and heating or air conditioning units. Sound levels within the classroom are also largely influenced by external noise sources, including road or air traffic and noise from other students in adjacent classrooms or in outside playing areas (Nelson, Soli, & Seltz, 2002).

Noise has documented, harmful effects on speech recognition in normal hearing and hearing impaired children and adults (Bronkhorst & Plomp, 1992; Brungart, 2000; Carhart, Johnson, & Goodman, 1975; Carhart et al., 1969; Danhauer & Leppler, 1979; C. E. Johnson, 2000; Papso & Blood, 1989; Rhebergen & Versfeld, 2005; Sperry, Wiley, & Chial, 1997; Stelmachowicz, Hoover, Lewis, Kortekaas, & Pittman, 2000). Specifically, studies have reported decreased speech recognition for normal hearing listeners when speech is presented in noise. Compared to adolescents and adults, normal hearing young children have less ability to extract meaningful speech information from distracting background noise (C. E. Johnson, 2000; Papso & Blood, 1989). Furthermore, when background noise is composed of meaningful speech it has a profoundly adverse effect upon speech recognition (Danhauer & Leppler, 1979; Papso & Blood, 1989; Sperry et al., 1997; Van Engen & Bradlow, 2007). Whereas a mature, adult auditory system may tolerate increased levels of noise and distraction, children are highly vulnerable to meaningful noise (Papso & Blood, 1989). Given the sensitive state of the developing auditory system, the importance of clear acoustic signals in a background with minimal noise distraction is essential. Yet, within poorly designed classrooms, sounds can be reflected and prolonged resulting in sub-optimal learning environments.

### 2.4.4 Reverberation

Reverberation refers to the prolongation or persistence of sound within an enclosure as sound waves reflect off of hard surfaces (Nabelek & Nabelek, 1994; Nabelek & Pickett, 1974a;

Nabelek & Pickett, 1974b). The prolongation of sound is typically the most important acoustic parameter defining the acoustic quality of the classroom (Crandell & Smaldino, 2000). The amount of reverberation influences the accuracy of speech recognition and is typically quantified by the early-to-late energy ratio (Bistafa & Bradley, 2000). However, it is more common to characterise the amount of reverberation in a room by the RT (Hodgson & Nosal, 2002). RT is used to determine how rapidly sound decays in a room. It is defined as the time it takes for a sound to decay 60 dB from its original intensity. RT varies depending on the amount of absorption provided by the surfaces of the room (Berg et al., 1996) and as a function of frequency (Bistafa & Bradley, 2000). Excessive reverberation degrades accurate speech perception as it causes the spectral energy of the vowels to mask succeeding lower intensity consonants (Nabelek & Nabelek, 1985; Nabelek & Robinson, 1982). Recommended optimal RTs for understanding speech range from 0.2 to 0.6 seconds for classrooms (Nelson et al., 2002).

Numerous studies have measured the RT of typical classrooms (Bistafa & Bradley, 2000; Bradley, 1986; Knecht, Nelson, Whitelaw, & Feth, 2002; Kodaras, 1960; Sato & Bradley, 2008) and the impact RT has on the accuracy of perception of speech (Bradley, 1986; Nabelek & Pickett, 1974a; Nabelek & Pickett, 1974b). Studies have also focused on the combined effect of reverberation and noise upon children's speech recognition abilities (Finitzo-Hieber & Tillman, 1978; Nabelek & Pickett, 1974a; Nabelek & Pickett, 1974b). Children under the age of 13 have been described as 'special listeners' (Nabelek & Nabelek, 1994) and likely to be uniquely vulnerable to reverberation and noise effects present within most classrooms.

#### **2.4.5 Distance**

While background noise and reverberation are influential obstacles to the learning and academic achievement of children (Picard & Bradley, 2001), teacher position is not fixed in modern teaching practice. Therefore, the signal reaching the student's ear may fluctuate depending upon teacher location within the classroom. In this respect the speech signal which reaches the listener's ear is subject to the acoustic properties of the listening environment (Boothroyd, 2004). Within a short distance, the direct sound-field predominates, that is, the listener receives a direct speech signal. Early components of reverberation arrive at the listener after only a few reflections. These early reflections are integrated with the direct signal and contribute to enhancing speech recognition (Boothroyd, 2004). As the distance between listener and speaker increase, the indirect or reverberant field begins to dominant (Crandell & Smaldino, 2000). The distance when the direct signal and the early reflections are equal is

termed the 'critical distance'. It is at this point that the indirect sound-field prevails. Moreover, sound intensity decreases with distance. The inverse square law states that with each doubling of distance, sound is reduced by 6 dB. However, within the classroom the intensity of the adult human voice is also determined by the directionality of sound and the absorption of the sound by students directly between the teacher and distant students (Egan, 1988).

Beyond the critical distance, the signal reaching the listener's ear comprises the direct signal relative to the distance travelled and reflected sound. Yet, components of the reflected sound have been lost due to multiple, repeated reflections. Energy reduces at each reflection and frequencies have been filtered by the absorptive characteristics of surfaces within the room. The reflected sound thus contains altered acoustical content in intensity, frequency and temporal domains (Crandell & Smaldino, 2000). Consequently, the quality of the acoustic content within the speech signal varies as a function of distance. Critical distance influences speech recognition scores (Crandell, 1991; Leavitt & Flexer, 1991). Only by decreasing the distance between speaker and listener will speech recognition ability improve. Furthermore, preferential seating allocation is only relevant when critical distance is maintained (Crandell & Smaldino, 2000).

In summary, the classroom is defined as a 'critical listening area' in which acoustic parameters may act to either compromise or enhance listening and learning. Learning of speech, language and literacy necessitates a clear, complete speech signal (Briscoe et al., 2001). Providing a means to enhance SNRs for optimal learning is therefore paramount for children (Brackett, 1997).

## **2.5 Sound-field amplification**

The use of SFA has been proven to be effective in combating adverse classroom acoustics by increasing the overall speech level of the teacher, improving the SNR, and producing a virtually uniform speech level in the classroom unaffected by teacher position (Flexer, 1994). These improvements create a more favourable learning environment which can benefit almost all children (Palmer, 1997). Consistently, research has demonstrated the benefits and overall improved academic and behavioural outcomes for students exposed to SFA systems (Allcock, 1997; Arnold & Canning, 1999; Bennetts & Flynn, 2002; Crandell et al., 1995; Eriks-Brophy & Ayukawa, 2000; Flexer, 1989; Flexer, 1997; Heeney, 2007; Matkin, 1996; Rosenberg et al., 1999; Sarff, 1981; Zabel & Tabor, 1993). Both large-scale studies (Heeney, 2007; Ray, Sarff, & Glassford, 1984; Rosenberg et al., 1999; Sarff, 1981) and smaller population investigations

(Allcock, 1997; Bennetts & Flynn, 2002; Eriks-Brophy & Ayukawa, 2000; McCarty & Ure, 2003; McLaren & Humphries, 2008) substantiate these outcomes.

The Improving Classroom Acoustics (ICA) project (Rosenberg et al., 1999) demonstrated that SFA provides positive and substantial benefits to young children. The effects of SFA on student behaviour, listening skills and academic achievement were compared between students in 64 amplified classrooms and 30 control (unamplified) classrooms. The project included 2,054 kindergarten to grade two students across 33 schools. Hearing screenings were administered to approximately half of the students. Up to 25% of these had a hearing loss greater than 15 dB, although type of hearing loss was not reported. Observational surveys were completed by the teachers prior to SFA installation and at six and 12 weeks later. Students in the SFA condition demonstrated significant improvements in the listening and learning behaviours and skills, and progressed at a faster rate than the control cohort in the unamplified classrooms. While results were not analysed separately for students with and without hearing loss, this study demonstrates that SFA can effect positive outcomes regardless of hearing impairment.

These results supported earlier research in which SFA was compared with withdrawal from the mainstream class for children with hearing impairment or specific learning needs (Ray et al., 1984; Sarff, 1981). Project MARRS (Mainstream Amplification Resource Room Study) was a three-year longitudinal study aimed at identifying a means of facilitating students with mild or fluctuating hearing impairment to compensate for inadequate classroom acoustics, thereby permitting them to remain in mainstream classrooms instead of costly withdrawal referral, identification and instruction. Researchers compared the academic performance of students in grades four to six. Students were assessed for minimal-to-mild hearing impairment, co-existing learning disorders and typical learning potential. 30% of the mainstream students and up to 75% of students with special education needs were found to have educationally significant hearing loss and failed a 15 dB hearing screen. Students were divided into one of three teaching groups comprising: typical classroom environment, combination of routine classroom instruction with additional withdrawal instruction, and, routine mainstream instruction utilising SFA. Both treatment and non-treatment groups demonstrated improvements with the greatest improvements observed in the treatment group. Students with minimal hearing loss in the SFA rooms made significant improvements in academic achievement test scores. This benchmark study established that children from special

populations need not suffer stigmatizing labelling or be withdrawn from mainstream classes when the learning environment is optimised.

Research has since continued to focus on establishing whether SFA can enhance conditions for children with hearing difficulties or specific learning needs (Eriks-Brophy & Ayukawa, 2000; Flexer, Richards, Buie, & Brandy, 1994; McCarty & Ure, 2003). These studies reported that SFA beneficially influenced at-risk students and multicultural populations challenged by high rates of hearing loss as well as for second language learners. Research from New Zealand based studies are providing mounting evidence that regardless of background, ethnicity, middle ear dysfunction or disability, the academic performance of New Zealand school children can significantly improve with SFA.

In a recent, large-scale New Zealand study (Heeney, 2007), classrooms fitted with SFA systems resulted in significant improvements across a range of academic measures, regardless of socio-economic background, ethnic group or middle ear dysfunction. 626 primary school children participated in this 12-month study. Students were divided into intervention (438 students in 30 classrooms fitted with SFA systems) and control (188 students in 12 classrooms without SFA) groups. The study investigated the efficacy of SFA compared with a representative control group and the variations of benefit for children from different socio-economic backgrounds, indigenous children and those with histories of middle ear dysfunction.

The majority of children in the study were New Zealanders of European descent (almost 60%), over a third identified as Māori (35%) and 8% identified as Pacific Islander or Asian heritage. Incidence of treated middle ear dysfunction varied with ethnicity. The combined reported incidence was reported at 32%, with Pakeha accounting for 28% of that figure, Māori at 39%, and Pacific Islander and Asian reporting 25%. Socio-economic status was based on the decile rating of each school in which a low-decile rating indicates a school with a significant number of disadvantaged children. Measures of listening comprehension, reading comprehension, reading vocabulary, mathematics and PA were obtained. Scores for the intervention group showed significant improvement across all measures. In addition, teachers reported that classrooms were quieter resulting in greater student attention, observed increased on-task and reduced disruptive behaviour from students, improved understanding of instructions and students co-operation, enhanced classroom harmony and reduced vocal strain. The use of SFA in these classrooms positively influenced children's academic measures regardless of socio-economic background, ethnicity and middle ear function. The author

commented that, while SFA was not a modern education panacea, it was one of the most cost effective interventions to increase literacy outcomes. While the acoustic design of these classrooms was broadly described, no acoustic measures of any classroom were obtained. Such measures would have described the acoustic environment children were expected to listen and learn in prior to the installation of SFA.

Such positive learning outcomes have also been demonstrated by smaller New Zealand studies. Allcock (1997) reported that on-task behaviour significantly improved for both children with normal hearing or hearing impairment in a classroom installed with SFA compared to without. These amplified classrooms outperformed parallel classrooms without SFA in measures of PA. McLaren and Humphries (2008) found that with SFA student's overall performance improved in conditions of low and high levels of background noise, although particularly for high levels. The efficacy of SFA on the listening and learning skills of children with Down syndrome has also been investigated (Bennetts & Flynn, 2002). These children were found to perceive significantly more speech when SFA was used. Notably, with SFA, the children's listening performance was not affected when SNR was reduced by increasing the level of background noise.

Thus, the acoustical design and environment can lend itself to either facilitate or thwart the child's ability to listen and learn. From this perspective, research promoting the use of SFA in classrooms is not without its critics. Whitlock and Dodd (2008) investigated the speech intelligibility requirements of New Zealand children in primary school classrooms and recommended that designing an optimum acoustic environment for primary school children was preferable to installation of SFA. The authors criticized the use of SFA on several counts: SFA failed to address the central issue of poor room acoustics, only enhanced communication between teacher and student, neglected the student-to-teacher and student-to-student communication during group work. Furthermore, that early use of SFA would in fact impede development of essential listening skills such as localization and discrimination as SFA systems took away the need, and potentially the motivation, to attend to the speaker. The authors suggested that: (1) student learning would suffer if students moved between schools or classes with SFA to without; (2) noise levels would increase in the classroom thereby significantly increasing the daily noise dose for the child; and (3) SFA could potentially create noise problems for adjacent classrooms. Finally, the authors suggested that the teacher may over-utilise the system without fully recognising the impact on students. These points are supported by the position statement of the Acoustical Society of America on the use of sound

amplification in the classroom (Acoustical Society of America, 2006). This statement clearly censures the use of SFA commenting that SFA does little to improve and may worsen student-to-student and student-to-teacher communication, and only improves teacher-to-student communication, if at all. The position states that sound amplification should *not* be routinely employed in typical, small mainstream classrooms but that good classroom acoustics can usually be achieved through renovation and architectural design practice. While these criticisms demand consideration the cost effectiveness of renovating many thousands of classrooms, at least in New Zealand, would not be economically tenable.

In summary, mounting evidence from international and New Zealand studies supports the use of SFA in New Zealand schools. Moreover, utilisation of SFA in classrooms has reportedly raised the literacy skills of children with normal hearing, mild hearing loss, learning disabilities and other specific populations (Flexer, Biley, Hinkley, Harkema, & Holcomb, 2002; Flexer, Millin, & Brown, 1990; Heeney, 2007; Richards, Flexer, Brandy, & Wray, 1993; Sarff, 1981). These studies evince that such intervention can assist in reducing disparity and improving learning outcomes for all New Zealand children in mainstream school environments, the stated goals for education by the New Zealand Ministry of Education (Ministry of Education, 2003). Following these reports, the benefits of SFA to children's literacy measures might be further enhanced when implemented with an evidence-based literacy skills intervention programme

## **2.6 Literacy skills and phonological awareness**

Reading is composed of two principal components: decoding ability (i.e. word recognition) and reading comprehension. It is widely recognized that the development of literacy skill is strongly related to PA (J. M. Carroll & Snowling, 2004; Catts, Fey, Zhang, & Tomblin, 2001; Gillon, 2004; T. P. Hogan, Catts, & Little, 2005; National Institute of Child Health and Human Development, 2000). PA is the explicit awareness of the sound structure of spoken words (Gillon, 2004; Stahl, 2001). Words are made up of component parts such as syllables and speech sounds or 'phonemes', which are discrete units of speech. Successful decoding of words requires the ability to break words down into these discrete units. PA is the ability to do this and may be demonstrated in a variety of skills including identifying and generating rhyming words, breaking words into syllables and phonemes, blending spoken syllables or phonemes together to form words, deleting syllables or phonemes from spoken words to form new words or counting the number of phonemes in a spoken word (Whitehurst & Lonigan, 2001). PA would therefore, be considered a bottom-up process. PA is often

confused with 'Phonics' (Schuele & Boudreau, 2008). In PA, the focus is upon the sound structure of spoken words. PA tasks are thus centred on the manipulation and analysis of sounds. Contrastingly, in phonics, attention is predominantly given to print, that is, that letter symbols are representative of sounds. Competency in phonics therefore requires PA (Torgesen, Wagner, & Rashotte, 1994). The crucial point is that alphabetic script is meaningless to a child who has little understanding that sounds form words. Understanding the representation of speech sounds in print facilitates orthographic knowledge (Beck & Juel, 1995; Stanovich, West, & Cunningham, 1991).

PA supports decoding skill development because children learn correspondences between phonemes and graphemes (letters or groups of letters which represent a single phoneme i.e. 'sh' or 'ph') providing them with a strategy to attempt unfamiliar words (Bird, Bishop, & Freeman, 1995). If children fail to distinguish phonemes in spoken words, identifying the link between print and language is challenging (Whitehurst & Lonigan, 2001). When children continue to fall behind in their reading skills, detrimental spin-offs follow: children receive less practice at reading than other children, meet reading material too sophisticated for their skills (Allington, 1984), have fewer opportunities to develop reading comprehension tactics (Brown, Palincsar, & Purcell, 1986) which often results in a negative perspective towards reading (Oka & Paris, 1987). Thus, the Matthew effect (Stanovich, 1986) is triggered (the rich get rich, the poor fall further behind). Yet, it is important to remember that risk is not destiny. Optimally timed, intensive and specific PA intervention can reverse the cycle of deficits.

