



Listening to Learn

**An Evaluation of Classroom Audio Distribution Technology for
Enriching Teaching and Learning**

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Executive summary

This report covers the findings from a research project designed to help teachers of professional development to promote teacher confidence and competence in developing strategies in both traditional and collaborative learning contexts. The aim is ultimately to assist schools in improving their achievement record by taking a fresh look at their professional practice based on teachers' action research observations.



Overall 22 schools, 12 primary and 10 secondary, from four West London boroughs Hertfordshire, Dudley, Northamptonshire, Manchester and Devon in England as well as 2 primary schools from Scotland are involved in this research. In the first stage from 2008-2014, REDCAT Classroom Audio Distribution (CAD) systems were installed in classrooms where traditional teaching techniques were being investigated. The second stage of the research that started in 2013 was undertaken by teachers experimenting with collaborative learning techniques and how to assess the results of group working. This second stage is still on-going but the emerging trends are also reported here.

In this study researchers have provided teachers and students with frameworks to help them explore the impact of two innovative technologies in the classroom and to draw their own conclusions about what works and what does not. The two audio distribution systems, REDCAT and FLEXCAT are developed by Lightspeed Technologies who commissioned this research from the MirandaNet Fellowship, an international professional organisation of educators and researchers who specialise in working with senior managers and teachers to effect the changes they want to see in education. REDCAT in the traditional classroom.

The first stage of the report focused on the REDCAT. This CAD system was designed because research studies over the last twenty years have shown that the learning of a surprisingly high percentage of children is impaired because they cannot hear their teacher well enough. The need for such a system was validated by the observations of 58 teachers in schools where REDCAT systems had been installed for a year with:

- 91% of teachers agreeing that their students are able to hear and understand instructions better;
- 79% of teachers agreeing that their students learn faster;
- 84% of teachers agreeing that their students' attention increases;
- 78% of teachers agreeing that their students' overall achievement improves;
- 71% of teachers agreeing that classroom management is easier;
- 77% of teachers agreeing that their students benefit from using a microphone when speaking to the whole class;
- 55% of teachers agreeing that they experience less vocal strain;
- 88% of teachers wanting to keep the REDCAT system in their classroom.



The large majority of the 554 students involved in the trial also valued the system highly:

- 70% of students agreeing that they can hear and understand their teacher better;
- 64% of students wanting to keep the REDCAT system in their classroom.

These statistics, show that at least 90% of teachers agree that their pupils were able to hear and understand them better when using the technology, thus strongly supporting previous quantitative research studies undertaken by other academics.

In the next phase focusing on traditional teaching techniques researchers concentrated on qualitative case studies of changes in professional practice. In the results, teachers agreed that students learnt more in the traditional sessions underpinned by the REDCAT device in five important areas:

- Improved hearing and understanding of teacher instructions;
- Improved on-task behaviour;
- Improved attention and engagement in discussion activities;
- Improved ability to follow directions;
- Improved self-confidence of pupils when speaking to the whole class.

For teachers, the professional benefits of the REDCAT system were judged to be:

- A need for fewer repetitions of instructions;
- Less vocal fatigue and tiredness;
- Improved ability to control and manage the class, leading to better behaviour;
- More time to support individual and small groups of learners.

The conclusions of the first stage of this research indicate how managing the environment is in promoting learning. The results indicate that by equipping classrooms with appropriate technology senior managers will be able to make an impact on levels of achievement throughout the school. These results indicate potential for the raising of measurable achievement that could also be used by senior managers as evidence of learning in Pupil Premium and OFSTED reports.

FLEXCAT supporting collaborative learning



The second stage of the research concentrates on improving collaborative learning techniques. In the first phase of this study the FLEXCAT, the new audio distribution system that complements the REDCAT, was

trialled in 6 schools across England and Scotland. This device retains the high quality speech intelligibility achieved by the REDCAT whilst also allowing the teacher to support more effectively small group collaborative teaching through the use of up to 6 audio pods that can be distributed around and outside the classroom.

