# Classroom Sound Field Amplification Systems for Language Development During Early School Years In Contexts Of Socio-Economic Exclusion: The Neglected Role Of Classroom Contextual Dimensions

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*Abstract*

*This study examined the efficacy of classroom sound field amplification system for the language development of children, aged 4-7, in early primary years in schools designated as disadvantaged in Dublin, Ireland. The language development of 65 study participants from 14 classes in 7 schools was assessed in a multiple baseline AB case study design supplemented by norm-referenced language assessments pre- and post-installation of the amplification systems. One hundred and seventy three 30-min classroom observations were conducted over a 9-month period. The intervention was found to bring statistically significant gains in the area of language comprehension and classroom participation, particularly in classes in which the support was introduced at the start of schooling. The study constitutes the first large-scale study on sound field amplification systems internationally that is entirely concerned with the effect of this intervention on the language development of children experiencing socio-economic exclusion.*

*Keywords: Sound field amplification system, systems theory, language development, socio-economic exclusion, early intervention.*

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## Introduction

The prevalence of language difficulties among children from socioeconomically marginalised areas is high in Britain and USA (Locke, et al., 2002). Children from areas of socioeconomic disadvantage have been found to have smaller vocabularies and less complex sentence structures than children from non-marginalised communities (Arriaga, Fenson, Cronan & Petnick, 1998; Hart & Risley, 1995; Locke et al., 2002; Pan, Rowe, Singer & Snow, 2005). While recognizing that some of these differences may result from a language difference, it has been suggested that children from socioeconomically excluded backgrounds are in need of greater language support, in particular throughout the early years of schooling (Locke et al., 2002). Justice et al. (2009) propose that given that the language difficulties in early schooling impact on the school success in general, the time of approximately 54 months of age or just prior to preschool entry time is a critical one for their identification and for language support in general. While at the age of 4 children in the US context typically start kindergarten, children aged 4-5 years in Ireland typically start formal schooling. 6 years is the common primary school start age in most of Western Europe, whereas 7 years is more common in Eastern Europe (UNESCO Institute for Statistics 2010).

This study looks at the efficacy of a classroom sound field amplification system for the language development of children between the ages of 4 and 7 in early primary years in 7 urban schools designated as disadvantaged in Dublin, Ireland. It adopts a systems theory approach in its focus on the efficacy of this intervention with a view to developing a more nuanced way of conceptualising classroom amplification systems. This current study interrogates a lack of a systems focus in previous sound field amplificaton research internationally and proposes a contextually based model of the intervention in response to this critique. Within this analytical framework, its purpose is to investigate the effect of this classroom intervention on language dimensions that regulate classroom discourse and have a potential to differentiate children with language dificulties from their typically developing peers. The research question of this study was:

> *Can classroom sound field amplification (SFA) play a causal role in a system of elements to bring improvements for the specific population of young early primary children in urban designated disadvantaged schools on a number of language dimensions*?

The interest in the sound field amplification technology in the speech and language literature arose out of concerns over the need to support children's listening and encoding skills in educational settings. The goal of the classroom sound field amplification system in mainstream schools is to improve not only children's level of hearing the teacher but also their levels of concentration and attention, and thus language development. The sound field amplification system is purported to minimise the distracting effects of background noise and equalizes the teacher's voice throughout the classroom providing consistency of the teacher's linguistic input for each child (Crandell

& Smaldino, 1995).

Classroom sound field technology introduces an acoustic modification to facilitate listening in the classroom. In this study, the sound field amplification system used wireless frequency modulated (FM) radio technology[3]. In the FM type sound field distribution systems, the wireless microphone worn by the teacher converts an acoustic voice signal into an electrical signal that, in turn, frequencymodulates a carrier frequency. A wireless receiver separates the original speech signal from the carrier signal, amplifies the original signal and delivers it to loudspeakers mounted at different positions on the walls of the classroom. This system generates a clear, uniform and constant sound level across the classroom, which is above the background noise at all times and in all classroom locations.

A prevention and early intervention focus in relation to sound field amplification systems is resonant with two of the key strategic goals for education in the European Union under the ET2020 strategy. These are that the share of early leavers from education and training should be less than 10 % and that the share of low-achieving 15-year-olds in reading, mathematics and science should be less than 15 %. However a danger of the ET2020 strategy is that its main focus is on older age groups and there may be a policy disincentive to direct resources into younger children's services (Downes 2013), as part of a prevention and early intervention approach. This is because the effects of such early intervention may be for an age group that will not yet be 15 years old by 2020.

Language development during early years of schooling for children from socioeconomically marginalised backgrounds is crucial not only due to its now widely recognized interrelationship with literacy development (Snow, 1991; Storch & Whitehurst, 2002). Language impairment, especially receptive type one, is a risk factor for the onset of emotional behavioural difficulties in mid-childhood (Botting & Comti-Ramsden, 2000) and a risk factor for correlates of early school leaving such as engagement in disruptive behaviour, with language problems reported to have an impact on the domains of conduct disturbance, antisocial behaviour and mental health issues, although not in a simple causal way (Rutter, Giller & Hagell, 1998; Rutter, 2003). Some researchers found a high prevalence of specific language impairment in psychiatric samples (Beitchman, Nair, Clegg & Ferguson, 1986; Cohen, 2007) while others found an association between preschool patterns of language development and future crime engagement (Stattin and Klackenberg-Larsson, 1993). Rates of language impairment are reported to reach 24% to 65% in samples of children identified as exhibiting disruptive behaviors (Benasich, Curtiss, & Tallal, 1993) and 59% to 80% of preschool- and school-age children identified as exhibiting disruptive behaviors also exhibit language delays (Beitchman, Nair, Clegg, Ferguson, & Patel, 1996; Brinton & Fujiki, 1993; Stevenson, Richman, & Graham, 1985). High comorbidity estimates are also reported between

[3] Most current sound field systems use infrared technology, in which the auditory signal is transmitted via infrared light rays from the microphone transmitter to the loudspeakers.

language difficulties and diagnoses of ADHD (Cantwell & Baker, 1991; Kim & Kaiser, 2000). Some speech and language problems among a group of children with behavioral social and emotional difficulties are not recognised until later childhood (Giddan, Milling & Campbell, 1996). It is to be acknowledged that these findings are correlational and not necessarily causal.