### **2.6.1 Phonological awareness intervention**

Research has repeatedly demonstrated that early PA skill is a strong predictor of later literacy, subsequent academic success, and has proven ability to reduce reading disparity between children (Bus & van Ijzendoorn, 1999; Catts et al., 2001; Ehri et al., 2001; Gillon, 2002; 2005; T. P. Hogan et al., 2005; Leitao, Hogben, & Fletcher, 1997; Torgesen, 2000; Torgesen et al., 1994). Research conducted by Catts and colleagues (2001) focused on the predictive abilities of PA in identifying ensuing literacy success. This longitudinal study provided conclusive results that PA was a convincing predictor of literacy achievement. PA assessment permits at-risk children to be identified before encountering negative literacy experiences in the first, formative years of schooling. Intervention studies have revealed that teaching PA skills can positively influence reading ability (Torgesen et al., 1994). Moreover, intervention that is optimally timed can influence later academic performance. Schneider and colleagues (1999) randomly selected kindergarten children classified as at-risk, average or above average in their

knowledge of the structural features of language or metalinguistic skill. The at-risk group received early PA intervention and significantly outperformed the two control groups. The benefits of early intervention stimulated successful reading and spelling results in the first two years of schooling. Optimally timed intervention may prevent a child from experiencing failure in early reading and spelling. Yet, research has also demonstrated that positive and sustained outcomes require more intensive training.

Intensive intervention targeting PA has been shown to have dramatic effects on children's literacy outcomes (Gillon, 2002; Gillon & Dodd, 1997; Schneider et al., 1999). Gillon (2004) specifies that concentrated periods of PA intervention are more likely to effect change than shorter periods of inconsistent training. Gillon and Dodd (1997) specifically investigated the impact of intensive training with adolescents (nine to 14 year olds). Shorter periods of twelve hours intervention were compared with twenty hours. Results confirmed that increases in reading skills were related to the duration of the training period. The research of Denne et al. (2005) supported this theory yet emphasized the time commitment required to deliver effective intervention. Less intervention time in this study (12 hours) resulted in less effect for literacy and speech outcomes.

While intervention intensity has been proven to be a key factor in enhancing children's literacy outcomes, it is the specific content of intervention that plays a crucial role in sustained and salient results for literacy. Intervention which specifically targets and focuses children's attention to the smallest unit of sound (i.e. to the level of the phoneme) is a proven and robust method in improving literacy skills (Catts et al., 2001; Gillon, 2002; 2005). Direct and precise instruction of PA tasks draws attention to the specific meaning of speech sounds within a literacy context and develops early and essential reading and writing skill (Gillon, 2004; Schuele & Boudreau, 2008). Early development and explicit training of PA has proven ability to rapidly propel children's perception and awareness of speech sounds within spoken words which is essential to literacy acquisition.

### **2.6.2 Whole-class training**

Evidence supports differing models of PA training including; individual, small group and class-based (Foorman, Breier, & Fletcher, 2003; Shapiro & Solity, 2008), and, involving speech language therapists, other reading specialists or trained teacher aides (Gillon, 2004). Team approaches were effectively utilised in the Gillon and Dodd study (1997) incorporating trained learning support teachers. Whole-class teaching has demonstrated less effective outcomes

compared to small-group intervention (Byrne & Fiedling-Barnsley, 1995). Yet, more recently, research has shown that class-based programmes can be effective in training PA (Foorman et al., 1998; Fuchs et al., 2001; Hatcher, Hulme, & Snowling, 2004; Leafstedt, Richards, & Gerber, 2004; Shapiro & Solity, 2008).

Shapiro and Solity (2008) conducted a three-year study in 12 British schools examining the effects of an intensive early reading research programme. The study investigated whether implementing intensive intervention incorporating both PA and phonics training in whole-class mixed-ability lessons would influence children at risk of developing reading difficulties as well as raising scores for typically developing children. Participating schools were matched for geographical proximity, SES and previous test results. Most of the students attending these schools came from low-income families. The reading abilities of more than 400 students were measured and monitored throughout their first to third year of schooling. The performance of children attending experimental schools were compared with a comparison group of children attending similar schools but who received routine teaching methods. Intervention involved development of phoneme awareness, phoneme level tasks, fostering letter-name and letter-sound knowledge, sight vocabulary and reading to, and with, children. Intervention took place over the first two years of schooling and was withdrawn in the third year to observe whether any gains made during the intervention years were maintained. This intervention totally replaced the content and organisation of the reading curriculum within six of the experimental schools. Each whole-class session lasted 12 minutes and was delivered by the class teacher three times a day over the two-year intervention period. Differing ability levels were facilitated by class division into higher, middle and lower achieving groups. In each session the teacher focused on content specific to each group's ability. The results of this study demonstrated that with purposeful intervention children's literacy skills progress more rapidly, children at different levels of PA appear to equally benefit from intervention and that significantly less children experience reading difficulties by the third year of school when compared with children receiving routine teaching. Notably, this study establishes that intensive and specific PA training can be successfully incorporated into whole-class teaching.

## **2.7 Integration of sound-field amplification and phonological awareness**

Research has demonstrated that SFA and PA, as stand-alone interventions are beneficial to reading development and overall academic achievement. Despite this, there has been a notable lack of research investigating the effects of combining the two treatment methods. Given that PA focuses on the *sounds* of speech, it is plainly an auditory skill. Enhancing the acoustic

environment would presumably improve phonemic distinctions. In a one-year study, Flexer and colleagues (2002) compared the phonological and phonemic awareness skills of four-year-olds following standard curriculum teaching, teacher-administered phonological and phonemic awareness instruction for 15 minutes, four times a week; and integrated sound-field system amplification with teacher-administered phonological and phonemic awareness instruction. Results suggested that PA training was more effective when SFA was added. However, comparisons between groups were limited with no statistical significance noted between the group receiving direct group PA instruction and teacher-administered PA instruction due to unequal and low participant numbers in the direct PA instruction group. This study indicated that for very young American children an enhanced acoustic environment can positively influence training the sound structure of spoken language. Investigation of young children's response to combined SFA+PA intervention has yet to be undertaken in the context of New Zealand classrooms.

## **2.8 Overall summary**

In summary, several points have been recognised as influential to a child's listening and learning within the classroom. Mild, fluctuating hearing loss due to OM, a low-income background and current teaching practices in New Zealand influence the academic outcomes of students, particularly those from certain ethnic minorities. Poor classroom acoustics may further jeopardise listening and learning. While SFA and PA intervention in isolation have been found to benefit the learning outcomes of children, their combined effect in enhancing skilled literacy acquisition has received little attention.

## **2.9 Research questions and hypotheses**

This study addresses the following question:

- a) Does the implementation of SFA and PA intervention improve the PA skills (phoneme blending, phoneme segmentation, phoneme reversal and phoneme manipulation) and subsequent reading ability of young school children beyond that of SFA alone?

Based on the literature from PA intervention and SFA within classrooms, the hypotheses for this study are:

- a) That the PA ability of the children in the SFA+PA condition will surpass the outcomes of the group with SFA only.

b) That the word-decoding ability of the children in the SFA+PA condition will surpass the outcomes of the group with SFA only.

The null hypothesis is that the PA and reading abilities of the children in the SFA+PA condition will not surpass the outcomes of the group with SFA only. The aim of this study was to disprove the null hypothesis.



## 3 Method

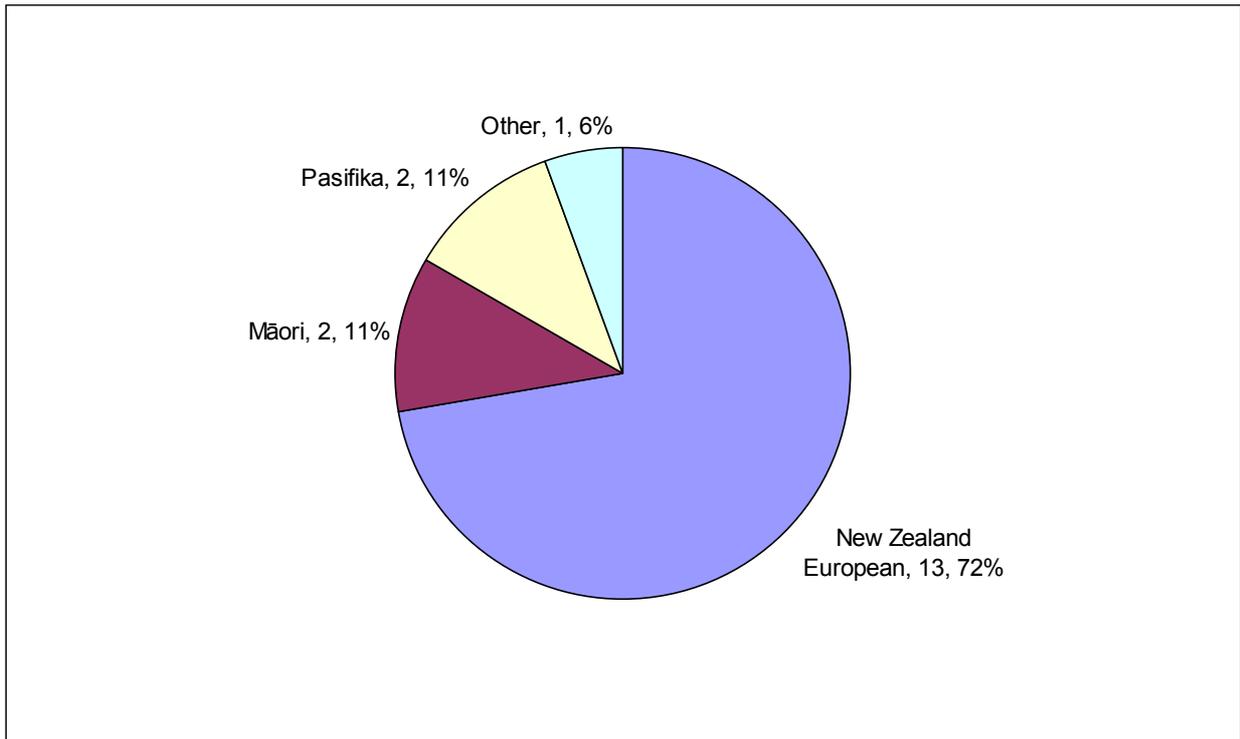
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### 3.1 Participants

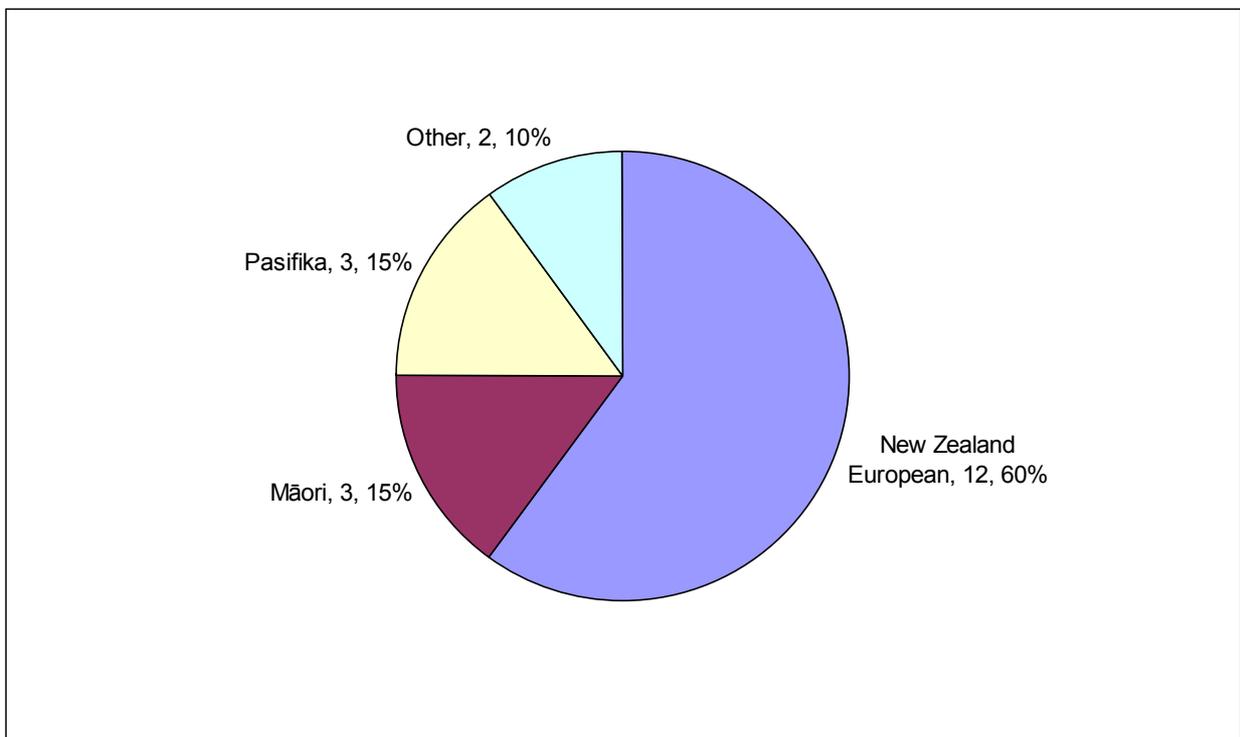
#### 3.1.1 School children

Forty-one (41) school children from two year 2 classrooms in a Christchurch primary school were invited to participate. At the beginning of the study, class 1 had 20 children and class 2 had 21. However, in class 1, one child moved to another school during the first term. Two children (one from each class) were unavailable to participate in the final assessment due to illness. Therefore, 38 children (18 in class 1 and 20 in class 2) participated. The school was in a lower socio-economic area as rated by the New Zealand Ministry of Education. The Ministry ranks schools based on a socio-economic scale of 1 to 10 (Ministry of Education, 2009a) in which a low-decile ranking indicates a significant number of disadvantaged children. For the purposes of this study, decile rating was used to define lower SES. The school was ranked at decile 3. Informed consent was collected from parents and caregivers who also completed a questionnaire with reference to their child's birth date, gender, ethnicity and any concerns regarding hearing, learning and language as shown in Appendices II - IV.

In class 1, 50% of the students were male (N=9). The average age in class 1 was 6.1 years (SD = 4.8 months). In class 2, 45% of the students were male (N=9). The average age in class 2 was 6 years (SD = 5.8 months). The majority of children in both classes were New Zealanders of European descent (class 1 = 72%, class 2 = 60%). Eleven percent in class 1 identified their heritage as Māori along with 15% in class 2. In class 1, 11% self-identified as Pacific Islander. In class 2, 15% self-identified as Pacific Islander and 10% identified as from African or Asian heritage. All children, excluding one child from class 1 (Fijian) and two children from class 4 (Somali and Korean) spoke English as the main language in the home. The distribution of children by ethnicity in each class is shown in Figure 1 and Figure 2.



**Figure 1: The distribution of students in class 1 by ethnicity. 'Other' ethnicities were Australian.**



**Figure 2: The distribution of students in class 2 by ethnicity. 'Other' ethnicities included Asian and African origin.**

In class 1, one child had identified hearing impairment related to OME and had had pressure equalising tubes. At the time of the study the tubes were no longer in place. Two children were identified by their parents as receiving extra learning support for reading or for learning and behaviour. Three children were identified as having previously received speech and language therapy for articulation and stuttering. In class 2, one child had identified hearing impairment related to OME and had had pressure equalising tubes inserted 12 months prior which were still in place. One child was awaiting assessment for attention-deficit hyperactivity disorder.

### **3.1.2 Teachers**

The teacher in class 1 (T1) was a 25-year-old female English teacher, trained in the United Kingdom with a degree in initial teaching training in primary with qualified teacher status and biological science. She had four years teaching experience. The teacher in class 2 (T2) was a 36-year-old male European New Zealand teacher, trained in New Zealand with a degree in horticultural science and a graduate diploma in primary teaching. He had eight years teaching experience, including four years teaching in the United Kingdom. Both teachers received professional development training and ongoing support on SFA use and maintenance.

## **3.2 Hearing Measurements**

### **3.2.1 Methods and Instrumentation**

Hearing screening of all children was conducted to identify hearing impairment, and to provide an estimate for the number of children experiencing mild, fluctuating hearing loss during assessment and treatment terms. Screening occurred once every 10 weeks. Hearing assessments were conducted in quiet rooms on the school premises in quiet school times and administered by final year Masters of Audiology students from the University of Canterbury. Research instruments consisted of a Heine mini 2000 otoscope (Heine Optotechnik, Germany) an Interacoustics AS208 audiometer (Interacoustics A/S., Denmark) (calibrated to 16 July 2010) and supra-aural Peltor headphones. An Interacoustics MT10 handheld tympanometer (Interacoustics A/S., Denmark) measured middle ear-function.

### **3.2.2 Hearing screening**

Hearing screening included otoscopy, air conduction thresholds and tympanometry. Tympanometry readings were classified according to Jerger's method (1970): type A (single peak at normal middle ear pressure and compliance), type B (flat with no discernable pressure peak), type C (single peak at a point of negative pressure). Type B tympanograms were

considered to be indicative of OME having been found to hold a positive predictive value for middle ear effusion (Babonis, Weir, & Kelly, 1991). Type C tympanograms were considered to demonstrate negative pressure within the middle ear. The more negative the pressure peak the more likely children are to suffer from repeat episodes of middle ear effusion (Bluestone, 1975). Therefore, type B and type C tympanograms were regarded as indicators of mild and fluctuating hearing impairment.

The hearing screening examination involved pure tone air-conduction threshold audiometry. Hearing sensitivity was classified as normal if thresholds of 20 dB HL (hearing level) were obtained across frequencies 250 Hz to 8000 Hz. A 'fail' was defined as hearing thresholds at any frequency exceeding 20 dB unilaterally. Also, when a presentation of 25 dB at two thresholds unilaterally occurred this also constituted a screen fail. Fourteen children failed the initial screen. Based on the premise that only 10% of the children would present with a hearing loss, a second screen was conducted. Three children failed the screening criteria and were thus identified for complete diagnostic assessment. No hearing loss was revealed in follow-up assessment of these three children.

### **3.3 Language assessment**

To gain information on the children's spoken language abilities the *Clinical Evaluation of Language Fundamentals Preschool – 2 Australian* (CELF-P2, (Wiig, Secord, & Semel, 2004) was administered individually to each child by the researcher (qualified speech-language therapist) or senior speech-language therapy students. This test provides comprehensive information regarding receptive and expressive language skills through administration of 11 core subtests adapted for Australian and New Zealand children.

The CELF-P core language mean in class 1 was  $M=85.1$  ( $SD = 15.3$ ) and in class 2,  $M=88.4$  ( $SD = 12.1$ ). An independent samples t-test showed no significant group difference ( $t = .723$ ,  $df = 36$ ,  $p = .474$ ). Individual inspection of the data revealed three children in class 1 and one child in class 2 performed 1.5 SD lower than the mean. The examiners identified one child as requiring in-depth assessment of articulation skills. This child in class 2 exhibited 77.4 percent consonants correct resulting in an estimated speech articulation severity of mild-moderate on the Goldman-Fristoe Test of Articulation (Goldman & Fristoe, 1986).

### **3.4 Routine class teaching**

The New Zealand curriculum served as the basis of teaching method in both classes (Ministry of Education, 2009b). Both teachers were implementing level one of the English curriculum.

A whole-language process dominates the teaching of English although indicators of student achievement using visual and grapho-phonetic information and associating sounds with letter clusters as well as with individual letters is included in the reading instruction. To this end, a phonics programme was part of routine teaching across all classes at this school. Therefore, the children in this study had previously received up to 15 months of phonics training delivered via junior school teachers and teacher aides. Phonics was implemented four days a week for up to 20 minutes a day and included: (1) listening to and discriminating sounds in speech, and hearing and generating words and phrases that rhyme, and (2) hearing, reading and writing the first 29 phoneme/grapheme correspondences and hearing the initial phoneme. In class 1, phonics was replaced with the PA class-based programme in Term 2. In class 2, the teacher suspended teaching the phonics programme and taught only letter-sound correspondences as part of the reading programme. Whole-language strategies predominated in reading tasks in class 2. Additionally, a few children from both classes received extra learning support through reading recovery programmes. Given that these children had received this intervention from age six years without discharge from the service, it was considered an inconsequential factor to the outcomes of this research.

### **3.5 Acoustic characteristics of classrooms**

#### **3.5.1 Methods and instrumentation**

Measurements of RT in occupied and unoccupied conditions, SNR and day long recordings to determine change in background noise levels were obtained in both classrooms. Measurements and equipment use were monitored by an Acoustics Engineering PhD student from the University of Canterbury.

Research instruments consisted of a Brüel & Kjaer type 2260 hand-held sound level meter (SLM) with a type 4189 microphone, a Brüel & Kjaer type 4296 omni-directional sound source, a Brüel & Kjaer type 2716 LAB Gruppen amplifier (Brüel & Kjaer Corp., Denmark) and a Neutrik noise generator (Neutrik ® AG., Principality of Liechtenstein). Equipment was calibrated in September, 2008. Prior to all acoustic measurements, the SLM was calibrated both internally and externally using the Brüel & Kjaer type 4321 sound level calibrator (Brüel & Kjaer Corp., Denmark).

#### **3.5.2 Test environment**

The two classrooms were located side-by-side forming part of a large multi-classroom and library complex. Both classrooms were flanked by other similarly sized classrooms, the school

library, bathrooms and smaller offices. The two classrooms share similar approximate dimensions of 8 ½ metres (length) x 8 metres (width) x 2 – 3 ½ metres (height). Other characteristics were wall-to-wall carpet, acoustic ceiling tile, three pin-board walls, one wall constructed as windowed sliding doors, two doors, and windows positioned above the pin-board on two of the walls.

### 3.5.3 Reverberation time

RT is defined as the time (in seconds) taken for the sound intensity or the sound pressure level to decay by 60 dB after the source has terminated (RT60) (Australian and New Zealand Standard, 2000). The RT20 and RT30 are defined as the time (in seconds) for the sound intensity to decay by the equivalent amount of dB after the source has terminated. The RT60 was approximated by measuring the time taken for a sound to decay from -5 to -35 dB (RT30), and multiplying by a factor of 2 resulting in the RT60, or from -5 to -25 dB (RT20), and multiplying by a factor of 3.

Room reverberation varies as a function of frequency, therefore, RT was measured at discrete frequencies from 125 Hz to 8000 Hz in occupied and unoccupied conditions as detailed in Appendix VI. An omni-directional sound source positioned in the centre of each room generated pink noise for six seconds at 77 dB A resulting in a close approximation to a reverberant field. RT20 and RT30 measures were obtained twice at three different positions in the class. T60 was linearly interpolated from the T20 and T30 as previously described. The RT60 values were then averaged to provide a single estimate of the reverberation time. The results are tabulated in Table 1.

**Table 1: T60 values averaged from the octave bands 125 to 8000 Hz to provide a single estimate of the reverberation time in the two classrooms in unoccupied and occupied conditions.**

Classroom	Condition	T60 average
1	Unoccupied	0.47
	Occupied	0.54
2	Unoccupied	0.48
	Occupied	0.52

In the occupied condition all children and adults wore Grade 5 hearing protection earmuffs.

The Australian and New Zealand standard states reverberation time of 0.4-0.6 seconds as optimal. The RTs measured in both classes indicated satisfactory acoustical room quality for optimal learning.

#### 3.5.4 Signal-to-noise ratio

The background noise level of each classroom was measured in the centre of the room in an occupied condition with students quiet. Three 30-second samples were obtained at 1-minute intervals and averaged. Teachers were then asked to speak at their usual instructional intensity to reflect the normal level of teacher instruction and student noise during a typical teaching interaction. Six 30-second samples were obtained at one-minute intervals and averaged. Results are tabled in Table 2. These measurements provided an estimate of the signal level during instructional teaching. The background noise level was subtracted from the teacher speaking noise level to determine the SNR of the classroom. The SNR of class 1 was estimated as + 21 dB whereas the SNR for class 2 was +17 dB. Details are recorded in Appendix VII.

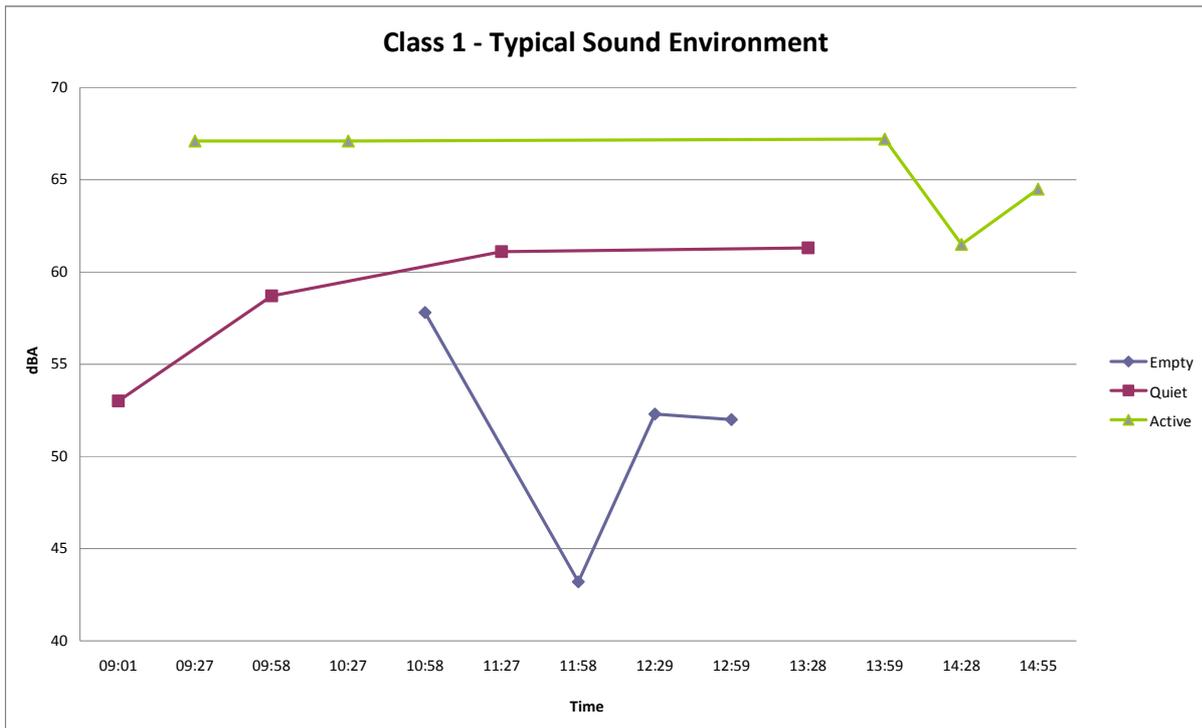
**Table 2: Estimation of SNR in both classes based on SLM measurements of background level noise in an occupied condition subtracted from averaged recordings of the teacher speaking measure.**

Classroom	Average (dBA)	SNR (dB)
1		
Teacher speaking	57.1	
Children in quiet	35.8	21.3
2		
Teacher speaking	58.7	
Children in quiet	41.7	17.0

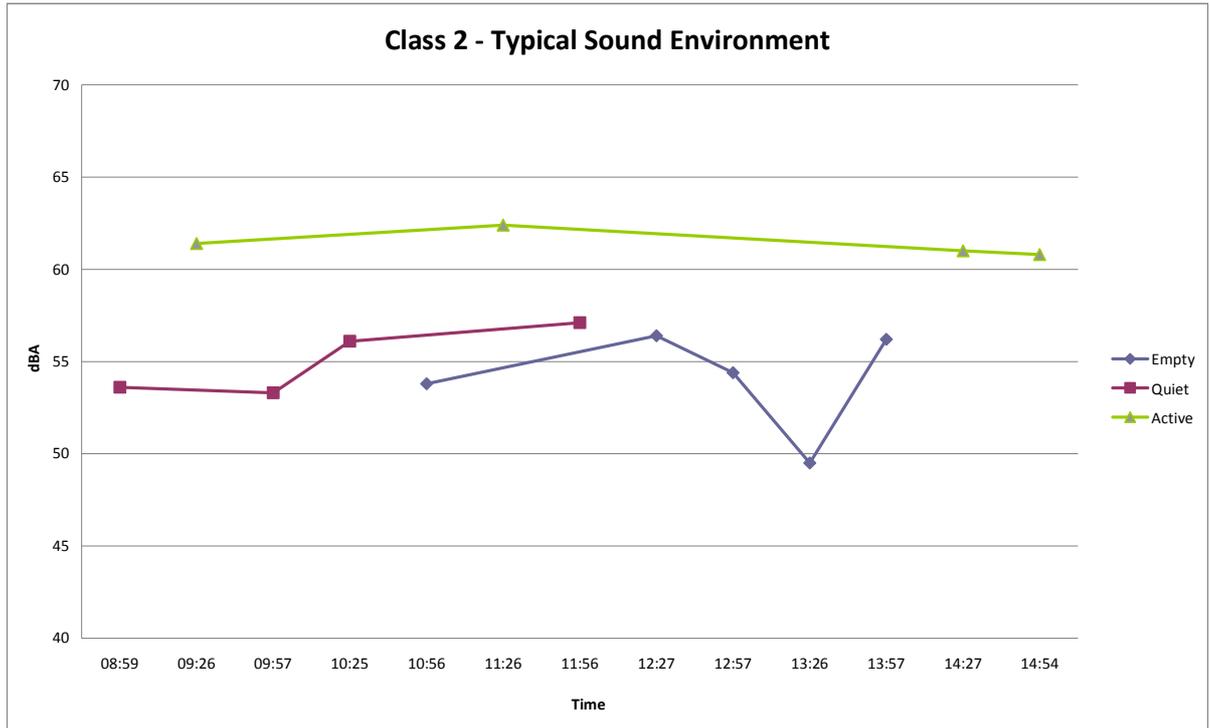
#### 3.5.5 Day long recordings

In both classrooms a ‘typical’ school teaching day was recorded with a SLM. At half hour intervals from 9am to 3pm recordings were taken from the same position in each classroom for a one minute interval. Teachers and children were instructed to ignore the intrusion and to carry on ‘as usual’. Three periods in the day were observed and defined as ‘quiet’ in which children worked quietly in the classroom, ‘active’, when an interactive task occurred or ‘empty’ when the classroom was empty of occupants. The different periods were accordingly grouped.

The background noise levels were first extracted in linear Leq form and equalized to generate data expressed in dB (A). This enabled comparisons with those in the literature. Leq, or the equivalent continuous sound level, is the time-averaged value of the sound exposure level in dB. A-weighted sound levels better approximate human hearing by simulating the sensitivity of an average human ear. Data was then averaged to provide a single, averaged estimate of the overall level of noise within each classroom. Results are illustrated in Figure 3 and Figure 4.



**Figure 3: Leq A-weighted one minute measurements obtained at half-hour intervals over a typical school day in class 1.**



**Figure 4: Leq A-weighted one minute measurements obtained at half-hour intervals over a typical school day in class 2.**

### 3.6 Study design

The study employed a comparative group design to determine the effectiveness of treatment condition, i.e., SFA+PA versus SFA alone, and the subsequent effects of each treatment condition upon PA and word-decoding for children in both classes. This study received ethics approval from the Ethics committee of the University of Canterbury Human Ethics Committee as shown in Appendix I.

### 3.7 Assessment battery

The following assessment battery was selected to gather baseline, mid- (i.e. pre-intervention) and post-intervention assessment data. All administration guidelines were strictly adhered to:

- (a) *Test of Phonological Awareness* (TOPA-2+) (Torgesen & Bryant, 2004). This test measures young children's competency to isolate individual phonemes in spoken words and their knowledge of relationships between letters and phonemes in English. This test can be administered to groups of young children and comprises two subtests: PA and letter sounds. In the PA subtest children are required to identify what word from a choice of three words ends with the same sound as the target word. There are 10 testing items. In the second PA task children are required to identify what word ends in a different sound from a choice of

four words. There are 10 test items. In the letter sounds subtest children spell 18 simple pseudo-words. Words all have one or two syllables varying from two to five phonemes in length. The TOPA-2+ provides norms for children ages five through to eight years. Standardised scores were used for data analysis. All children were assessed with the TOPA-2+ at baseline, mid- and post-assessment measures.

(b) *Burt single-word reading test – New Zealand revision* (Gilmore, Croft, & Reid, 1981). This test is an individually administered test, providing a graduated measure of real word recognition. A test card consists of 110 words printed in decreasing size of type and graded in approximate order of difficulty. Used with other information this test allows a broad estimate of a child's reading achievement and is an indicator of possible wider reading problems. Raw scores were used for data analysis as standard scores are not available for this assessment. All children were assessed with this test at baseline, mid- and post-assessment measures.

(c) *Stahl and Murray tests of phonemic awareness (S&M)* (Stahl & Murray, 1994). Provides a measure of underlying PA. Fourteen tests of five items each represent four basic PA skills; phoneme blending, isolation, segmentation and deletion at four levels of linguistic complexity; onset-rime, vowel-coda, cluster onset and cluster coda. Blending requires the integration of segmented phonemes to identify a whole word. Phoneme isolation requires the discrimination of the first or last sounds of a spoken word. Deletion requires the removal of sounds from the beginning or end of a word to form another word. Segmentation requires isolating and then sounding out the individual sounds in a word. This 70-item measure has a Cronbach's alpha of .96, indicating its high reliability. Raw scores for each subtest representing the four basic PA skills were used for data analysis. These tests were used as probe measures to track and monitor PA progress over the course of the first term. It was also used at the mid- and post-assessments.

(d) *Informal non-word reading task* (Calder, 1992). Non-word reading requires specific grapheme-phoneme decoding and establishes the child's ability to map morpho-phonemic letter-patterns onto underlying phonological representations. This test requires the child to decode 30 non-words. Correctly read words were scored and used for data analysis. This test was used as a probe measure over the course of the first term and also in the mid- and post-assessment battery.

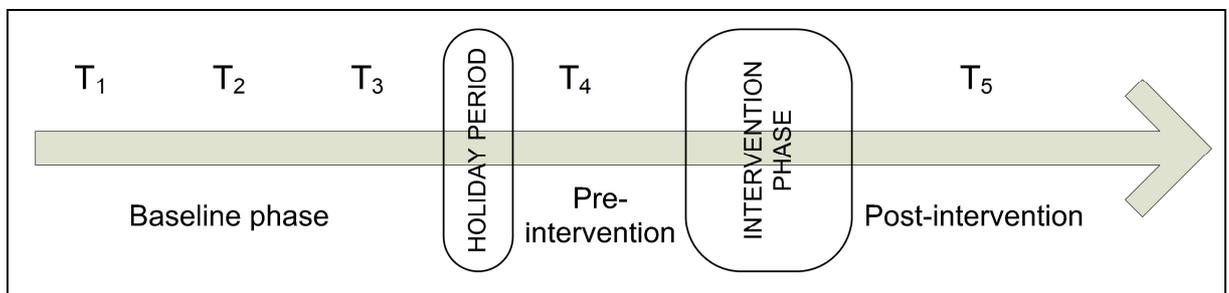
### 3.8 Procedures

#### 3.8.1 Measurements and test environment

Literacy measures were administered by senior speech language therapy students completing their final year of professional training at the University of Canterbury. Each child underwent all probe tests at one sitting although if the child showed fatigue short breaks were given. Probe tests (S&M tests of phonemic awareness and the informal non-word reading task) were digitally recorded to allow verification. All literacy assessments were conducted in the school hall or in a quiet office space.