In Irish contexts of urban designated disadvantaged 'DEIS' schools, teachers and school principals consistently rated language support by speech and language therapists as a priority need for a strategic approach to early school leaving prevention and for improved academic performance for those at risk of poor school attendance at primary level (Downes 2004; Downes & Maunsell 2007). Speech and language intervention can bring mental health benefits in terms of giving confidence to quiet, withdrawn children, improving peer interaction, as well as facilitating children's engagement and comprehension of complex directions with consequent benefits for in-class behaviour (Downes, 2011). The issue of a language development dimension is not simply to target those at the level of a clinical speech and language disorder but to support the development of language from an early age in a variety of contexts in which this development takes place.

It is generally agreed that language learning should be viewed as a complex, interactive and dynamic process. This is in concurrence with a bioecological model of development (Bronfenbrenner & Morris, 1998) which views development as a complex dynamic comprising structural and process variables as well as the interactions between them. This systemic model recognises the importance of *simultaneous* efforts directed at fostering language development at both school and community levels across a lifespan. Within this recognition, a large body of literature focuses on the experiences within the classroom (and school) and their contribution to pupils' competence growth and competence change (Maughan, 1994; Rutter, 1983), including studies focused on the quality of the language learning environment in early education settings. The quality of early education settings matters especially for children from areas of socioeconomic exclusion (Marcon, 1999).

The role of language input - although debatable from the perspective of innatists in its specific impact on syntactic language dimensions (Chomsky, 1965; Pinker, 1994) - is acknowledged in all theories of language acquisition. Literature within the social-interactionist model of language acquisition (Tomasello, 1992), based in the writings of Vygotsky (1978), shows that specific aspects of adult speech are facilitative for child language development, particularly for children from areas designated as disadvantaged (Whitehurst, 1997) and especially for vocabulary development. These include aspects of language modelling, including labelling, and discourse enabling techniques including expanding and extending, as well as adult questioning techniques (Weitzman & Greenberg, 2002; Walsh & Blewitt, 2006; Whitehurst et al., 1988). Researchers have shown also less obvious links between language input and syntax development. Huttenlocher, Vasilyeva, Cymerman & Levine (2002) argued for an association between

the children's receptive language and their teachers' speech input by finding that preschool children whose teachers use more complex sentences score higher on tests of comprehension of complex syntax. Further, Vasilyeva, Huttenlocher & Waterfall (2006) found a link between children's usage of passive forms and their exposure to them in a preschool settings. It is crucial to acknowledge at this point that the linguistic markers of complex sentences are often short and unstressed (e.g. *unless, although, since, either/or*) and can thus be 'missed' by young children unfamiliar with them in unfavourable listening conditions. The nature of linguistic interaction and the context for language use can either enable or hinder the presence of some linguistic features, for example the presence of a more complex sentence structure (Dickinson, 2001a; 2001b). For instance, enabling narrative and expository discourses in the classroom, in addition to a conversational language mode, can affect pupils' language performance (Scott, 1995).

The bioecological model of development recognises the importance of social processes in social systems. It highlights also further dimensions of the dynamic of the social systems, namely resources and organisation of resources, with the latter comprising such aspects as, for example, staff training, the organisation of a learning space, the size of the class and the classroom as well as the acoustic qualities of the latter. The quality of listening conditions in the classroom is one structural dimensión of the school context that may influence the complex system of factors affecting the development of language in early childhood. While it is the frequency of opportunities for formulation of language that is necessary for it to develop, language is ultimately learnt through listening.

Poor classroom acoustics may be in particular detrimental for younger children, especially children starting school. Firstly, young children have immature listening skills related to the process of neuromaturation of the auditory system (Gil-Loyzaga, 2005; Moore, 2002). Secondly, the youngest learners do not have rich linguistic experience to fill in the gaps in communication and reconstruct a lost speech signal. There is wide international literature on the impact of noise on learning (see e.g. Darmody et al., 2010, for a review). There has also been a plethora of studies on the specific impact of noise on listening and understanding in the classroom, two dimensions that underlie the very premise of education. Most of these studies evidenced decreased speech perception and speech understanding of young children in the presence of noise (Bluestone, 2004; Bradley & Sato, 2004; Gil-Loyzaga, 2005; Jones et al., 1989; Moore, 2002; Nelson & Soli, 2000; Stelmachowicz, Hoover, Lewis, Kortekaas, & Pittman, 2000; Zabel & Taylor, 1993). Thus, they support the claim that young children need more favourable acoustical conditions than adult listeners to achieve equivalent recognition scores. The reference to inexperienced listeners gains particular importance in Irish infant classrooms which are attended by children aged 4-6. Furthermore, poor acoustical conditions may be an additional disadvantage to children who already experience comprehension problems, as noise may mask some words for them, making the speech even more difficult to fully understand.

The sound field amplification literature to date has claimed the benefits of this intervention for a number of diverse dimensions including listening and learning behaviour in the classroom (Darai, 2000; McSporran, Butterworth & Rowson,1997; Rosenberg, Blake-Rahter, Heavner, Allen, Redmond, Philips & Stigers, 1999), speech recognition (Bradley & Sato, 2004; Jones et al., 1989; Zabel & Taylor, 1993), on-task behaviour in the classroom (Allen & Patton, 1990; Eriks & Brophy & Ayukawa, 2000) and a number of academic dimensions including phonemic awareness (Flexer, Kemp Biley, Hinkley, Harkema & Holcomb, 2002), writing and numeracy (Massie & Dillon, 2006) and reading literacy (Darai, 2000; Massie & Dillon, 2006). As these dimensions represent a diverse set of skills, one can conclude that this intervention has the potential to accelerate the learning in the classroom in general. A range of research on classroom sound field amplification supports the claim of its efficacy for different populations and for different aspects of development. However, this large body of research has failed to bring more knowledge and more meaning about the context for this intervention.

In the sole classroom amplification study that applied an ecological perspective to the evaluation of its benefits, classroom behaviour of 8 pupils was observed in interaction with their contexts, i.e. activity type, task type, classroom structure (e.g., group versus individual work), teacher's position and teacher's behaviour in an ABA design (Palmer, 1998). The author of the study predicted that some elements of the classroom may mediate the effect of this intervention. She observed three elements of the classroom, namely task type, activity type and classroom structure. However, a cluster approach was adopted to the analysis of these findings. It simply compared the baseline and the intervention data, concluding no substantial differences between them. Thus, while an ecological perspective is present in the study design, the *conceptualisation* of sound field amplification still conforms to the simple linear relation of one-antecedent-one-consequence. The ecological approach in this study seems to be actually utilised to augment the logic of simple linearity.