#### 3.8.2 Assessments

At the initial, mid- and post-assessments all children underwent hearing screening prior to literacy assessments. In the baseline phase, literacy assessments were carried out at the beginning of the first school term. Probe assessments were conducted in the fifth and ninth weeks of that term to monitor the children's PA progress, to gauge the effect of the phonics programme on measures of PA and to identify children who were continually scoring lowest on these measures. Mid-term (i.e. pre-intervention) assessments were conducted following two weeks of school holidays at the beginning of the second term of school and prior to the implementation of the sound-field systems in the classrooms. Post-assessment measures took place at the end of the second term of school. The structure of assessment times and phases are illustrated in Figure 5 where 'T' indicates the assessment time. Given the intensive 'block' model of the intervention, repeated absenteeism was considered influential to outcomes. For this reason levels of student absenteeism were noted for children in both classes over the baseline and intervention phases.



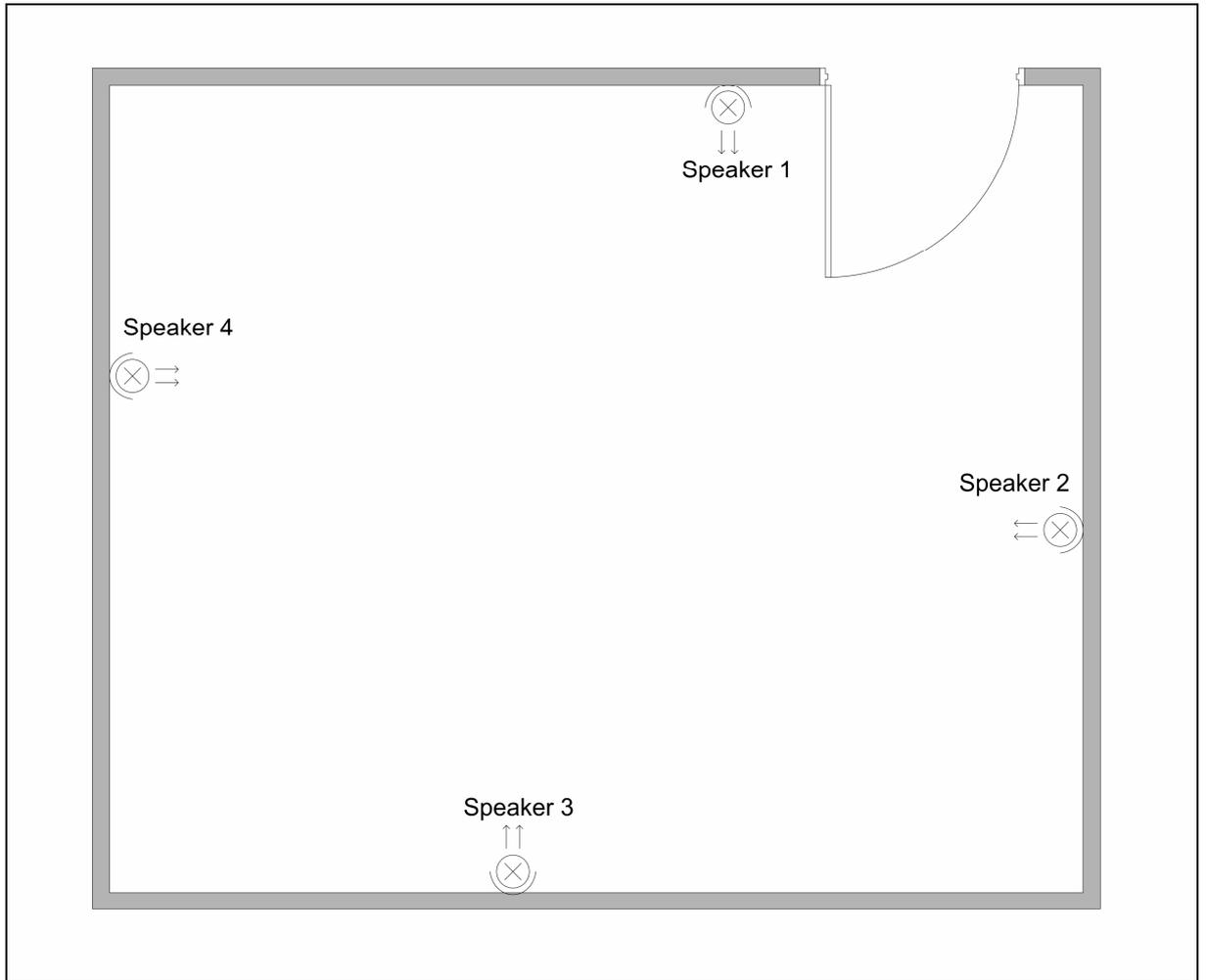
**Figure 5: Illustration of phases and assessment periods over time (T1 = first assessment time, T2 = second assessment time, etc).**

### **3.9 Intervention measures**

#### **3.9.1 Sound-field amplification**

The Phonic Ear FrontRow Pro Digital four-speaker, pendant microphone sound-field amplification system (Phonic Ear A/S., Denmark) was installed in both classrooms. This system maximises the even distribution of sound and increases the SNR. Because both classrooms were similarly designed the location for speaker placement was also similar. Figure 6 illustrates approximate positioning of speakers in both rooms. Care was taken to mis-align speaker placement in order to avoid the generation of standing waves.

Specific professional development training covering the rationale for use of this intervention and explanation of how sound distribution systems work was delivered by a trained audiologist with 14 years of experience with sound-field amplification systems. This training took approximately one and a half hours. Teachers were able to contact this professional directly and at any time regarding use, rationale and management of the equipment. Teachers were requested to use the sound-field equipment in all teaching sessions.



**Figure 6: Approximate speaker placement in both classes.**

### 3.9.2 Phonological awareness intervention

PA intervention was implemented in Class 1 only. The whole-class programme used was part of a pilot study for the development of a teacher-administrated classroom-based PA programme (Gillon & Carroll, 2009). The programme involved daily 20-minute sessions conducted each morning, before the instructional reading programme. Sessions were designed to follow a set structure and were graduated. Weeks one to three targeted lower levels of PA comprising syllable, rhyme, and onset-rime awareness. Final weeks targeted higher levels of PA comprising phoneme level tasks and revision of syllable, rhyme or onset-rime. From week two, four key elements were required in each session; a phoneme level task, a phoneme level task with letter knowledge, phoneme manipulation task with letters, and an activity that used phonological cues in reading. This programme was part of a concurrent study investigating models of how teachers implement teaching techniques (J. L. D. Carroll, 2009). In this study, teachers are encouraged to make their own choices regarding which activities and resources to

use and implement as may be typically seen in consultancy models. No corrective feedback is given.

Therefore, T1 was provided with two in-service instruction periods and programme resources. T1 was encouraged to use the resources and integrate the activities each morning prior to instruction reading, yet was left to decide which elements she felt were most beneficial to students. PA sessions were monitored by the main research on four occasions over the eight-week intervention block. Both teachers were in contact with and supported by the main researcher throughout the study.

## 4 Results

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### 4.1 Statistical analysis

All statistical analyses were carried out using Predictive Analytics Software. One-way repeated measures analyses of variance (RM ANOVAs) were performed to compare group mean performance. Within each ANOVA, Mauchly's Test of Sphericity was used to assess equality of variance and covariation. If a significant result was observed this led to using the Greenhouse-Geisser corrections to the sums of squares in testing within-subjects effects. Equality of error variance in both classes was further assessed using Levene's test (Portney & Watkins, 2000). A significance level of 0.05 was selected and used to evaluate the statistical outcome of the various measures. Pairwise comparisons between groups across times were conducted using paired samples t-tests. At each testing, time differences between the groups were assessed using both t-tests and the non-parametric Mann-Whitney U test. Follow-up analysis of the gains between immediate pre- and post-intervention scores was conducted using analyses of covariance (ANCOVAs).

### 4.2 Assessment probes

The data were first analysed to examine group performance on the experimental PA and informal non-word reading probes. Accordingly, the first phase was the baseline phase (i.e., the first 10 weeks of the school year, Term 1) in which assessments were implemented at three equal points over this period while children received the regular class programme without SFA. The second phase occurred between pre- and post-intervention (i.e., eight weeks in Term 2).

#### 4.2.1 Baseline Phase

Analysis using multiple single-factor RM ANOVAs (assessment times one, two and three) revealed no significant group difference (at  $p < .05$ ) between groups on PA, non-word reading and single-word reading measures.

Paired samples t-test revealed that for the S&M both groups significantly improved their performance from assessment times one to two (class 1:  $t = 4.41$ ,  $df = 17$ ,  $p = .000$ ; class 2:  $t = 3.38$ ,  $df = 19$ ,  $p = .003$ ), but no significant difference between times two to three (class 1:  $t = .955$ ,  $df = 17$ ,  $p = .353$ ; class 2:  $t = .819$ ,  $df = 19$ ,  $p = .423$ ). The informal non-word reading paired samples t-test showed that class 1 improved significantly between times one and three

( $t = 2.48$ ,  $df = 17$ ,  $p = .024$ ) and times two and three ( $t = 2.60$ ,  $df = 17$ ,  $p = .018$ ). No difference was observed between times one and two. For class 2, significant improvements occurred between times one and two ( $t = 3.20$ ,  $df = 19$ ,  $p = .005$ ). No difference was observed between times two and three ( $t = 0.60$ ,  $df = 19$ ,  $p = .953$ ).

Both classes displayed wide-ranging scores resulting in large standard deviations and revealing relative instability. Thus, the equality of error variance in both classes was assessed using Levene's test. Across the three assessments during the baseline phase the variance between the groups was equal. Descriptive data for each group are displayed in Table 3.

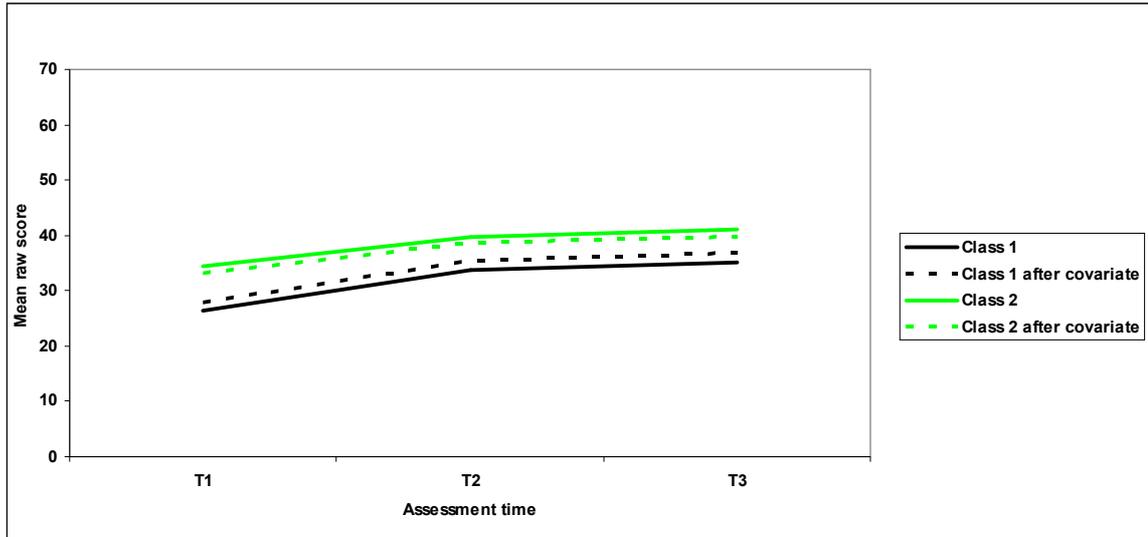
**Table 3: Assessment data for classes 1 and 2 on the Stahl and Murray probes (S&M) and informal non-word reading during the baseline phase.**

Tests	Class	T1	T2	T3
SM	1	M	26.3	M 33.8
		SD	19.1	SD 18.8
	2	M	34.4	M 39.8
		SD	21.6	SD 21.1
Informal non-word reading	1	M	3.7	M 4.2
		SD	5.6	SD 4.9
	2	M	7.1	M 8.8
		SD	7.6	SD 8.4

#### 4.2.2 Covariates for statistical control

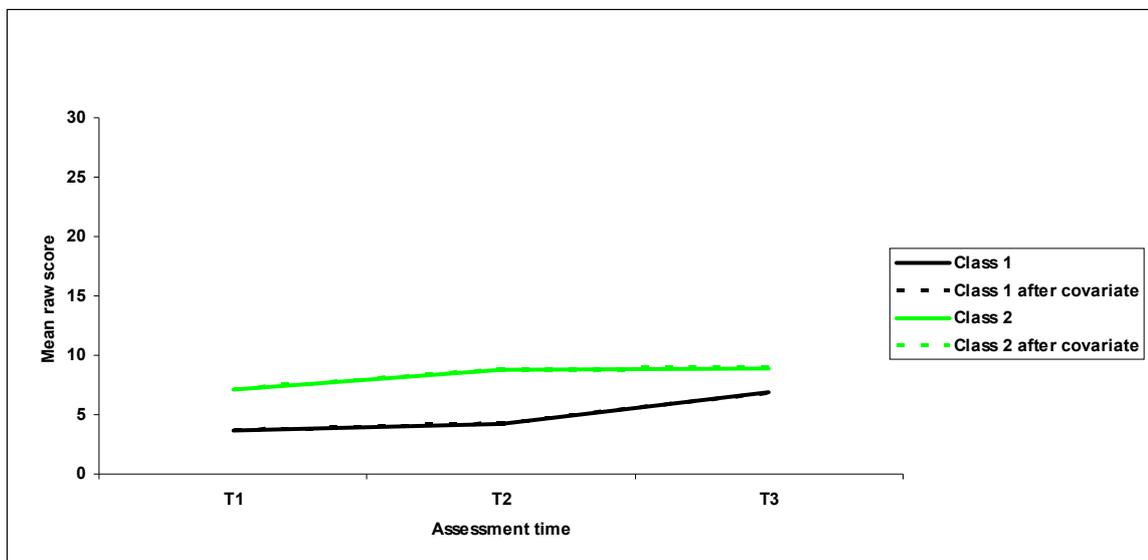
The CELF-P2 was utilised to enable baseline information regarding the degree of each student's individual language development. However, the differences between the groups may have been affected by differences in language scores, which potentially influenced performance outcomes. To control for this, language was included as a covariate as indicated from the core language score from the CELF-P2. The outcome of the final hearing screening was also used as a covariate, however, this was shown to have no effect on scores.

The influence of the language covariate on the S&M means for both classes is shown in Figure 7. Both classes are observed to exhibit low values at the beginning of the school term, show significant improvement between times one and two and begin to level off between times two and three.



**Figure 7: Classroom by time effect on the S&M means with and without language covariate.**

Language had no effect on the non-word reading means over the pre-intervention time period as illustrated in Figure 8.



**Figure 8: Classroom by time effect on non-word reading means with and without language covariate.**

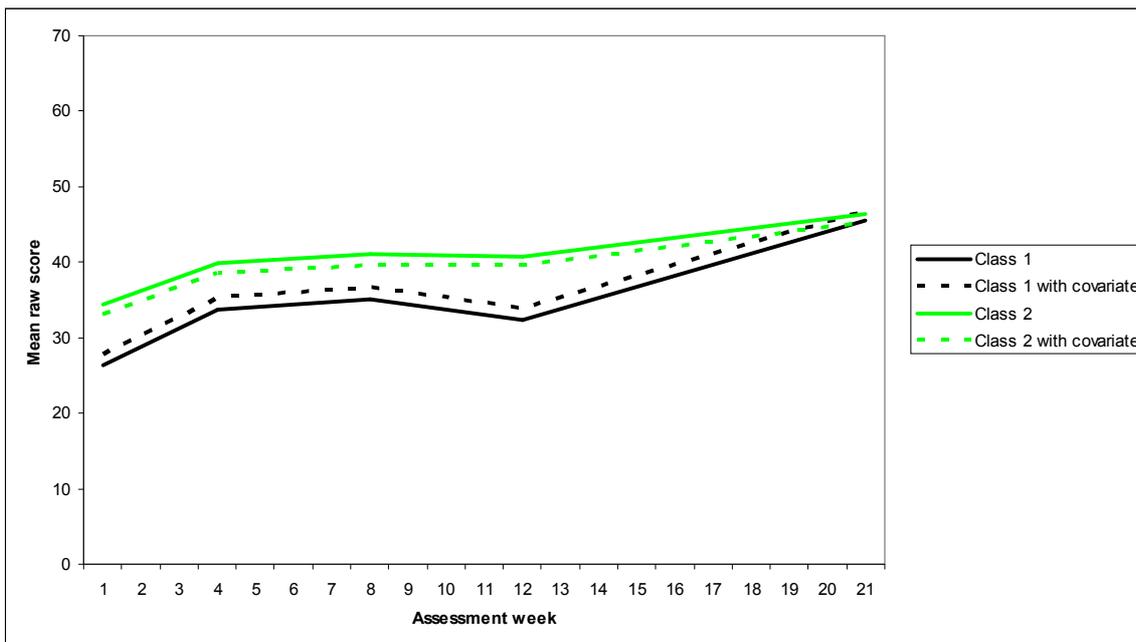
### 4.3 Intervention phase

RM ANOVAs performed on all pre- and post-intervention tests (assessment times four and five) revealed a significant time effect and a non-significant difference between the classes. However, follow-up ANCOVAs were also conducted. These analysed the post-intervention scores (assessment time five) with pre-intervention scores (assessment time four) used as the

covariate. ANCOVAs revealed that gains made between immediate pre- and post-intervention scores were significant for the S&M while non-significant for all other measures. Language development was also considered a covariate as indicated from the core language score of the CELF-P2. The influence of the language development covariate varied depending on the test.

### 4.3.1 Phonological awareness

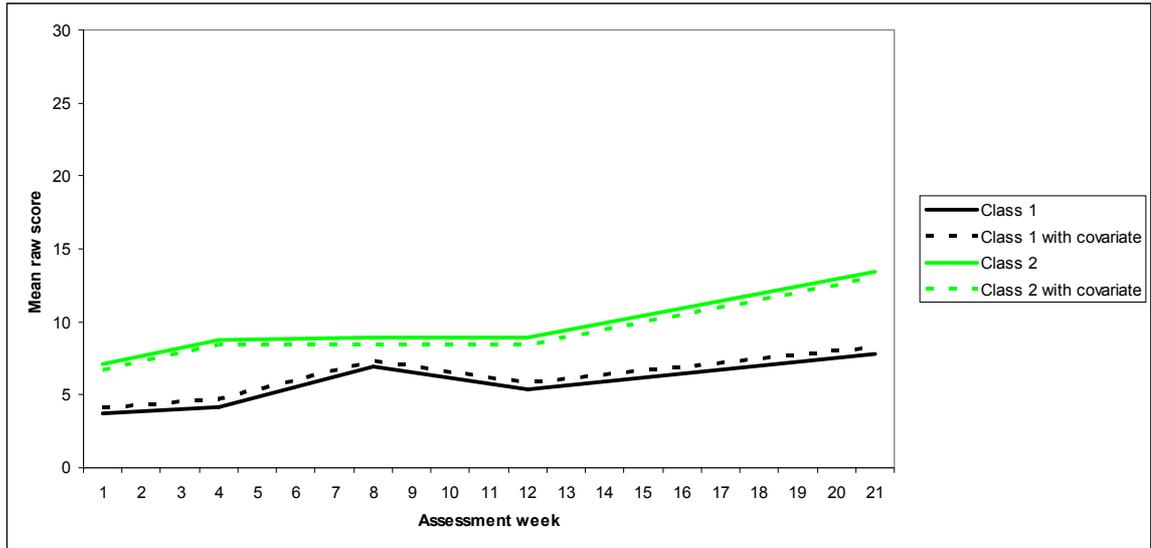
The RM ANOVA for the S&M probes obtained at pre- and post-intervention revealed a significant time effect with no classroom effect. Yet, follow-up analysis using ANCOVA on pre- and post-intervention scores showed a significant classroom effect ( $p = .023$ ,  $F [1, 35] = 5.65$ ) as shown in Figure 9. The means were adjusted for the effect of the language covariate which was a significant factor to the final outcomes for class 1 ( $p < .001$ ) and are shown across the weeks of assessment.



**Figure 9: With language controlled, class 1 mean scores on the S&M, as indicated using the ANCOVA, reached and significantly exceeded the mean scores of class 2.**

### 4.3.2 Informal non-word reading

Both classes revealed a significant time effect on informal non-word reading scores. When language was controlled for, differences between the classes were minimally reduced and mean scores for both classes improved as shown in Figure 10. Class 2 showed improvement given the static nature of their scores pre-intervention.



**Figure 10: Pre- and post-intervention mean scores with and without language covariate influence for both classes following intervention.**

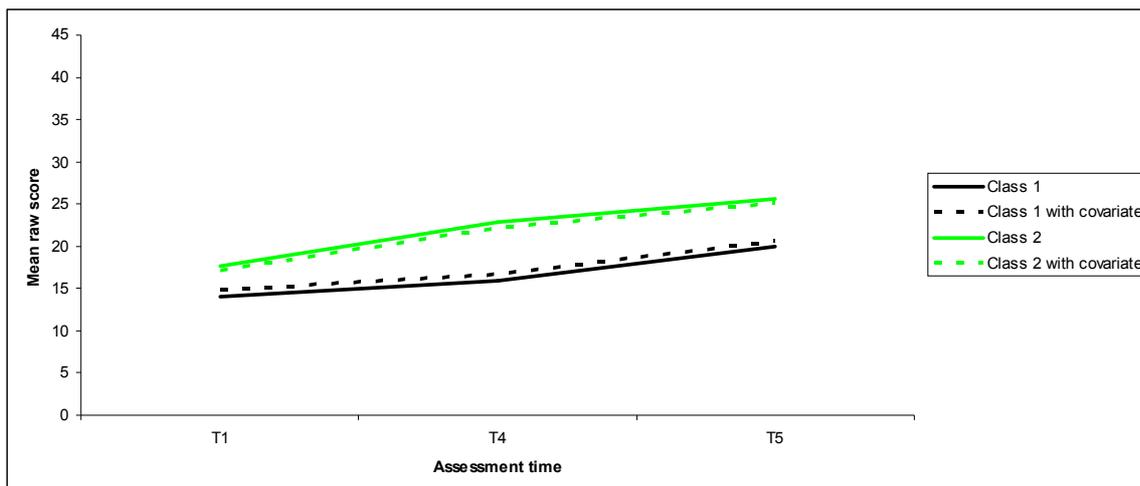
#### 4.3.3 Formal assessment

Data were analysed to compare performance on formal PA and literacy measures at baseline, pre- and post-intervention repeated over three equally-spaced time brackets (assessment times one, four and five). Class means and standard deviations for both classes on the single-word reading and TOPA PA and letter sounds (LS) measures are presented in Table 4.

**Table 4: Assessment data for classes 1 and 2 on the tests of single-word reading, TOPA phonological awareness (PA) and TOPA letter sounds (LS).**

Test	Class	Mean & SD	Baseline	Pre-	Post-
Single-word reading	1	M	14.1	15.9	19.9
		SD	9.6	10.1	8.7
	2	M	17.7	23.1	25.6
		SD	12.3	13.4	14.9
TOPA PA	1	M	6.7	7.1	9.4
		SD	3.1	3.7	3.1
	2	M	7.3	8.1	9.8
		SD	3.2	3.3	3.8
TOPA LS	1	M	6.4	6.9	8.1
		SD	2.0	2.1	2.1
	2	M	7.1	7.5	8.7
		SD	2.1	2.4	2.3

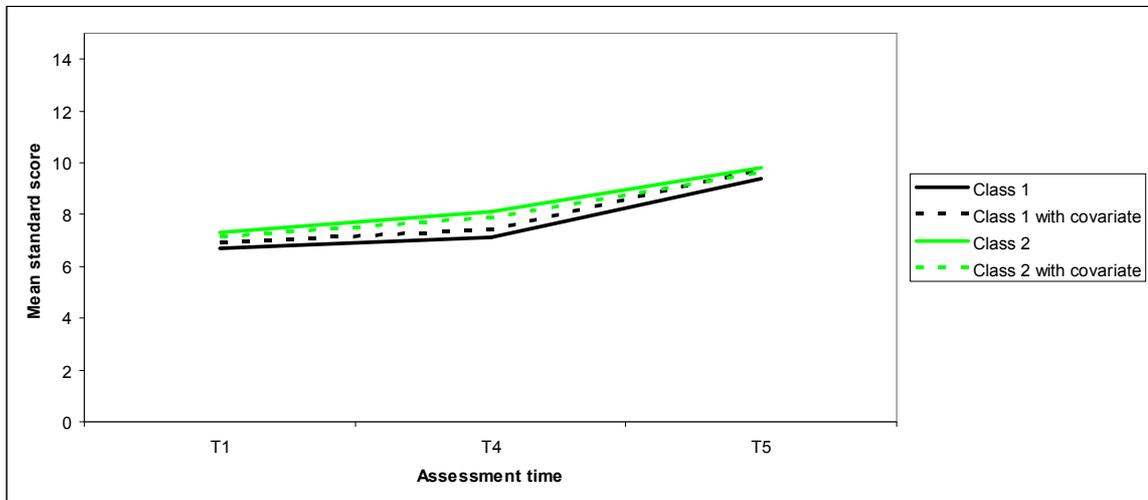
For the single-word reading measures significant improvement occurred across all time measures for both classes ( $p < .001$ ) although classroom was not significant ( $p = .157$ ). The language covariate was significant in all instances ( $p = .001$ ) and its influence slightly reduced the difference in scores between the classes as shown in Figure 11.



**Figure 11: Single-word reading mean raw scores for both classes with and without language covariate.**

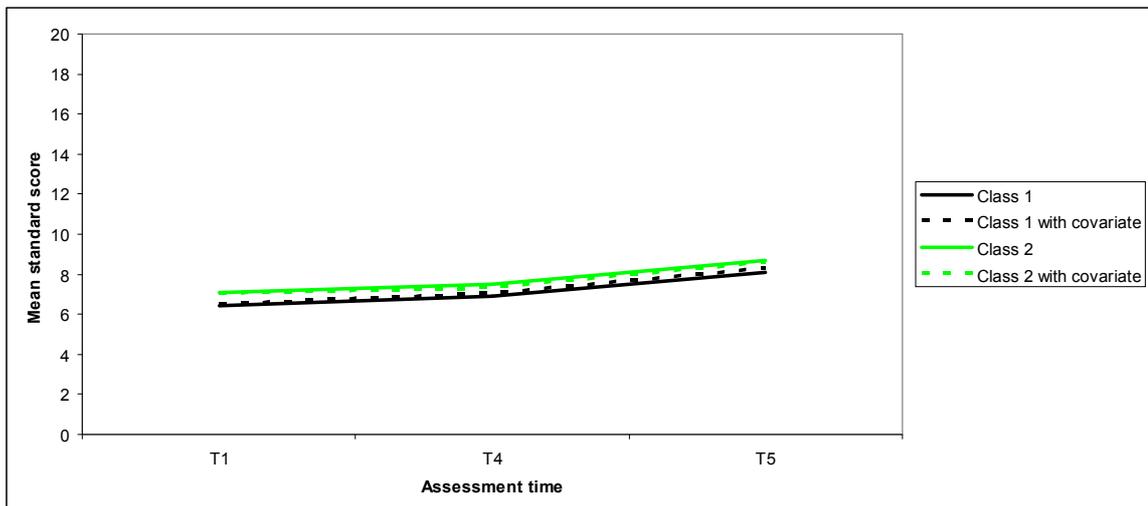
Similar to the single-word reading measures, time was significant at each assessment measure for both classes on the mean standard scores for the TOPA PA ( $p < .001$ ) (used for

participants six years and older). Classroom was not significant ( $p=.532$ ). The language covariate was significant ( $p<.001$ ) and its effect is displayed in Figure 12.



**Figure 12: TOPA PA mean standard score across baseline, pre- and post-intervention time points.**

The TOPA LS mean standard scores followed the same trend as seen in the TOPA PA. Time was significant across each assessment measure ( $p<.001$ ) and classroom was not significant ( $p=.338$ ). The language covariate was a significant factor ( $p<.001$ ) as shown in Figure 13.



**Figure 13: TOPA LS mean standard score across baseline, pre- and post-intervention time points.**

#### 4.4 Analyses of poor readers

The scores of the children who consistently ranked lowest in baseline and pre-intervention measures of PA (S&M, informal non-word reading, TOPA) were also separately visually

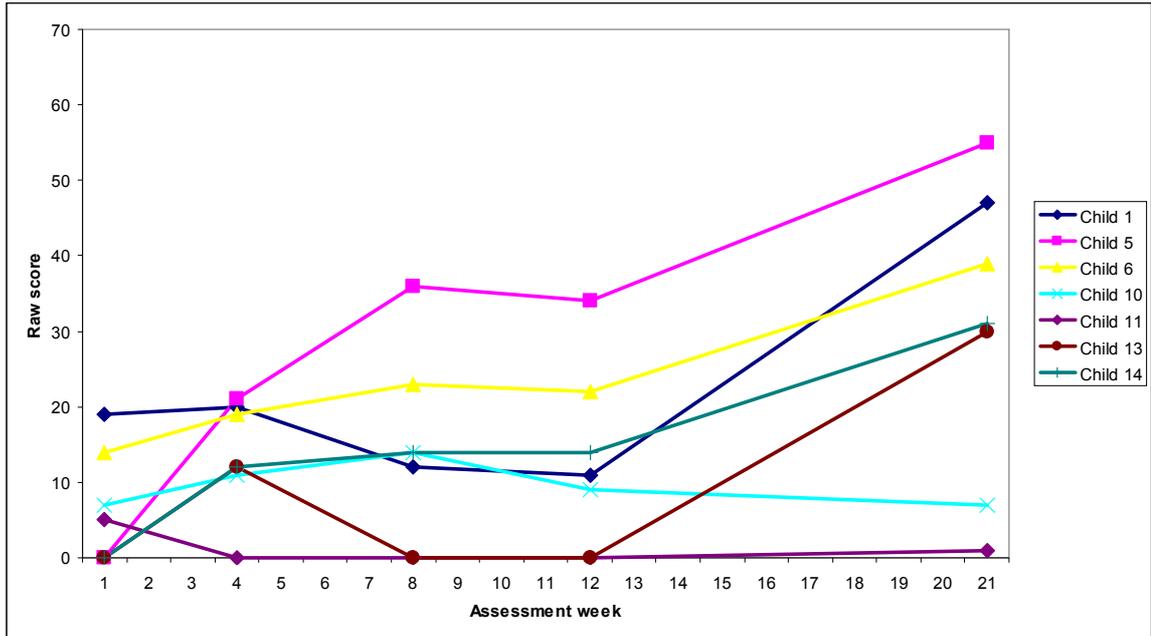
analysed. Due to their consistent low-level scoring which continually fell outside of the average scores of their classmates, these children were identified as 'at-risk' for reading difficulties. Visual analyses were conducted on the S&M, informal non-word and single-word reading measures. TOPA scores reinforced those patterns. While all improvements were non-significant, the trend consistently illustrated that poor readers in class 1 outperformed poor readers in class 2.

The two standard deviation band method was utilised to indicate if variation between the baseline-probe monitoring and post-intervention phases were suggestive of significant improvement following intervention (Portney & Watkins, 2000). This method involves calculating the mean and standard deviation of the baseline-probe monitoring phase. The mean and two standard deviations above and below the mean of that phase are plotted through the pre- and post-intervention phases. If at least two consecutive data points in the intervention phase fall outside the banded area, the change in performance is considered significant (Portney & Watkins, 2000). While only one post-intervention assessment was undertaken prior to another holiday break, this method was considered valid in its ability to indicate whether intervention was moving towards a significant outcome for the children identified as 'at-risk'.

#### **4.4.1 Profile plots for poor readers**

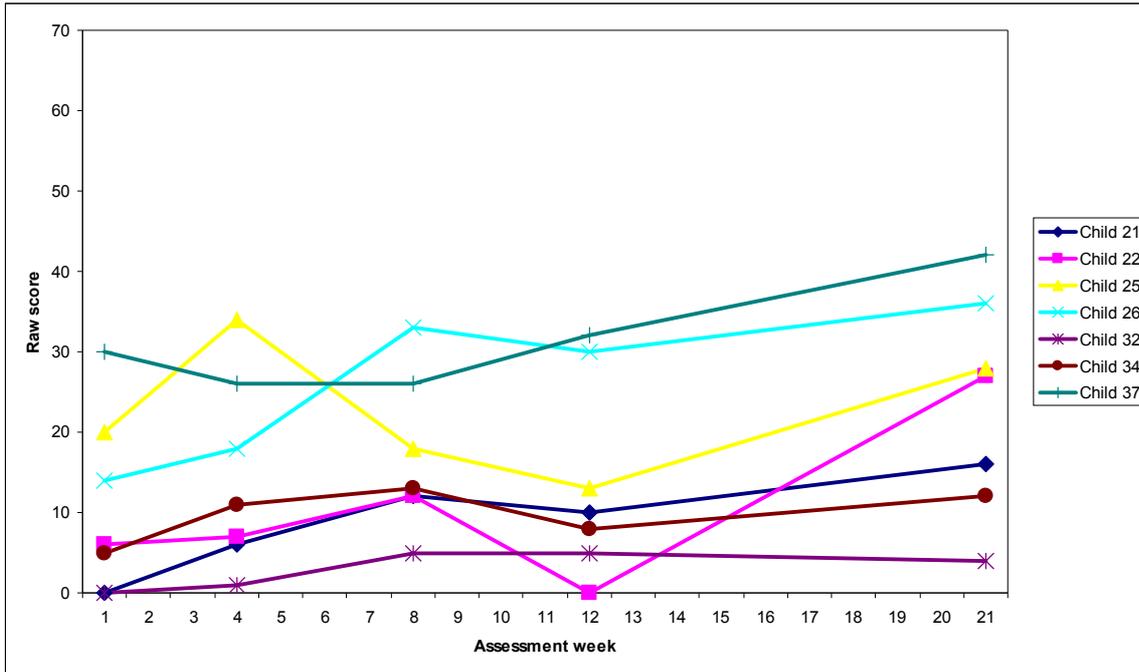
The poor readers in class 1 scored lower than the poor readers in class 2 prior to the pre-intervention assessment. Following intervention all mean scores for the poor readers in class 1 had surpassed the poor readers in class 2.