The influence of context on the efficacy of classroom sound field amplification was acknowledged also in another study that measured the effects of classroom amplification on speech perception by longitudinally observing children in 7 amplified and 7 non-amplified classrooms (Mendel, Roberts & Walton, 2003). The authors of the study noted that one experimental class showed a significantly larger improvement in reading than the other experimental classes. They engaged in no further discussion on the implications of their findings on conceptualising the classroom sound field amplification system as an educational and developmental intervention and simply concluded that teacher variability was a potential factor that had an influence on the results of their study and that it was 'difficult to control'. Rather than 'control' it, however, it may prove interesting to observe it closely and analyse it together with the pupils' performances.

The majority of previous sound field amplification studies of children's language development in schools did not take into account the context in which the amplification

systems operated; thus they conceptualized this intervention in the paradigm of simple linearity between one causal antecedent and one consequent. This traditional dichotomy model fails to recognise that classroom amplification is a supportive intervention, which needs certain classroom conditions 'to work'. The current study extends the paradigm of simple linearity into one of complex causality. In other words, while the efficacy of the intervention was studied for the purposes of this research using the empirical model of AB design consistent with behaviourism, the system of the classroom was observed in terms of the conditions it created for this intervention. Thus, it is recognised that classroom context can have a potentially moderating effect on the impact of sound field amplification in the classroom. This seemingly trivial element was absent in most previous classroom amplification evaluations.

To date, classroom sound field amplification literature has presented either small size research (e.g., Crandell, 1996; Eriks-Brophy & Ayukawa, 2000; Flexer et al., 2002; Palmer, 1998) or has taken a cluster approach in an analysis of larger samples (e.g., Darai, 2000; Massie & Dillon, 2006; Rosenberg et al., 1999). The proposed analytical framework situated within a systems theory requires one to analyse a diverse and wide sample of individual classrooms, rather than take a cluster approach. One of the methodological limitations of previous studies concerned with the effect of this intervention on broadly defined academic achievement is that they have adopted almost exclusively a cluster approach in an analysis of their findings (Darai, 2000; Rosenberg et al., 1999). While the benefits of classroom sound field amplification for more general academic performance are well evidenced in literature, its specific benefits for language development have not been studied in great detail, i.e. with inclusion of an array of language dimensions. This study utilizes classroom observations, in a combination with norm-referenced methods of language assessment, to measure the effect of classroom sound field amplification on 6 language dimensions of children aged 4-7 attending designated disadvantaged 'DEIS' schools.

## Method

### *Design*

The multi-method design of the study included a multiple baseline pre-intervention phase (A) and an intervention phase (B) case study design, combined with pre-intervention and post-intervention standardised tests administration. This is in accordance with the current model of good practice in the speech and language therapy field which recommends a combination of standardised tests and contextually-based language assessments. Contextually-based language assessment is a strength-based assessment that allows the observation of a context in which language is assessed, and in which language develops. The participants of the study were observed systematically both before and after the intervention in their naturalistic setting (i.e. the classroom), where the actual development transpires, to arrive at a pattern of their activity from which their development can be inferred. This methodological approach allows for the systemic analysis of the SFA and is directly relevant to the theoretical framework of the

intervention.

*Participants*

In selecting participating schools and classes, criterion sampling by a) geographic area, b) disadvantage status and c) age of children was used. School principals from 7 designated disadvantaged schools in two geographical areas in Dublin were asked to select one junior infant class (4-5 years of age), one senior infant class (5-6 years of age) and one first class (6-7 years of age) in their schools for participation in the study. All participating schools had a status of DEIS Band 1 which in Ireland is associated with schools with the highest level of socio-economic marginalisation. The school principals selected the classes on the basis of teacher willingness to participate in the study. Out of the twenty one selected classes, fourteen were chosen randomly on the basis of availability for having language lessons videotaped pre- and post-installation of the systems. Five children identified as experiencing language difficulties were then selected by their teachers from each participating class for standardized testing and classroom observation.

Participants were 65 children (39 boys and 26 girls) who were 4.2-7.1 years of age (M=5.1 [SD=0.92]). English was the first language for 59 participants and an additional language for 6 participants. Two students had medical diagnoses of ADHD and 1 student had been previously referred for speech and language therapy services. The students had no reported learning disabilities.

*SFA Installation*

The sound-field amplification FM systems were installed in the classrooms either at the end of the school year (May) or at the start of the school year (November). The intervention was introduced either at the start of the school year (in November 2005) or at the end of the school year (in May 2005) in junior and senior infants and at the start of the school year (in November 2005) in first classes. Classroom observations were conducted from March 2005 to June 2006 and language assessments were administered in March/April 2005 (baseline) or September/October 2005 (baseline) and May/June 2006 (post-intervention) . There was an eight week time period after the summer time holiday during which no observations were conducted to allow the children to settle down in classes. An extended period of adaptation after the installation of the sound field was not found necessary by other researchers who reported immediate change in behaviour (Palmer, 1998).

All teachers knew in advance when the researcher would be coming to video record the class. Such notice was requested by the teachers. This was likely to imply what is termed in participant research as a Hawthorne effect (Landsberger, 1958), i.e. to have some implications for the behaviour of the observed pupils and teachers. The camera might have been threatening to some study participants and its presence could have led to the staging of some of the lessons. It might have been that the teachers presented lessons that were more language-rich while being observed and/or that the quality of the

observed lessons differed from the quality of unobserved lessons. Equally, the initial camera intrusiveness could have equally resulted in teachers presenting more structured lessons and thus children making fewer elaborations. These influences were reported also by other studies that used video cameras (Girolametto, Hoaken, Weitzman & Van Lieshout, 2000).