Across the five assessment periods poor readers in both classes showed varying degrees of improvement on the S&M as illustrated in Figure 14 and Figure 15. Only child 5 in class 1 was observed to be improving over the three assessment periods and intervention period. The scores for children 10 and 11 remained relatively static throughout and even through the intervention period showed no improvement. Child 10 appeared to improve minimally over the three assessment periods in which only routine class instruction was offered. Yet, following the holiday period (between times 3 and 4) appeared to regress over the intervention phase. The scores for children 1, 6, 13, and 14 changed minimally in the pre-intervention phase. However, following intervention, these four children showed greater improvements compared to routine class instruction alone.



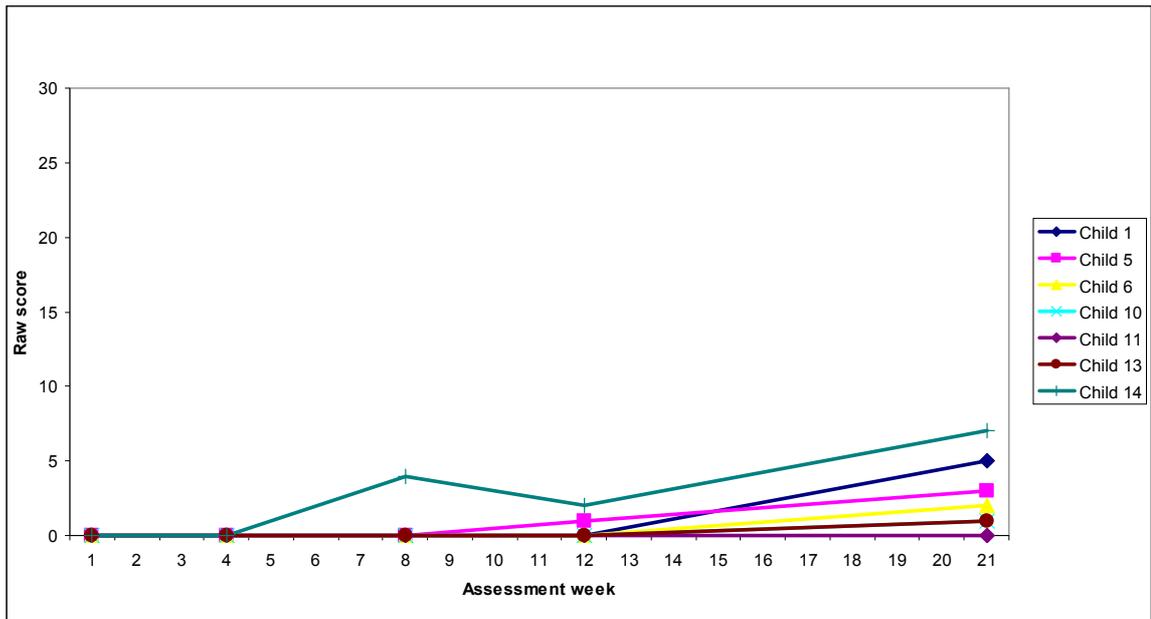
**Figure 14: S&M probe results for poor readers in class 1. Scores indicate varying levels of improvement to no improvement across the three assessment periods and following intervention.**

In class 2, child 26 showed improvement over the pre-intervention phase and only minimal improvement over the intervention phase. Child 37 appeared to plateau during routine class instruction, improved over the holiday period and continued improving with intervention. Child 21 showed slight improvement over the pre-intervention phase, and continued this minimal growth over intervention. Child 22 improved marginally over the pre-intervention phase, regressed following the break, yet recovered over the intervention phase. Child 25 showed particular variability in his learning over the pre-intervention phase, regressed following the holiday, yet showed some recovery following intervention. Children 32 and 34 showed minimal improvement in the pre-intervention phase. Child 32 showed little to no improvement over intervention. Child 34 showed slight growth over intervention.



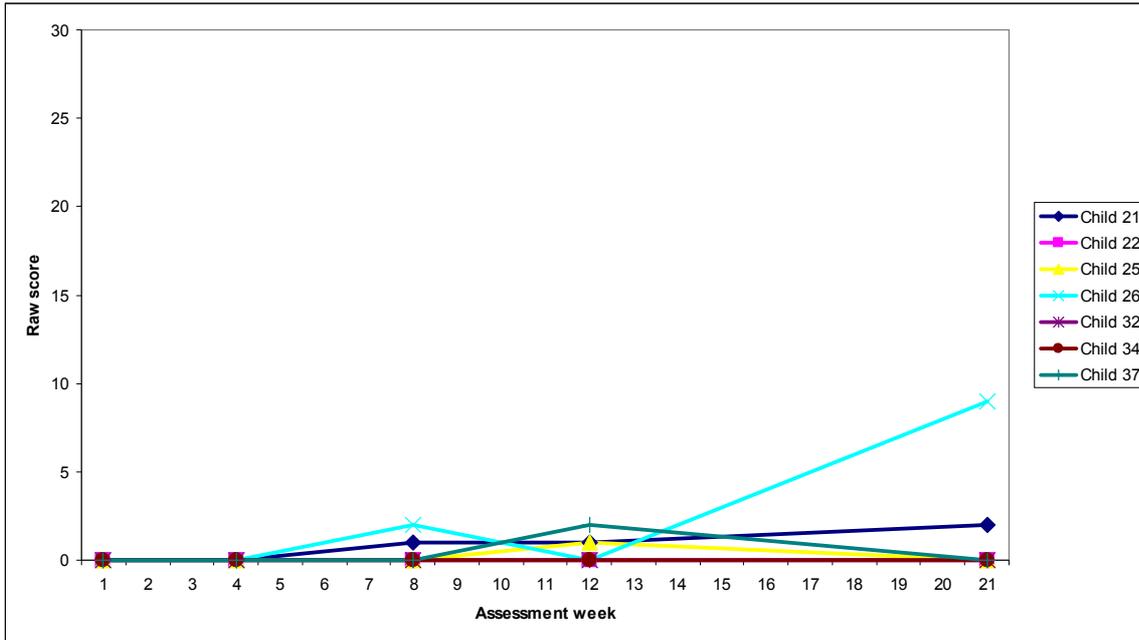
**Figure 15: S&M probe results for poor readers in class 2. Three children showed only minimal improvements following SFA intervention alone.**

For the informal non-word reading probes most of the poor readers in class 1 improved. In class 2 only one of the children appeared to improve. These results are graphed in Figure 16 and Figure 17. In class 1, child 14 showed particular improvement between times two and three and child 5 showed growth following the holiday period. Children 1, 6 and 13 only showed growth over the intervention phase. Children 10 and 11 showed no growth throughout all phases.



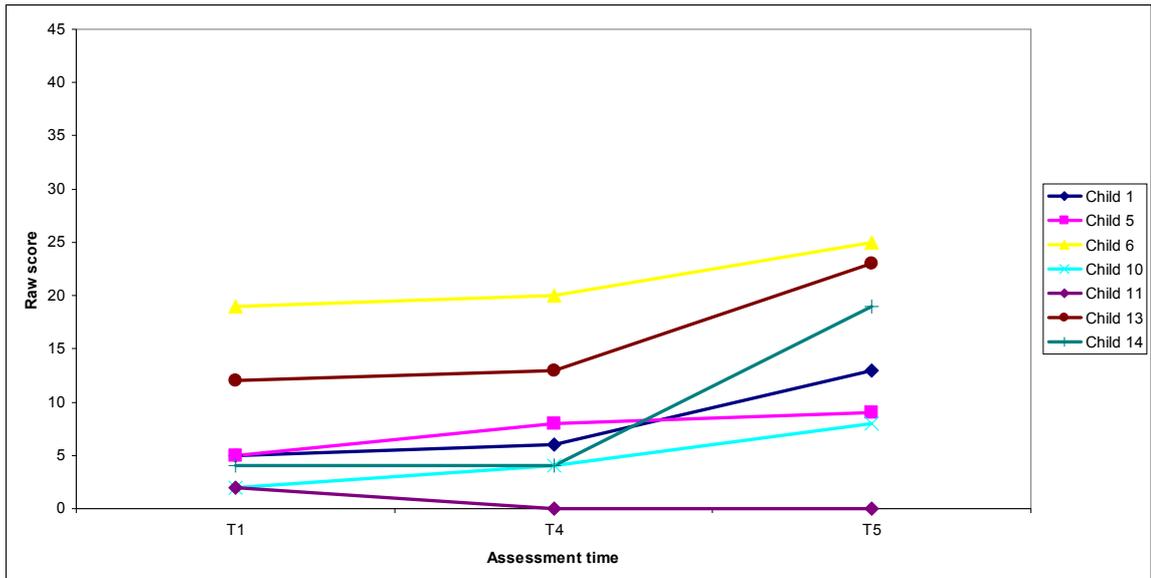
**Figure 16: Non-word reading probe results show the pattern of development between baseline and post-intervention for poor readers in class 1.**

In class 2, child 26 showed slight improvement between times two and three, yet regressed to zero following the holiday and then showed recovery and improvement following intervention. Child 21 showed some improvement between times 2 and 3, maintained this over the holiday period and continued to improve minimally over intervention. Children 25 and 37 showed improvement after the holiday yet regressed following intervention. No improvement can be observed for other children either in pre- or post-intervention.



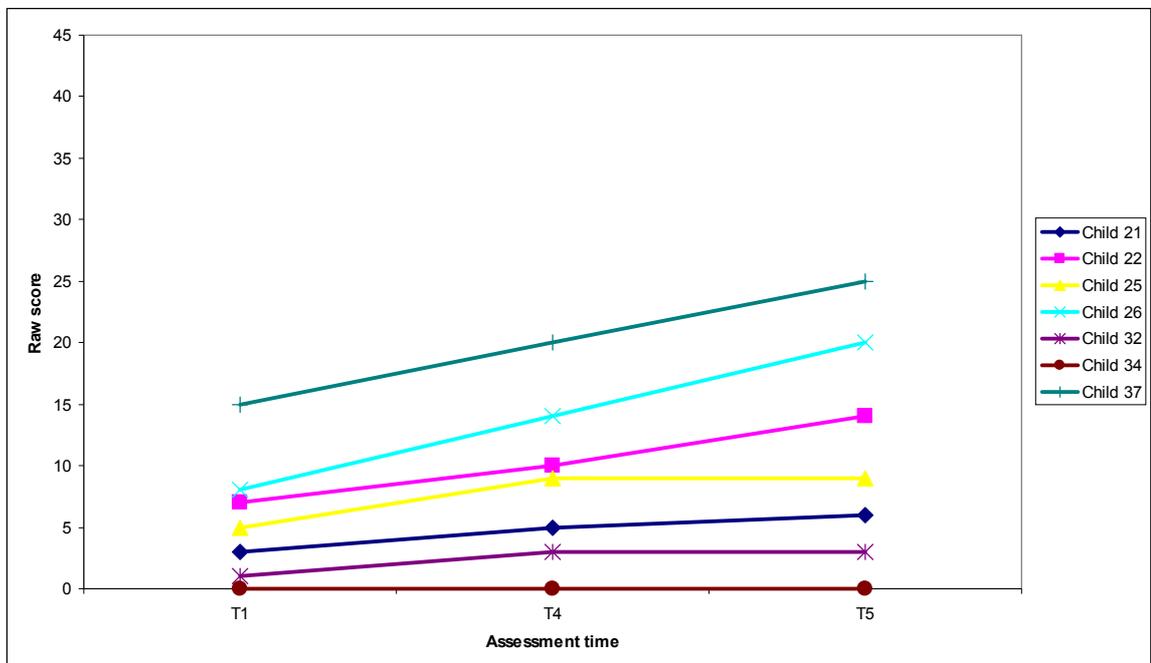
**Figure 17: Non-word reading probe results show the pattern of development between baseline and post-intervention for poor readers in class 2.**

For single-word reading children in class 1 showed greater improvements compared to children in class 2 as shown in Figure 18 and Figure 19. In class 1, across the first two assessment times (initial and pre-intervention) all children were relatively static in their scores or showed slight regressions. Following SFA+PA intervention all children had improved with the exception of child 11. Children 13 and 14 in particular showed improvement following intervention.



**Figure 18: Single-word reading results show the pattern of development between baseline and post-intervention for poor readers in class 1.**

In class 2, children 22, 26 and 37 showed steady improvement between times as shown in Figure 19. The other four children's scores remained relatively static with minimal to no improvement following SFA intervention.



**Figure 19: Single-word reading results show the pattern of development between baseline and post-intervention for poor readers in class 2.**

#### **4.4.2 Two standard deviation band method for poor readers**

The poor readers consistently scored the lowest in each class. Because of this, the lower boundary of the two standard deviation band typically fell into negative figures. These lower boundaries were set to zero. As only one post-intervention assessment was completed, post-scores do not indicate significant differences but suggest that intervention for some children was facilitating improvement. Table 5 shows the pre-intervention mean scores for the S&M which was monitored over the five assessment periods, estimated range of two standard deviation band method and post-scores for children in both classes. The scores of children 1, 6, 13, 14 in class 1 and children 22 and 37 in class 2 exhibited accelerated progression beyond the expected trajectory of the two standard deviation band method.

**Table 5: Pre-intervention Stahl & Murray probes (S&M) mean for times one to four (Pre-M) and standard deviations (SD), Est. 2SD = Estimated range of two standard deviation band method (post-intervention scores must be above the estimated range to be considered significant). Note: The asterisked post-intervention scores were above the estimated two standard deviation band suggesting that these children improved as a result of the intervention.**

S&M Probes				
Participant	Class	Pre-M (SD)	Est. 2SD	Post
Child 1	1	15.5 (4.6)	6.1-24.8	47*
Child 5		22.7 (16.5)	0-55.8	22.7
Child 6		19.5 (4.0)	11.4-27.6	39*
Child 10		10.2 (2.9)	4.3-16.2	7
Child 11		1.2 (2.5)	0-6.2	1
Child 13		3 (6.0)	0-15.0	30*
Child 14		10 (6.7)	0-23.4	31*
Child 21	2	7 (5.3)	0-17.6	16
Child 22		6.2 (4.9)	0-16.0	27*
Child 25		21.2 (8.9)	3.2-39.2	28
Child 26		23.7 (9.1)	5.4-42.1	36
Child 32		2.7 (2.6)	0-8.0	4
Child 34		9.2 (3.5)	2.2-16.2	12
Child 37		28.5 (3.0)	22.5-34.5	42*

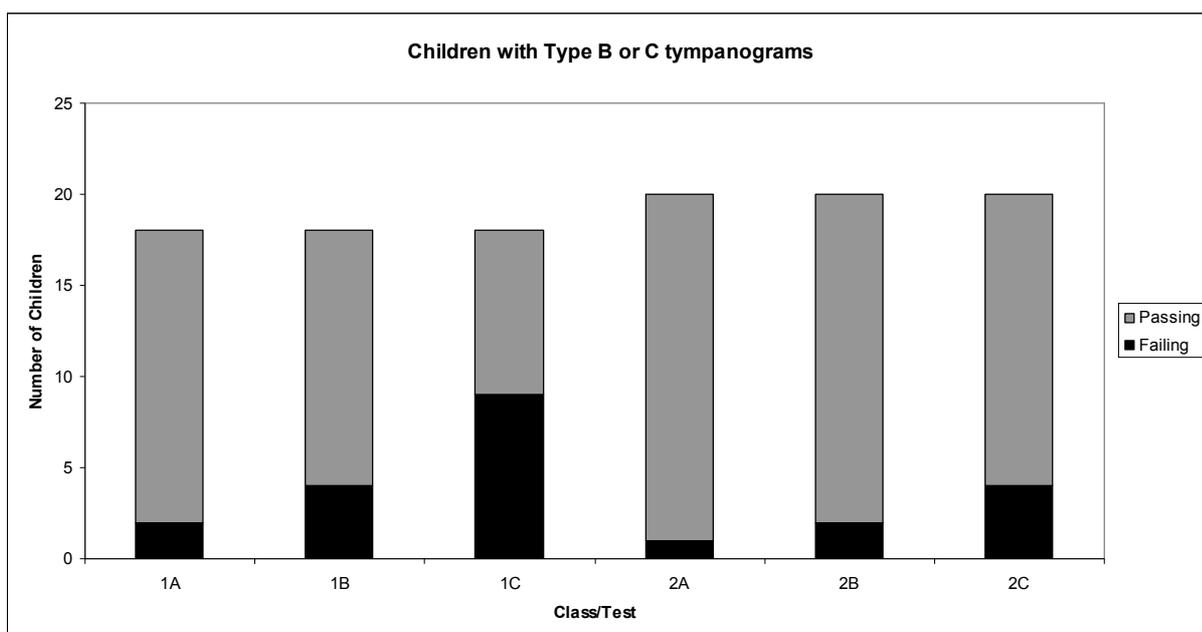
This method could not be used for the non-word reading probes, also monitored over the five assessment periods, as for most of these children there was little variability with scores of zero on all occasions. However some of the children improved following intervention. In class 1, child 1 scored a final raw score of five following four consecutive zero scores. Child 14 made the most improvement. In the first two assessment periods this child scored zero. At times three and four he scored four and two respectively. At post-intervention testing he scored a final raw score of seven. In class 2, only child 26 improved with zero scores at times one, two and four and a score of two at time three. Her final raw score was nine following SFA intervention.

#### 4.5 Student absenteeism

Student absenteeism was monitored through the school administration system and calculated for individual children over the course of the first two school terms. The average number of days absent during the baseline phase or Term 1 in class 1 was 2.1 days (SD= 1.7) and in class 2 was 2.4 days (SD= 2.5). The average number of days absent during the intervention phase or Term 2 in class 1 was 3.7 days (SD= 3.2) and in class 2 was 4.8 days (SD = 4.3). Notably, over 50% of children in each of the poor reader groups were also observed to be absent more than the average. In the case of poor readers in class 1, absence for some children was double that of the average absence value for the class. For the poor readers in class 2, absences for some children were triple the average absence value for the class.

#### 4.6 Indicators of mild, fluctuating hearing loss

Type B and C tympanograms were considered as indicators of mild and fluctuating hearing loss. The number of children in each class that presented with Type B and C tympanograms is plotted versus the number of children with normal tympanograms in Figure 20. It was occasionally observed that pure tone screening within the study criteria could be obtained (i.e. hearing sensitivity was classified as normal if thresholds of 20 dB HL were obtained across frequencies 250 Hz to 8000 Hz). These cases were therefore not included as indicators of mild and fluctuating hearing loss.



**Figure 20: Number of children with type B and C tympanograms indicating mild, fluctuating hearing loss.**

#### **4.7 Teacher observations of improved listening**

A teacher questionnaire given at the end of the intervention period specifically requested teachers to comment on (1) frequency of use, (2) effects on student behaviour, (3) effects on teacher behaviour, (3) students' comprehension of teacher instructions, (4) general improvement in academic areas, and (5) effective teaching practices (see Appendix V). Both teachers completed this questionnaire. Regarding frequency of use both teachers used the equipment "all day, everyday". Both teachers commented that the SFA systems had a limited effect on perceived noise levels within the class but that children were much quicker to respond to commands. This difference was particularly obvious when the SFA was not used after using it consistently.

Both teachers experienced positive change in on-task behaviours of children with the use of SFA. T2 observed that SFA had a beneficial effect on students working below expected norms, while T1 observed that children of middle ability made a significant jump in progress and that all children were recording sounds in writing more clearly. In terms of effects on teacher behaviour T2 noticed the SFA greatly reduced vocal strain, he experienced more energy and less tiredness and that the SFA seemed to enable a lower stress, calmer classroom environment. T1 commented that her health and energy levels had been compromised by illness which had lead to episodes of hospitalisation over the intervention period.

Both teachers commented that comprehension of teacher instructions had improved and that students' abilities to follow instructions had changed positively. T1 further commented that she was able to position herself anywhere in the classroom knowing all children would hear her instructions clearly. Both teachers regarded the SFA systems as having contributed beneficially to all academic areas. T1 noted that she had observed some children were reading more fluently, using more reading strategies and self-correcting. This had generalised further to their written work, in which more children were using more correct sounds in their words. Both teachers felt their classroom teaching practices had benefited from the consistent use of the SFA systems.

#### **4.8 Reliability**

All PA tests were digitally audio-recorded to allow 20% of the audio-recorded tests to be re-scored by the main researcher. Pearson's correlation coefficients were used to compare scores reported by the assessors. Additionally, an independent assessor who observed four video-recorded PA treatment sessions validated each session for observations of teacher application

and facilitation of the programme. The inter-scoring reliability across all tests were strong with Pearson's correlation coefficients of at least .848 ( $p < 0.01$ ). The one exception was the scoring of the S&M on the third assessment period in term one which had a correlation coefficient of 0.543.

## 5 Discussion

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This study examined the effects of an integrated sound-field amplification plus phonological awareness programme (SFA+PA) versus SFA alone upon the PA and word-decoding skills in two groups of young school children. In the first classroom (class 1), a combined intervention of an enhanced listening environment and a teacher-administrated classroom-based PA intervention programme which specifically focused on improving children's awareness of sounds in words was implemented. In the second classroom (class 2), the audibility of the signal (i.e. the teacher's voice) was enhanced thus improving the standard listening environment in a classroom receiving regular reading instruction. Children's hearing levels, PA, letter knowledge and decoding skills were monitored at regular intervals prior to the intervention period and following completion of the intervention programme. The intervention was administered over one eight-week block. Comparisons on measures of literacy pre- and post-intervention were made between the two groups.

The first hypothesis tested was that the PA ability of the children in the SFA+PA condition would surpass the outcomes of the group with SFA only. This hypothesis was partially supported by the data. A significant classroom effect was observed on phoneme awareness scores only. Studies have found that SFA alone has a significant beneficial influence on PA (Allcock, 1997; Flexer et al., 2002; Heeney, 2007). Reports of PA intervention alone have also shown it to make a statistically significant contribution to PA skills and reading acquisition (Bus & van Ijzendoorn, 1999; Ehri et al., 2001; Gillon, 2002; Torgesen, 2000). For the children in this study, providing combined SFA+PA intervention demonstrated some beneficial effects. From both audiological and literacy perspectives, the ability to make fine-grained auditory discrimination or detect subtle acoustic features is well recognised as a developing fundamental academic competency, and crucial for academic success (Chermak & Musiek, 1997; Dobie & Berlin, 1979; Elliott, Hammer, & Scholl, 1989; Gilbertson & Bramlett, 1998). It is from this starting point that further opportunities to develop wider reading and language skills are made.

PA is an auditory skill in which the sounds of spoken language are perceived and interpreted, thus giving speech meaning. Research suggests that most reading problems are connected with core deficits in phonological processing (Adams, 1990; Snow et al., 1998; Torgesen et al., 1994), therefore, the combination of both utilising a system which enhances the classroom acoustic environment and a programme designed to facilitate PA skill should actively boost

PA development. The phoneme awareness scores of this study demonstrated this conclusion to be valid. Additionally, the questionnaire completed by both class teachers suggested that the children in class 1 were benefiting from the SFA+PA combined intervention. T1 specifically noted that following intervention, aside from other observed benefits, children were recording sounds more accurately in written work. Although SFA was not specifically examined, Gillon's previous study (2005) provided focused PA intervention with enhanced listening conditions and reported positive findings. A combined SFA+PA approach was successfully demonstrated for children aged three and four-years-old with moderate or severe speech impairment. Phoneme awareness development was achieved concurrently with improvement in speech intelligibility and letter knowledge while utilising SFA. SFA was used for all intervention sessions therefore comparisons of results with and without SFA were not possible.

What must be considered in the present study is why a significant effect was only seen on the phoneme awareness probes and not for the other measure of PA, that is, the TOPA PA task. Firstly, the TOPA-2+ is a norm-referenced measure of PA and letter-sound knowledge with demonstrated reliability in yielding valid results for children aged five through to eight years. While the TOPA can be administered any time during the year, it is reportedly most sensitive to individual differences during the second-half of the year (Torgeson & Bryant, 2004). This suggests that progress on TOPA sub-tests require longer periods of intervention or training before significant differences can be noted. In the present study, all testing took place in the first-half of the year after a brief intervention period. In contrast, the phoneme awareness probes are designed to determine whether children have reached a defined performance level, and facilitate a more comprehensive assessment of specific types of PA tasks. These probes have high reliability and validity (Stahl & Murray, 1994), and are able to gauge subtle indications of progress.

Secondly, the testing tasks were different, primarily in that the TOPA PA test required the language ability to understand the distinction between 'same' and 'different'. While each sub-test begins with two practice trials, this task was not easy for many of the children in this study who appeared to struggle with comprehending that distinction in order to make accurate selection between pictures. The phoneme awareness probes, on the other hand, required children to understand 'first' and 'last'. Children in this study found this much easier and had little trouble in performing this task. Furthermore, several practice trials enabled the examiner to train the child to identify the first or last sound prior to the test condition.

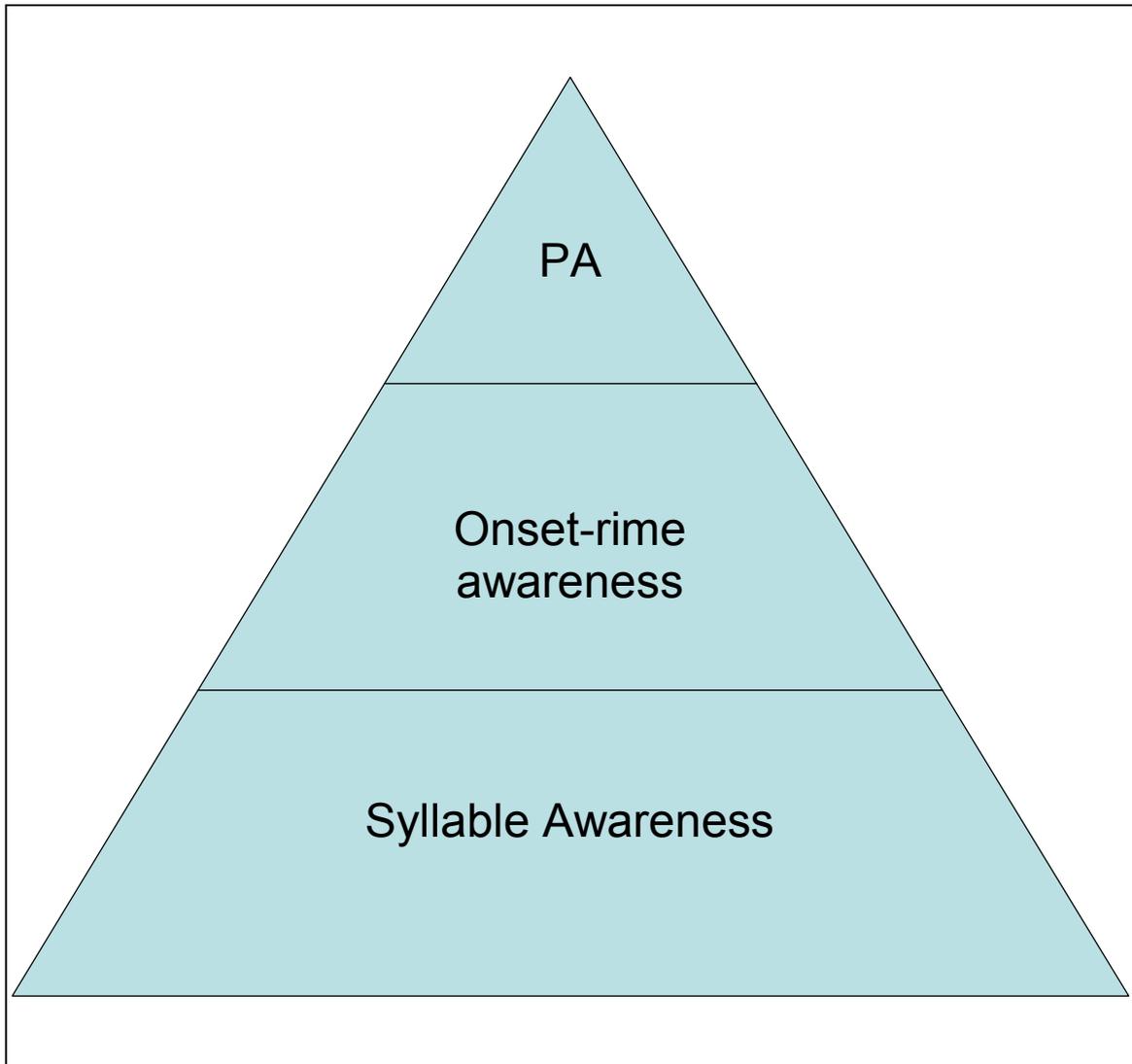
The third difference between the tests was that the phoneme awareness probes were individually assessed while the TOPA was group administered. Behaviour management of small groups was especially challenging for the senior speech language therapy students involved. Off-task behaviour and distraction were drawbacks in administering this test. For the children in this study the one-to-one assessments appeared to facilitate more on-task behaviour and concentrated effort compared with the group assessment. Therefore, the non-significant difference observed in the class means for the TOPA PA primarily reflected the difference between the tests in that the phoneme awareness probes facilitate the measurement of finer changes compared to the TOPA PA, and to a lesser extent, the differences in task demand and mode of administration.

The second hypothesis tested was that the word-decoding ability of the children receiving SFA+PA would surpass the outcomes of the group with SFA only. This hypothesis was not supported by the data. This study employed a brief eight-week intervention block in which SFA was consistently used throughout the school day by both class teachers over that period. Earlier research has employed longer periods of intervention in which one to three years of SFA exposure has resulted in significant change to measures of PA and reading (Flexer et al., 2002; Heeney, 2007; Ray et al., 1984; Sarff, 1981). The literature also demonstrates that by stimulating the progression of PA through intensive, focused intervention significant changes in children's literacy outcomes are evident (Denne et al., 2005; Gillon, 2002; Gillon & Dodd, 1997; Schneider et al., 1999). That is, children who are better at detecting phonemes learn to decode words more easily even after variability in reading skills due to intelligence, receptive vocabulary, memory skills and social class are accounted for (Bus & van Ijzendoorn, 1999). Yet, data from this study yielded non-significant results for both decoding and real word reading measures for the children in class 1 receiving both SFA+PA. Several potential variables may have influenced outcomes. These variables are discussed in the following section.

Ehri and colleagues (2001) have reported that PA instruction is more effective when children are taught in small groups than individually. However, more recent research suggests classroom instruction can be effective when teachers are provided with feedback following four professional observations a term, four training sessions a term and five half-day plenary sessions (Shapiro & Solity, 2008). The quality and frequency of intervention teaching in the Shapiro and Solity study was carefully recorded thus ensuring a high degree of treatment fidelity. The present study used a pilot teacher-administrated classroom-based PA programme

(Gillon & Carroll, 2009), specifically designed to emulate the typical model of professional development in New Zealand (Timperley, Wilson, Barrar, & Fung, 2007). This model provides teachers with professional learning opportunities, the ability to interpret and utilise those understandings and skills, subsequently resulting in either a change in practice or no change in practice. Therefore, in the present study, the model allowed the teacher to decide the manner in which the programme was directed and which skills were facilitated. That is, T1 underwent progressive training in the PA programme (T1 participated in two training occasions over the intervention period), use of resources was demonstrated, and examples of teaching method were given. Assistance for any aspect of the programme was readily available by telephone or email. Subsequently, following each training session T1 was left to administer the programme as she chose. This level of in-service teacher education and support is typical for teachers, and, is an acknowledged concern for the Ministry of Education (Sankar, 2009) as it may not meet teacher needs and student outcomes may be affected. The efficacy of delivering programmes that do not closely adhere to intervention guidelines may subsequently offer less than optimal results.

In this study, T1 was provided with training and support, yet did not receive any feedback for her decisions or programme focus as commonly occurs with typical professional teacher development models. T1 opted to use classroom resources (not the resources designed for the PA programme), and to concentrate on syllable and rhyme awareness. These two skills are at the lowest level of PA (Stahl & Murray, 1994; Treiman & Zukowsky, 1991), were the earliest introduced in the programme and received the least amount of focus. PA sessions in class 1 were observed and video-recorded for treatment fidelity on four occasions over the intervention period. T1 chose to implement syllable and rhyme activities to which the children responded well and engaged in enthusiastically. The programme was administered at its most basic level, i.e. at the level of the rhyme and syllable for the entire intervention block. The levels of PA are illustrated in Figure 21.



**Figure 21: Phonological awareness (PA) is a multi-level skill of breaking down words into smaller units (Stahl & Murray, 1994; Treiman & Zukowsky, 1991).**

Research suggests that PA skills follow a developmental sequence in which an awareness of larger units in words (i.e. syllable and onset-rime) develops before an awareness of smaller word units (i.e. phonemes) (Stanovich, Cunningham, & Cramer, 1984; Treiman & Zukowsky, 1991). Yet, reading achievement is most strongly indicated by performance on phoneme level tasks (Catts et al., 2001; Catts & Kamhi, 2005; T. P. Hogan et al., 2005; Lundberg, Olofsson, & Wall, 1980). By definition, ‘focused’ PA intervention denotes explicit attention to phoneme level skills (Gillon, 2004), and has been highlighted in studies that have failed to observe the benefits of integrating specific PA activities into treatment. Nancollis, Lawrie and Dodd (2005) revealed that intervention directed at developing syllable and rhyme awareness in preschool children from deprived social backgrounds made little impact in measures of reading age or spelling two years later. The authors concluded that while focus on syllable and

rhyme awareness was developmentally appropriate, the results of the programme were likely to have been more effective if content was implemented at the phoneme level. The classroom-based PA programme employed for this study recognised that PA follows a developmental progression beginning with the lowest level, that is, larger unit (syllable and rhyme) recognition and rehearsal. However, this component was gradually superseded by smaller unit application to focus at phoneme level skills.