*Classroom Observations*

One hundred and seventy three 30-min classroom observations were conducted over a 9-month period (October through June) to assess the children's performance on the dimensions of classroom participation, responsiveness and pragmatic adequacy of responses. Responsiveness and pragmatic adequacy were selected to observe the occurrences of communicative breakdowns such as lack of response, confusión or misunderstanding (Lund, 1993). Pragmatically inadequate responses were defined after Adams et al. (2006) and Bishop et al. (2000) as conversationally inadequate due to either some linguistic limitation or a comprehension failure. The 4-5 children in each class were observed at the same time. Observations were made during school morning sessions and all were made during English language lessons in a whole class format. The request to introduce whole class format was directed in order to reduce some of the variables affecting language, maximise the sound quality of the recordings and minimise the time spent on recordings. The whole class format was used for collection of linguistic data and there was no assumption of causal attribution between language gains and teaching in a whole class format.

All observations were videotaped to facilitate coding for multiple dimensions and reliability checks. Additional voice recordings were made using an omni-dimensional microphone to aid the accuracy of transcription. All recordings were transcribed orthographically verbatim. Transcripts were then coded according to an agreed framework that quantified data on individual language dimensions and classroom interactions. Two research assistants who were living in the area of the studied population were employed to review the accuracy of transcripts where doubts occurred.

The design of the study was a multiple baseline AB case study design supplemented by norm-referenced assessment of language pre- and post-installation of systems. Each child was observed on average 3.5 times before the introduction of intervention (A) (SD=0.62, range 2-5) and on average 9 times after the introduction of intervention (B) (range 5-17, SD=3.14). The intervention phase (B) was segmented into sub-phases (B1, B2, B3) with on average 3 data points per phase, based on the criteria of the number of weeks passed between recordings and the wealth of linguistic material recorded. The rationale behind this segmentation was to observe potential developmental patterns relating to maturation effects of irreversible linguistic behaviour in the absence of a non-intervention 'control group'. The mean number of recorded lessons (data points) per phase was 3.5 (range: 2-5, SD=0.74). The intervention was withdrawn in 5 classes chosen by the criterion of age, namely 2 junior infant classes in which the intervention was introduced at the start of junior infants, 1 senior infant class in which the

intervention was introduced at the end of junior infants, 1 senior infant class in which the intervention was introduced at the start of senior infants and 1 first class in which the intervention was introduced at the start of first class. The ABAB design was used to observe classroom participation.

*Dimensions*

The focus of the study was on the dimensions that regulate the classroom discourse, such as responsiveness and participation (Lund, 1993) and pragmatic adequacy of children's responses (Adams et al., 2006; Bishop et al., 2000) as well as commonly studied in the speech and language literature dimensions of receptive language, expressive language and receptive vocabulary (Dunn, Lloyd, Dunn, Whetton & Burley, 1997; Wiig, Secord & Semel, 2004). These dimensions have a potential to differentiate children who experience language difficulties from their typically developing peers (Lund, 1993; Scott, 1995).

Transcripts were analysed on three dimensions of responsiveness, participation and pragmatic adequacy. These dimensions were derived from the speech and language development literature (e.g. Adams et al., 2006) and modified to suit specificity of classroom discourse. *Responsiveness* was defined as the number of 'child's responses' to the number of 'teacher's obligations'. *Participation* was defined as the total number of combined 'volunteering for response' (HA) and 'not obligated responses' (self-initiated and volunteered responses) to the number of 'teacher's questions' (defined as teacher's solicitations for verbal response). *Pragmatic adequacy* was defined as the proportion of 'conversationally adequate responses' in all *verbal and nonverbal* responses produced. The same researcher coded all conversational indices and so internal consistency was maintained.

Standardised tests of language were administered to ensure trans-contextual validity of the language assessment. Three standardised tests were used: Clinical Evaluation of Language Fundamentals – Revised UK (CELF-3UK) (Semel, Wiig & Secord, 2000), Clinical Evaluation of Language Fundamentals – Preschool (CELF-P) (Wiig, Secord & Semel, 1992) and British Picture Vocabulary Scale II (BPVS-II) (Dunn, Dunn, Whetton & Burley, 1997). Participating children were selected to be tested on at least one language dimension: expressive language (CELF), receptive language (CELF) and/or receptive vocabulary (BPVS), according to the selection criteria of availability of testing space and availability of time. An effort was made to assess each child on at least two different dimensions of standardised tests. Standardised tests were administered according to the Examiner manual - that is, the stimulus was not repeated if the manual did not allow for that. No feedback was given.

*Observation of the Classroom System*

The observations of the classroom microsystem comprised of categories related to the teacher-child interactions which have been recognised by early childhood researchers to be key features of the effective early language pedagogy (Bickford-Smith et al., 2005;

Dickinson, 2001a; 2001b; Walsh & Blewitt, 2006; Weitzman & Greenberg, 2002; Whitehurst et al., 1988). The coding process was based on the categories of presence/ absence and frequency/non-frequency of occurrence of the observed phenomena. Recording sheets, reporting on these aspects, were devised and completed on the basis of lesson transcripts, field notes and revisiting of video recordings. The following table 1 presents the categories of the process data that were measured in the study. Mean levels of each of the dimensions of the quality of classroom interactions were calculated for each class across all observations. Inter-coder reliability for the classroom process data was computed. A qualified primary school teacher underwent a half day training on coding the interactions in the classroom and was then employed to code teachers' questions in 5% of the recorded material. Inter-coder reliability computed on the basis of a percentage agreement across questions for the 5% of the recorded material was very high and equalled 0.94 (i.e. 94% agreement).

**Table 1.**

*Analytical Framework of the Study: Observed Elements of the System*

| **Interactions (observed for the class)** |
|---|
| Teacher's use of open-ended questions (frequent / not frequent) |
| Was expository discourse enabled in the class? (yes / no) |
| Teacher's use of language stimulation techniques (incl. language modelling, expanding, extending, recasting, evaluating) (frequent / not frequent) |
| Were the elements of dialogic story reading present? (yes / no – frequent / not frequent) |
| Were the power relations shifted towards the children? (yes / no) |
| Other observations (e.g. relating to the style of teaching, whether or not children were given choices, etc.) |

## Results

The data analysis was conducted across dimensions, individual classes and individual study participants within each class, and augmented by the process data on each classroom microsystem. The findings on the observed language dimensions for samples within individual participating clases are shown below in tables 3-6. The outcome changes were defined as 'gains' if the increase in the score was greater than 0.04 which is the estimated natural variation in similar conversational índices as reported by Adams et al. (2006) for children with typical language development. Table 2 below reports on outcome changes in norm-referenced comparison.