Successful performance on phoneme level tasks has been reported to appear around age five among children from middle-class families, but may take longer to emerge in children from families with lower incomes (Longian et al., 1998). The children in this study were from a low socio-economic area. These results evidenced features commonly associated with this group; fluctuating hearing loss due to OM, language impairment, low levels of PA ability, poor word decoding and high levels of absenteeism. The reported levels of absenteeism for children in both classes revealed that those children who needed intervention the most (i.e. the poor readers) were those children most often likely to be absent. In addition, it was most often these children that were absent for the longest periods of time.

Finally, T1 was unwell for the duration of the intervention and was hospitalised for a week during that time. She commented that her energy levels were generally low over the intervention period. Her absence consequently reduced the PA intervention period from eight weeks to seven weeks. While research has shown that shorter, intensive periods of PA can effect change for children (Ehri et al., 2001), the syllable and rhyme awareness focus of training was unlikely to be specific enough to manifest the significant results hypothesised. Therefore, the failure of the children to demonstrate significant gains in all assessment measures post-intervention were influenced by:

- (a) the use of the typical professional development model currently employed in New Zealand,
- (b) the focus on syllable and rhyme awareness,
- (c) variables connected to socio-economic background,
- (d) the illness and fatigue of T1.

However, the results of this study demonstrated a significant difference between the classes in one measure of phoneme awareness even though training was conducted at the lowest level of

PA. This outcome suggests that implementing combined SFA+PA intervention for poor readers can effect positive change. The questionnaire completed by both class teachers endorsed the subjective observations of teaching professionals in other reports in which teachers found that SFA led to an improved classroom environment, increased student attention, easier classroom management, less student distraction and improved comprehension of instructions (Eriks-Brophy & Ayukawa, 2000; Heeney, 2007; McCarty & Ure, 2003; McLaren & Humphries, 2008; Mendel, Roberts, & Walton, 2003; Rosenberg et al., 1999). Specifically, the teachers in the present study observed that:

- (1) on-task behaviour improved particularly for children working below expected norms and of middle ability,
- (2) that comprehension of teacher instructions and children's ability to follow instructions thereby responding more rapidly had changed positively and,
- (3) that SFA had contributed beneficially to all academic areas.

Notably, T1 reported that following intervention children were reading more fluently, using more strategies to read, self-correcting during reading and that benefit had further generalised to written work with more children recording sounds more accurately. T1 accounted for these observations due to the consistent use of SFA, which is in accord with Heeney's findings wherein children significantly improved in reading measures following one school year of SFA exposure (2007). Although T1 did not correlate any effect with the teacher-administered PA programme, the absence of any such comments from T2 suggests T1 was observing the effects of the integrated SFA+PA intervention approach.

Furthermore, visual comparisons between the scores of the poor readers in both classes revealed that for the majority of poor readers in class 1, scores improved following intervention. The two children who did not show any improvement in this group were children 10 and 11. Child 10 exhibited severe language impairment. Child 11 had parents with low-levels of literacy, demonstrated undiagnosed learning disorders and social problems. In class 2, only a couple of children in the poor reader group responded favourably to SFA whereas the scores for all other children remained relatively static. Research has established that competency in areas of spoken language is crucial for early reading success and acquisition of written language (Longian et al., 1998). Furthermore, children from low-income backgrounds and with parents with limited education and low levels of literacy are more likely to experience reading difficulties (Longian & Whitehurst, 1998; Nicholson, 2003; Snow et al.,

1998). In the present study, no exclusionary criteria were applied as it was hoped that integrated SFA+PA intervention would influence the abilities of all children in class 1. While it is clear from the completed teacher questionnaires that all children responded favourably to SFA experience and that PA training at the lowest level was able to effect significant change in one measure of PA, the specific learning needs for particular children were unlikely to have been met by the brief intervention period employed in this study.

### **5.1 Theoretical and clinical implications of the findings**

The results from this thesis add to the mounting body of evidence demonstrating the positive effects of SFA on behavioural and academic achievement (Heeney, 2007), and, the effectiveness of PA in fostering early reading development by specifically enhancing PA skill (Ehri et al., 2001). Children in both classes responded positively to SFA, the benefits of which were observable by both teachers within a few days of installation. A significant gain was demonstrated in one measure of phoneme awareness even though training was implemented at the lowest level. Given that findings were based on a small number of children, interpretation of the results warrant caution. However, this study demonstrated that intervention for young school children should not be limited solely to methods designed to enhance early literacy development. Other means to facilitate attention to sound structure must also be explored. The behaviour and general academic performance of these children benefited from an enhanced acoustic environment which recognised and countered the detrimental impact of fluctuating hearing loss and inadequate classroom acoustics. Long-term SFA exposure alone has been demonstrated to significantly improve measures of PA and reading in New Zealand classrooms (Heeney, 2007).

The lack of conclusive results across most assessment measures in this study have important implications for typical models of professional teacher development and the specific content and intensity of teacher-administrated classroom-based PA approaches. The implementation of supportive frameworks in which the teacher is provided with specific and timely feedback may facilitate optimal delivery of literacy programmes thereby resulting in measurable improvements in the classroom. Teacher-administrated PA programmes must focus on phoneme level skills rather than at rhyme level to provide the strongest impact on early reading development (Muter, Hulme, Snowling, & Stevenson, 2004; Nanocollis et al., 2005). Although these results suggest positive treatment effects for poor readers following the lowest level of PA intervention, it is critical to develop and utilise approaches that facilitate sustained PA, reading and spelling development for at-risk readers. In young children, it is possible to

stimulate early phoneme level skills through simultaneously targeting speech, early phoneme awareness and letter-sound knowledge (Gillon, 2005). Thus, improving the access children have to the sound structure of spoken words via SFA in combination with a classroom-based teacher-administrated PA programme has the potential to provide cost-effective, efficacious benefits.

## 5.2 Limitations of the current research

This study employed a simple comparative design between two classes. Class 1 received combined intervention (SFA+PA) while class 2 received SFA alone. A control group was not considered necessary as the benefits of SFA between classes with and without amplification systems has already been extensively demonstrated. However, these results may have benefited from the potential contrast between a group with routine classroom teaching only, a group with SFA only and a group with combined SFA+PA.

The present study chose to utilise (and thereby demonstrate the potential drawbacks of) the typical model of professional teacher development. This resulted in T1 selecting to focus the classroom programme at the lowest level of PA development, i.e. syllable and rhyme awareness. This highlighted a difference between the present study and other intervention studies which typically implement programmes adhering to defined and prescribed methods. The treatment fidelity in this study included observations and monitoring of the programme, however, intervention choice and administration was ultimately decided by the teacher.

Fortunately, the bridge between teaching and the scientific community is strengthening, thus resulting in the increased implementation of evidence-based intervention methods within the classroom. While this is clearly a step forward, it suggests that locating a classroom of children that has *not* yet received some form of phonics or PA-type instruction may be more and more challenging for researchers wanting to conduct comparison studies. This was a significant confounding factor for this study. The children in both classes had already received up to a year and a half of phonics training prior to the intervention they received in this study. Ideally, comparison would have been best implemented with children who had not received any form of phonics or PA training.

Finally, the generalisation of these results was limited due to the exploratory nature of the study. It is important that results are replicated with larger numbers of children for longer intervention periods so that treatment effects can be more critically evaluated.

### 5.3 Future directions

Although the primary objective of this thesis was only partially supported, these findings highlight many future directions for integrated SFA+PA intervention research. First and foremost, it is important to determine the effect of SFA plus specific phoneme level PA intervention. Such study would show whether combined SFA and (focused phoneme level) PA intervention was able to rapidly facilitate reading development in young school children. In addition, whether SFA was able to augment that facilitation due to the enhanced acoustic signal. Consequently, future investigations are needed to examine the effectiveness of an integrated SFA+PA approach for a larger number of young school children. Longitudinal studies would specifically demonstrate whether intensive, focused and acoustically enhanced intervention is able to maintain long-term reading benefits.

Similarly, replication of Gillon's work (2005), with and without SFA, may further demonstrate and delineate the advantages of implementing PA with an enhanced sound-field on the speech production, PA and letter knowledge skills of young children.

This combined intervention approach may hold implications for other populations including children with (1) severe deficits in PA or phonological representation, (2) speech impairment, (3) language impairment, (4) special needs, and (5) children learning English as a second language.

The acknowledged concerns of the Ministry of Education regarding the typical model of professional teacher development in teacher application and implementation of programmes continue to require examination and monitoring.

The use of efficacious teaching approaches lead to stronger learning and literacy outcomes for young New Zealand school children. This study provides encouraging evidence that optimising the classroom listening environment through SFA in combination with PA activities facilitates early reading development.

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## Appendix I – Human Ethics Committee Approval Letter

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Ref: HEC 2008/141

16 January 2009

Virginia Good  
Department of Communication Disorders  
UNIVERSITY OF CANTERBURY

Dear Virginia

The Human Ethics Committee advises that your research proposal “The benefits of sound-field amplification combined with a class-based phonological awareness programme on literacy skills in at-risk school children” has been considered and approved.

Please note that this approval is subject to the incorporation of the amendments you have provided in your email of 12 January 2009.

Best wishes for your project.

Yours sincerely

Dr Michael Grimshaw  
*Chair, Human Ethics Committee*

## Appendix II – Parent Information Sheet

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December 10th, 2008

Dear Parents

I'd like to invite your child to be a participant in a research project examining literacy enhancement in early readers. This project aims to investigate how your child's learning is influenced by the installation of a specialized sound-system within the classroom and a comprehensive reading enhancement programme in the second term of the school year.

The project has the support of your class teacher and school principal. Virginia Good, Masters student in audiology and qualified speech-language therapist, will lead this research under the supervision of Professor Gail Gillon and Dr. Valerie Looi at the University of Canterbury

The project aims to investigate whether a specialized sound system is able to improve upon the benefits of an enhancement reading programme. The sound-system involves the teacher wearing a headset and having his or her voice amplified sufficiently and heard through four speakers placed within the classroom. This ensures that in all areas of the classroom his or her voice is heard clearly by all children. The sound system will be switched on in Term Two in both classrooms. At this time, only one class of children will receive the classroom enhancement reading programme delivered by the school teacher within the usual daily teaching. At the completion of the study, the second class will also receive the classroom enhancement reading programme. All that is required of your child is to attend school regularly as he or she would normally do. The two sound systems, valued at approximately \$2,000 each have been kindly donated to Shirley Primary school by PhonicEar via Oticon, New Zealand for the purpose of this research project.

Your child's involvement in the study will require him or her undergoing a hearing screening as well as being assessed on a range of reading tasks at Shirley Primary School on three occasions. These assessments will take place within school time. The first assessment will be in the second week of the first school term 2009. Ongoing monitoring of your child's reading abilities will take place over the first school term at intervals within school time. The second assessment will occur in the last week of the first school term and then finally, in the last week of the second school term. The hearing screening assessment will enable us to identify if your child has any hearing problems that would hinder normal speech and language development. The reading assessments will help us to identify what level of reading ability your child begins with initially and to monitor their progress over the first two school terms.

The reading assessment sessions will be video- and audiotaped so we can check your child's responses after the completion of the assessment session. The results of the project may be published, but you may be assured of the complete confidentiality of data gathered in this investigation: the identity of the participants will not be made public without your consent. To ensure confidentiality, all information collected for the project will be stored in a lockable filing cabinet in the researcher's office. A case number, rather than your child's name, will be used for all information about your child entered into the computer.

The assessments are of course free of charge and we will write a report detailing your child's current hearing and literacy skills for your information, as well as their progress over the course of the first two school terms.

If you are interested in your child participating in this project, please complete the parent's permission form below. Virginia Good, Masters student in Audiology is managing the assessment sessions. Virginia will supervise senior undergraduate students in speech and language therapy in conducting the assessment sessions. Virginia can be contacted through the Communication Disorders department.

Many thanks for considering this request. We are keen to advance our knowledge of speech, language and hearing development in young New Zealand children and your child's participation will help us in this endeavour. Our project has received ethical clearance from the University of Canterbury Human Ethics Committee.

Virginia Good  
MAud student  
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## Appendix III – Consent Form

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### **Audiology Research Project**

“The benefits of sound-field amplification combined with a class-based phonological awareness programme on literacy skills in at-risk school children”

Researcher: Virginia Good  
Department of Communication Disorders  
University of Canterbury  
November 17, 2008

I have read and understood the description of the above-named project. On this basis I agree for my child to participate as a participant in the project, and I consent to publication of the results of the project with the understanding that my child's name will remain confidential and will not be published in any of the research reports. I also consent to the results of these assessments being made available for future studies if required. I consent to the assessment of my child being video- and audiotaped. I would also be pleased to receive a copy of my child's current hearing and literacy skills following assessments. I understand that I may at any time withdraw my child from the project, including withdrawal of any information I have provided or that my child has provided.

Child's name \_\_\_\_\_  
Parent/s name \_\_\_\_\_  
Parent's Signature \_\_\_\_\_  
Date \_\_\_\_\_  
Contact Phone number: \_\_\_\_\_

## Appendix IV – Parent Questionnaire

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### Audiology Research Project

“The benefits of sound-field amplification combined with a class-based phonological awareness programme on literacy skills in at-risk school children”

Because this research considers how two types of intervention may benefit your child’s reading skill (the sound system and the classroom enhancement reading programme), the following questions are simply to help us to know if your child may require, or, has received any other help from teaching staff or other educational professionals.

Has your child been diagnosed with any learning disability? (for example: ADHD, dyslexia, dyspraxia) Yes/No

If yes please provide details:

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Has your child ever been diagnosed with hearing loss? Yes/No

If yes please provide details:

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Has your child received support for attention or behaviour? Yes/No

If yes please provide details:

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Has your child received extra learning support? Yes/No

If yes please provide details:

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Has your child received, or currently receives speech and language therapy? Yes/No

If yes please provide details:

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## Appendix V – Teacher Questionnaire

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Please comment on the following aspects following the SFA trial.

1. Please indicate frequency of use of equipment:

I used the equipment consistently for most teaching sessions

Y/N

I used the equipment consistently for selected sessions (specify type):

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I used the equipment inconsistently due to (specify):

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2. Please comment on any effects on student behaviour you noticed while using the sound-field.

Noise levels:

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Levels of fatigue:

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Learning problems:

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Hearing loss:

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On task/off task behaviour:

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Disruptive behaviour:

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3. Please comment on any effects you or others have noticed about your own health and well-being.

Vocal Strain:

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Tiredness/energy:

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Reduction in irritability levels:

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Absenteeism from school:

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4. Please comment on your perceptions in the learning environment that facilitated better learning.

Better comprehension of teacher instructions:

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Improved student cooperation:

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Students' abilities to follow instructions:

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Seating options:

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You may also wish to comment on improvements in academic areas:

- 
- 
5. Please comment on any other aspects of using the sound-field system relating to effective practice, improving learning outcomes, or other areas you wish to comment on that are not listed above.
- 
-

## Appendix VI – Reverberation Times

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Classroom	Condition	Frequency (Hz)	T60
1	Unoccupied	125	0.72
		160	0.43
		200	0.65
		250	0.5
		315	0.53
		400	0.45
		500	0.45
		630	0.51
		800	0.44
		1k	0.42
		1.25k	0.45
		1.6k	0.43
		2k	0.47
		2.5k	0.38
		3.15k	0.45
		4k	0.45
		5k	0.41
6.3k	0.43		
8k	0.37		
		<i>Average 0.47</i>	
Occupied	125	0.5	
		160	0.65
		200	0.49
		250	0.68
		315	0.59
		400	0.52
		500	0.51
		630	0.65
		800	0.43
		1k	0.51
		1.25k	0.66
		1.6k	0.66
		2k	0.54
		2.5k	0.41
		3.15k	0.77
		4k	0.38
		5k	0.41
6.3k	0.43		
8k	0.53		
		<i>Average 0.54</i>	
2	Unoccupied	125	0.64
		160	0.44
		200	0.47
		250	0.55
		315	0.54

			400	0.53
			500	0.51
			630	0.52
			800	0.5
			1k	0.8
			1.25k	0.45
			1.6k	0.49
			2k	0.5
			2.5k	0.41
			3.15k	0.4
			4k	0.4
			5k	0.39
			6.3k	0.37
			8k	0.36
			<i>Average</i>	0.48
Occupied	125	0.53		
			160	0.7
			200	0.47
			250	0.61
			315	0.61
			400	0.62
			500	0.53
			630	0.58
			800	0.64
			1k	0.54
			1.25k	0.5
			1.6k	0.4
			2k	0.37
			2.5k	0.51
			3.15k	0.62
			4k	0.56
			5k	0.44
			6.3k	0.42
			8k	0.32
			<i>Average</i>	0.52

---

T60 values and overall averages at octave bands 125 to 8000 Hz providing a single estimate of the reverberation time in the two classrooms in unoccupied and occupied conditions.

## Appendix VII – Signal-to-Noise Ratio Estimates

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Classroom	dB A	Average (dB A)	SNR (dB)
1			
Teacher speaking	54.2		
	59.1		
	49.1		
	60.5		
	60.2		
	59.7		
		57.1	
Children in quiet	35.1		
	37.2		
	35.2		
		35.8	21.3
2			
Teacher speaking	57.5		
	57.5		
	58		
	57.6		
	58.6		
	63.5		
		58.7	
Children in quiet	42.3		
	43.3		
	39.7		
		41.7	17

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Estimation of signal-to-noise ratio in both classes based on sound level meter measurements of background level noise in an occupied condition subtracted from averaged recordings of the teacher speaking.