**Table 2.**
*Pre-Intervention (A) and Post-Intervention (B) CELF Mean Standardised Score Results for Samples Within Individual Classes: Receptive Language, Expressive Language and Receptive Vocabulary*

| | **Receptive language** | | | **Expressive language** | | | **Receptive vocabulary** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Class** | **Pre-** | **Post-** | ***P value*** | **Pre-** | **Post-** | ***P value*** | **Pre-** | **Post-** | ***P value*** |
| A | **91.60*** | **98.60** | | | | | | | |
| B | | | | **84.75** | **88.25** | | 95.40 | 97.60 | |
| C | 76.50 | 77.25 | | **74.75** | **70.50** | | | | |
| D | **74.50** | **79.50** | | 74.75 | 75.50 | | | | |
| E | | | | | | | 93.00 | 94.40 | |
| F | | | | **83.40** | **75.80** | | 96.40 | 90.00 | |
| G | 75.60 | 77.60 | | | | | | | |
| H | 89.25 | 86.75 | | | | | 101.00 | 105.00 | |
| J | | | | 82.60 | 85.20 | | 94.20 | 99.80 | |
| K | **83.20** | **90.60** | | 79.40 | 79.80 | | | | |
| L | | | | **80.50** | **84.50** | | 92.75 | 91.50 | |
| M | **78.00** | **72.25** | | 73.25 | 72.00 | | | | |
| N | | | | | | | 94.60 | 91.20 | |
| O | **77.86** | **84.14** | | | | | | | |
| MEAN | 80.81 | 83.34 | ***0.04**** | 79.18 | 78.94 | *0.40* | 95.34 | 95.64 | *0.43* |
| SD | 6.50 | 8.50 | | 4.42 | 6.53 | | 2.80 | 5.46 | |

*Note.* *differences (B-A) outside of 68% confidence intervals are bolded, mean score increases (B-A) outside of 68% confidence intervals are underlined, **P value < 0.05 was set as significant

As evidenced in tables 2-7, statistically significant gains were noted in norm-referenced receptive language and participation. Most of the observed classes gained in norm-referenced language (6 out of 8 classes tested), regardless of the average age and the gender of the class. A majority of participating classes showed gains in norm-referenced receptive vocabulary (4 out of 7 classes tested on this dimension), however, gains in receptive vocabulary were not statistically significant for the whole sample. A majority of the observed classes showed either clear or probable gains in participation, both in AB design (6 out of 9 classes) and in ABAB design (3 out of 5 classes) (Tables 3,4), meaning that more children volunteered to contribute to the classroom discussion under improved listening conditions. These gains were observed in classes of different age

level with a majority of them occurring immediately after the introduction of intervention and thus exhibiting no incremental pattern. It can thus be concluded that, at a class level, the classroom amplification system contributed mostly to gains in children's comprehension (i.e. receptive language and receptive vocabulary) and classroom participation. Junior infant pupils (i.e., ages 4-5) were more likely than the older study participants to show gains in the dimensions of pragmatic adequacy of utterances, expressive language and receptive vocabulary.

**Table 3.**

*Participation in AB Design – Performance Across the Whole Study: Baseline (A) and Intervention (B) Phases for Samples Within Individual Classes: Mean Raw Scores**

| Class | Number of children | A Mean number of recordings =3.5 | B-phase 1 Mean number of recordings =3.5 | B-phase 2 Mean number of recordings =3.5 | Findings |
|---|---|---|---|---|---|
| C | 4 | 19.32 | 74.23 | 51.07 | clear gains |
| G | 4 | 53.95 | 27.36 | 29.43 | decrease |
| H | 4 | 54.40 | 49.90 | 37.83 | decrease |
| J | 5 | 29.39 | 118.80 | 76.68 | clear gains |
| K | 5 | 53.07 | 67.26 | 65.12 | clear gains |
| L | 4 | 26.98 | 28.85 | 22.36 | no gains |
| M | 4 | 28.48 | 28.33 | 35.46 | gains in last phase |
| N | 5 | 42.82 | 90.78 | 95.82 | clear gains |
| O | 4 | 81.18 | 102.53 | 119.98 | incremental gains |
| MEAN | n=39 | 43.29 | 65.34 | 59.31 | probable gains |
| SD | | 19.43 | 34.19 | 32.99 | |
| Range | | 19.32-81.18 | 27.36-118.80 | 22.36-119.98 | |

*Note.* *scoring scale was constructed for the use of the study (0.00 = minimum score, no maximum score)

Responsiveness clearly improved with the introduction of the intervention in half of the participating classes (7 out of 14 classes) (Table 5). The observed gains occurred immediately after the introduction of intervention in a majority of these classes and thus exhibited no incremental pattern. No students gained in responsiveness in classes K, O and F. All of these three classes were first classes (i.e.,.ages 6-7) This finding indicates that when it comes to responsiveness, the intervention appeared to be more supportive for the younger children. The observed gains in pragmatic adequacy occurred mostly in junior infant classes as 5 out of 6 classes that showed improvements in this dimensión were junior infants (Table 6). The intervention thus appeared to be more supportive for pragmatic adequacy of younger children's responses. Gains in pragmatic adequacy for most of the observed children occurred immediately after the introduction of amplification and thus they did not exhibit incremental pattern.

**Table 4.**

*Participation in ABAB Design - Performance Across the Whole Study: Baseline (A), Intervention (B), Withdrawal of intervention (A) and After the Return of Intervention (B) Phases for Samples Within Individual Classes: Mean Raw Scores*

| Class | Number of children | A Mean number of recordings =3.5 | B-phase 1 Mean number of recordings =3.5 | B-phase 2 Mean number of recordings =3.5 | A Mean number of recordings =2.0 | B Mean number of recordings =2.0 | Findings |
|---|---|---|---|---|---|---|---|
| A | 5 | 9.35 | 17.48 | 59.65 | 19.64 | 36.88 | clear gains in ABAB |
| B | 6 | 34.34 | 37.42 | 47.89 | 28.89 | 40.42 | clear gains in ABAB |
| D | 4 | 34.24 | 70.83 | 69.53 | 81.35 | 74.05 | clear gains in AB |
| E | 5 | 47.22 | 46.08 | 73.33 | 80.00 | 19.29 | no clear AB/ABAB |
| F | 4 | 58.95 | 86.92 | 145.00 | 66.84 | 103.33 | clear gains in ABAB |
| MEAN | n=24 | 36.82 | 51.75 | 79.08 | 55.34 | 54.79 | clear AB/not clear ABAB |
| SD | | 18.48 | 27.44 | 38.14 | 29.12 | 33.60 | |
| Range | | 9.35-58.95 | 17.48-86.92 | 47.89-145.00 | 19.64-81.35 | 19.29-103.33 | |

**Table 5.**

*Responsiveness – Performance Across the Whole Study: Baseline (A) and Intervention (B) Phases for Samples Within Individual Classes: Mean Scores**

| Class | Number of Children | A Mean number of recordings = 3.5 | B-phase 1 Mean number of recordings = 3.5 | B-phase 2 Mean number of recordings = 3.5 | B-phase 3 Mean number of recordings = 3.5 | Findings |
|---|---|---|---|---|---|---|
| A | 5 | 0.33 | 0.67 | 0.71 | 0.72 | clear gains |
| B | 5 | 0.84 | 0.87 | 0.93 | | clear gains |
| C | 4 | 0.62 | 0.85 | 0.87 | | clear gains |
| D | 3 | 0.82 | 0.88 | 0.91 | 0.97 | clear incremental gains |
| E | 4 | 0.73 | 0.84 | 0.86 | 0.86 | clear incremental gains |
| F | 3 | 0.95 | 0.95 | 0.95 | 0.92 | no gains |
| G | 4 | 0.67 | 0.96 | 0.92 | | clear gains |
| H | 4 | 0.89 | 0.85 | 0.99 | | no clear pattern |
| J | 4 | 0.98 | 0.91 | 0.96 | | decrease |
| K | 3 | 0.93 | 0.90 | 0.72 | | decrease |
| L | 4 | 0.89 | 0.89 | 0.84 | | no gains |
| M | 4 | 0.83 | 0.83 | 0.90 | | gains in last phase |
| N | 5 | 0.90 | 0.93 | 0.94 | | clear gains |
| O | 1 | 0.75 | 0.57 | 0.93 | | no clear pattern |
| MEAN | n=53 | 0.80 | 0.85 | 0.89 | 0.87 | clear gains |
| SD | | 0.17 | 0.11 | 0.08 | 0.11 | |
| Range | | 0.33-0.98 | 0.67-0.96 | 0.71-0.99 | 0.72-0.92 | |

*Note.* scale 0.00-1.00, score 1.00 = 100%

**Table 6.**
*Pragmatic Adequacy – Performance Across the Whole Study: Baseline (A) and Intervention (B) Phases for Samples Within Individual Classes: Mean Scores**

| Class | Number of Children | A Mean number of recordings =3.5 | B-phase 1 Mean number of recordings =3.5 | B-phase 2 Mean number of recordings =3.5 | B-phase 3 Mean number of recordings =3.5 | Findings |
|---|---|---|---|---|---|---|
| A | 5 | 1.00 | 0.97 | 0.98 | 0.99 | decrease |
| B | 6 | 0.93 | 0.97 | 0.95 | | clear gains |
| C | 4 | 0.84 | 0.93 | 0.94 | | clear gains |
| D | 4 | 0.92 | 0.91 | 0.93 | 0.93 | no clear pattern |
| E | 5 | 0.90 | 0.92 | 0.93 | 0.95 | clear gains |
| F | 4 | 0.94 | 0.96 | 1.00 | 1.00 | clear incremental gains |
| G | 4 | 0.93 | 0.98 | 0.98 | | clear gains |
| H | 3 | 0.97 | 0.98 | 0.98 | | no gains |
| J | 5 | 1.00 | 0.97 | 0.97 | | decrease |
| K | 5 | 1.00 | 0.96 | 0.98 | | decrease |
| L | 4 | 0.95 | 0.97 | 0.96 | | no gains |
| M | 4 | 0.97 | 0.97 | 0.97 | | no gains |
| N | 5 | 0.92 | 0.98 | 0.97 | | clear gains |
| O | 4 | 0.96 | 0.97 | 0.94 | | no clear pattern |
| MEAN | n=62 | 0.95 | 0.96 | 0.96 | 0.97 | marginal gains |
| SD | | 0.44 | 0.02 | 0.02 | 0.03 | |
| Range | | 0.84-1.00 | 0.91-0.98 | 0.93-1.00 | 0.93-1.00 | |

*Note.* scale 0.00-1.00, score 1.00 = 100%

Most tested classes (6 out of 8) showed gains in norm-referenced performance in receptive language (table 2). There was only one class in which all students deteriorated in post-intervention norm-referenced performance in this dimension (class M-senior infants). Gains in receptive language were noted in classes of different age level. Half of the tested classes (5 out of 10 classes) gained in norm-referenced expressive language, four of them junior infant classes (classes J, B, H and E). Thus, it can be concluded that gains in expressive language were noted mostly for junior infants. A small majority of tested classes (4 out of 7 classes) gained in receptive vocabulary. Gains in receptive vocabulary were noted in classes in 4 different schools but only in junior infant classes (classes J, B, H and E). Overall, norm-referenced gains in receptive language were greater than gains in expressive language and receptive vocabulary. This conclusion is strengthened by the fact that 3 classes out of 6 that gained in receptive language gained by 5 or more standardised points, while no classes assessed on expressive language gained by 5 or more standardised points and only 1 class assessed on receptive vocabulary gained by more than 5 standardised points. All class levels gained in receptive language but only junior infant classes gained in receptive vocabulary and mostly junior infants gained in expressive language. It must be emphasised that these

performances were norm-referenced and thus the gains made by junior infants could not have been attributed to a developmental effect.

**Table 7.**
*Baseline (A) and Intervention Phase (B1) Results for Samples Within Individual Clases: Pragmatic Adequacy, Responsiveness and Participation*

| | **Pragmatic adequacy** | | | **Responsiveness** | | | **Participation** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Class** | **A** | **B1** | ***P value*** | **A** | **B1** | ***P value*** | **A** | **B** | ***P value*** |
| A | 1 | 0.97 | | 0.33 | 0.67 | | 9.35 | 17.48 | |
| B | 0.93 | 0.97 | | 0.84 | 0.87 | | 34.34 | 37.42 | |
| C | 0.84 | 0.93 | | 0.62 | 0.85 | | 19.32 | 74.23 | |
| D | 0.92 | 0.91 | | 0.82 | 0.88 | | 34.24 | 70.83 | |
| E | 0.9 | 0.92 | | 0.73 | 0.84 | | 47.22 | 46.08 | |
| F | 0.94 | 0.96 | | 0.95 | 0.95 | | 58.95 | 86.92 | |
| G | 0.93 | 0.98 | | 0.67 | 0.96 | | 53.95 | 27.36 | |
| H | 0.97 | 0.98 | | 0.89 | 0.85 | | 54.4 | 49.9 | |
| J | 1 | 0.97 | | 0.98 | 0.91 | | 29.39 | 118.8 | |
| K | 1 | 0.96 | | 0.93 | 0.9 | | 53.07 | 67.26 | |
| L | 0.95 | 0.97 | | 0.89 | 0.89 | | 26.98 | 28.85 | |
| M | 0.97 | 0.97 | | 0.83 | 0.83 | | 28.48 | 28.33 | |
| N | 0.92 | 0.98 | | 0.9 | 0.93 | | 42.82 | 90.78 | |
| O | 0.96 | 0.97 | | 0.75 | 0.57 | | 81.18 | 102.53 | |
| MEAN | 0.95 | 0.96 | *0.08* | 0.80 | 0.85 | *0.09* | 40.98 | 60.48 | ***0.01**** |

*Note.* *p value < 0.05 was set as significant

Language gains were clearly observable in the same classes, namely class B where gains were observed in all 5 studied dimensions, class E where gains were observed in 4 out of 5 studied dimensions, and classes A, N and G where gains were observed in 3 out of 4 studied dimensions (Tables 2-6). Three of these classes (B, E and N) were junior infants, class A was senior infants and class G was first class. As these classes were from different schools and different grade level (see table 8 for profiles of individual classes), although a majority were from junior infants, these patterns suggest the presence of a 'class effect', i.e. the presence of some elements of the classroom microsystem that maximised the efficacy of the studied intervention. There were a number of distinctive factors identified in class B where gains were noted in all studied dimensions (see table 8) which were consistent with the indicators of good quality of language teaching characterised by a frequent use of open-ended questions, dialogic reading techniques including language modeling, expanding and recasting, as well as expository language enabling and shifting of power relations in favour of the pupils (Bickford-Smith et al., 2005; Ezell and Justice 2005; Justice et al. 2005; Justice and Pence 2005; Whitehurst, 1997). There was no other class participating in the study in which all of these indicators of good quality of language teaching were observed (see table 8).

**Table 8.**
*Interactions in Individual Classes**

| Class code (A-O) | A | B | C | D | E | F | G | H | J | K | L | M | N | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| School code (1-7) | 1 | 2 | 3 | 4 | 7 | 2 | 5 | 4 | 1 | 4 | 2 | 5 | 6 | 1 |
| Class grade (junior infants / senior infants / first class) | JI | SI | JI | SI | JI | FC | FC | JI | JI | FC | SI | SI | JI | FC |
| Teacher's use of open-ended questions (frequent / not frequent) | F | F | F | F | F | NF | Y | Y | NF | NF | F | NF | F | F |
| Was expository discourse enabled in the class? (yes / no) | N | Y | N | Y | Y | Y | N | N | Y | Y | Y | N | Y | N |
| Teacher's use of language stimulation techniques (incl. language modelling, expanding, extending, recasting, evaluating) (frequent / not frequent) | F | F | F | NF | F | F | F | NF | NF | F | NF | NF | F | F |
| Were the elements of dialogic story reading present? (yes / no – frequent / not frequent) | Y F | Y F | Y NF | Y F | Y NF | Y NF | Y F | Y F | Y NF | Y F | Y NF | N | Y NF | Y F |
| Were the power relations shifted towards the children? (yes / no) | Y | Y | Y | Y | Y | Y | Y | Y | N | N | N | N | Y | N |

*Note.* *JI – junior infants, SI – senior infants, FC – first class, F – frequent, NF – not frequent, Y – yes, N - no

No children in class M showed norm-referenced gains (Table 2). Rather, decreases in norm-referenced performance in both receptive language and expressive language dimensions were noted in this class. The teacher of class M was observed not to shift power relations in favour of the children, namely she posed many closed questions and was observed to discourage pupils' contributions during, for example, story reading. The enabling of the expository type of language was not recorded in this class on any occasion. Thus, although some gains in participation and responsiveness were observed in this class, these gains were shown only when the teacher was actually wearing the microphone. There were no long-term language gains in expressive or receptive language modalities in this class.

## Discussion

A number of factors must be discussed when analysing the finding that gains were larger in classes in which SFA was installed at the start of the junior infants year. These relate to the neuromaturation of the auditory system, classroom noise levels and the schooling effect. Firstly, children younger than 5 years of age are likely to have less mature listening skills due to an unfinished process of neuromaturation of the auditory system than the older pupils from senior infants and first classes (Gil-Loyzaga, 2005; Moore, 2002). More complex cortical processing of auditory stimuli that allows for greater speech perception in noise is formed during later childhood identified as occurring between 5-12 years of age (Moore, 2002). Secondly, noise levels are likely to be higher in junior infant classes, partly due to the use of more active teaching methodologies. One can thus predict that an improved signal-to-noise ratio (SNR) is likely to bring benefits to language learning in particular in classrooms with poorer listening conditions (e.g., with more internal noise generated). Thirdly, it is now generally recognised that children experiencing socioeconomic exclusión are more dependent on a good quality early education setting in their development than their more advantaged peers. One might argue that the results of this study partly reflect the impact of the first year of schooling on the development of these children. This hypothesis would imply that children living in areas of socioeconomic exclusion improve their language performance in comparison to norms for age in their first year of schooling (age 4-5).

The fact that classroom sound field amplification proved supportive to individual children within individual classes and not to the whole sample studied does not prove that this intervention is not beneficial. Rather, it proves that sound field amplification can be beneficial for some children and in some situations, i.e. under certain conditions. This finding emphasises the need for more contextual approaches to evaluating the efficacy of the classroom amplification systems, which shift perspective from the intervention per se to the setting into which the intervention is introduced. Interestingly, if one adopted a cluster approach (i.e. a whole simple approach) in the current study, gains (large, incremental or marginal) would have shown on all language dimensions observed in the classrooms. However, when one analyses individual classes, the evidence of gains presents a more complex and varied picture. While an attempt was made to find common distinctive factors in the classes in which the effect of SFA was maximised and in those in which this effect was minimised, it is equally possible that the observed class effect was related to factors that could not be observed. One such factor that could mediate the effect of SFA is the teacher expectations for the class. It has been argued by many researchers that it is the teacher's expectations for the *whole class* that has a greater impact on pupil achievement rather than the teacher's expectations for individual pupils (Weinstein, 2002).

The absence of language gains - or the observed deterioration in norm-referenced performance - observed in some classes must be interpreted in the context of the unique characteristics of the studied children who experienced socioeconomic exclusion (DEIS

schools) and potential language difficulties. It is possible that the intervention prevented difficulties for participants who made no perceptible progress in some language dimensions. Furthermore, it is worth remembering that when it comes to evaluating early interventions, it may be difficult to capture the clear-cut outcome changes, as early intervention is expected to prevent problems in the first place.

It is recognised in this study that a range of conditions need to be met for language development to take place, with an improved hearing canal being only a one single contributor. While it is recognised that classroom sound field amplification may be limited in its more direct impact on expressive language, the results of this study suggest that this intervention has a clear potential to aid the growth of the comprehension in the classroom. This is evidenced by clear and statistically significant gains in the dimensions of receptive language and classroom participation. In the speech and language development literature, there are not many language interventions that were found to be beneficial for receptive language and not many language interventions that actually target receptive language (Law et al., 2004). It is understandable that the evaluation of the classroom amplification technology should not be with a view to replace any clinical language interventions. It should not be understated, however, that this educational tool, as opposed to direct speech and language interventions, has a potential to augment the comprehension of language in one of its key naturalistic settings and language comprehension is central to the development of both expressive language and literacy. The relative absence of gains in expressive language most likely reflects the 'weaknesses' of classroom sound field amplification as an educational intervention that does not target any specific language areas but the listening channel. It is possible, however, that greater gains for receptive language than for expressive language observed in this study could be also due to a relatively short period of the intervention, which was insufficient to impact greater on expressive language, as well as to potential linguistic biases of standardised tests used for the assessment of expressive language, a language modality that is usually considered to be more susceptible to linguistic biases in a static assessment than receptive language.

The findings presented in this study support the hypothesis that classroom sound field technology can aid classroom language learning of children with language difficulties from infant and first classes in urban designated disadvantaged schools in Ireland. As this study showed, however, this hypothesis can only be true under the assumption that this technology is brought into a system whose other elements are not operating in opposition to the goals of this intervention. The benefits of this intervention are hindered when the elements of the classroom system, specifically related to the quality of language teaching, are not 'aligned' with the goal of this intervention, i.e. if they do not support the child's language learning. One must recognise that the effect of classroom sound field amplification is not 'a given', i.e. narrowly deterministic. Rather, this effect is actively constructed by the teachers and constructed differently in each classroom. These findings have implications for the conceptualisation of the efficacy of other educational resources in the classroom and call for more interrogation of theory in

studies examining their efficacy.

Foster-Fishman, Nowell & Yang (2007) note that intervention in only one part of the system can bring the desired outcomes only if concurrent changes occur in other parts of the system. The complex dynamics of multi-level social settings has implications for the validity of interventions introduced in the school context, or in fact in any non-clinical setting. As Downes (2007) observes, the recognition of a presence of supporting background conditions that contribute to the efficacy of the 'cause' was acknowledged already by Mill (1872), and reiterated by Rutter (1985):

> It is commonly but wrongly assumed that a significant main effect in a multivariate analysis means that variable has an effect on its own. It does not. What it means is that there is a significant main effect for that variable, after other variables have been taken into account: that is not tantamount to an effect in the absence of all other variables (p. 601).

Systems theorists argue that resources are insufficient to bring about a change in the system without 'healthy' working social processes (Tseng & Seidman, 2007). The classroom sound field amplification system can be considered a resource; its power is insufficient on its own. It needs to be linked with social processes, most critically, with good quality teaching. One must recognise the existence of infinite and largely unstated auxiliary hypotheses that need to be met in order for any one hypothesis to show true value (Quine, 1953). This view recognises that negative results do not necessarily fault the articulated hypothesis (Gergen, 1982, p. 8), but that some background conditions (hypotheses) might have hindered the expected outcomes.

There are a number of limitations that qualify the findings of this study. Maturation effect must be acknowledged as data collection took place over one academic year. It is important to note, however, that no language gains observed in this study can be simply attributable to maturation as varying intervention outcomes were observed for different clases and grade levels. One cannot assume that maturation was relevant to those classes that made gains and not relevant to those where negative outcomes were noted. It is likely that the presence of the researcher videotaping the lessons modified the behaviour of both the pupils and the teachers, a phenomenon known in participant research as the Hawthorne effect. Participating children did not receive medical screenings and their history was not known in relation to hearing impairments, including potential periodic (fluctuating) hearing difficulties. Finally, the acoustic qualities of individual classrooms were not formally measured in terms of reverberation time and noise levels.

This evaluation showed that gains tended to be present in certain classes and absent in some other classes at the same grade level, a finding indicating a teacher effect. Given a possible teacher effect, it is recommended that future researchers studying sound field amplification technology evaluate its effect on the same class but with different teachers and in different classrooms, e.g., across a few academic years. This would enable an

exploration of whether the benefits of this intervention are carried over to other classes and of what happens when children change classrooms and teachers.

A large majority of classroom amplification studies to date are based on a linear view of development. This study initiated a systemic approach in the current literature on this intervention. There is a need to develop it further by focusing on strengths and weaknesses of this intervention and the elements supporting and hindering its efficacy. While this study revealed a somewhat obvious - yet ignored by previous researchers - link between the teaching and the sound field amplification systems, future researchers may focus on specific dimensions of teaching that support the efficacy of this classroom intervention in relation to language. Such dimensions of teaching that require further investigation in the context of sound field amplification systems include the scale of teacher-led language in a lesson, the questioning approaches of teachers such as frequency of use of open-ended questions and higher order questions, degree of scope for pupil initiated questions and responses, dialogic reading techniques, adoption of role play and shifting of power relations in favor of the pupils. Future research would also benefit from examining the role of sound field amplification systems over a longer timeframe, in wider cultural contexts and also at preschool level for pupils experiencing poverty and socio-economic exclusion.

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