The results from this first phase were:

- Teachers and students enjoyed the immediate and on-going improvement in speech intelligibility throughout the classroom;
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- Classroom management was improved with students settling to work more quickly as a result of hearing instructions clearly the first time;
- Increased on-task behaviour was achieved as a result of student's knowing that the teacher could unobtrusively monitor their group discussions at any time;
- Teachers reported that they heard contributions from students that they would not have expected from them, helping improve the quality of their feedback and lesson planning;
- Teachers were able to provide timely interventions to individuals and small groups without disrupting the whole class;
- Students were more able to share their ideas and progress achieved with the whole class;
- Teachers were able to maintain contact with groups working outside the classroom thereby making maximum use of the space available for learning;
- Difficulties with the design and performance of the prototype technology prevented teachers and students from gaining the full potential from the FLEXCAT systems.

The first phase results have informed the second stage, the full results of which will be reported at the end of the research stage. However the trends that are emerging already suggest that this technology that supports the development of collaborative learning has much to offer.

The second phase of the research programme, using the technically improved FLEXCAT system has confirmed the trends highlighted from the first phase research and identified some new trends. The key trends are as follows:

- Assured high quality speech intelligibility and the use of six pods is allowing teacher to make maximum use of learning spaces including those outside the classroom;
- Students are increasingly remaining on-task when engaged in small group collaborative activity as a result of the teacher being able to unobtrusively monitor discussions. This is increasing teachers' confidence in the frequency they can employ this highly effective learning style;
- The flow between whole class and small group working is easily managed;
- The quality of formative assessment of student contributions to small group discussion has improved significantly and teachers are increasingly able to provide more specific well-targeted feedback to individuals and small groups of students;
- The speed at which well-targeted intervention can be given is raising the quality of group discussions and the pace of learning overall;
- Teacher use of the pods is resulting in fewer disturbances to students not needing to hear interventions;
- Use of the pod call button is minimising the time when students waste time waiting for teacher support;
- More frequent use of student reporting to the whole class is occurring because of the availability of the pod microphone;
- There is growing evidence that students with profound hearing loss are benefiting from the use of the FLEXCAT system;
- Trial schools are beginning to invest in the technology as they see the results of its use to support effective whole class and small group collaborative teaching and learning.

Many of the technical challenges of the FLEXCAT system identified in Phase 1 have been overcome. However, in response to the teachers' and students' feedback further work is being carried out to improve technical issues like the speed of response of the handset and the clarity of the pupil's voice through the pods.

These collaborative techniques will now be more important in school internationally because new PISA criteria for the International Organisation for Economic Co-operation and Development (OECD) emphasises the value of group learning and collaborative problem solving alongside scores for individual achievement.



Conclusion

Most of the teachers taking part in this research project were unaware of the variability of the sound field experienced by many learners in classrooms, not just those with hearing challenges. Installing the REDCAT CAD system is shown here to have significant impact on achievement in all kinds of classrooms. However, the teachers involved have now turned their attention to innovation. The trends that are emerging so far suggest that not only traditional teaching can be improved but also the skills of collaborating and sharing can be enhanced by the judicious use of systems that extend and enrich teachers' access to classroom exchanges. What is valuable for teachers in this study is the detailed description of methods of improving teaching practice in order to improve the learner experience.

N.B .The validity and reliability of the research findings

Because creating a good sound field in classrooms is clearly an important factor in improving achievement in schools, Lightspeed Technologies, a learning organisation, has partnered with professional educators in schools to research and develop their product with the MirandaNet Fellowship, founded in 1992. This professional organisation with nearly 1,000 educator members in education in 80 countries has an international reputation for researching the value of technologies in improving teaching and learning. The members' aim to use their findings to enhance teaching and learning strategies and embed change in practice in collaboration with senior management teams.

These change management strategies are achieved through the iCatalyst programme a method of continuing development in which the MirandaNet team works with teachers as co-researchers. In this partnership with professionals, companies who are committed to learning, ensure that the research they commission is appropriately designed and executed, valid and reliable. In addition teachers and associates gain knowledge and experience through the iCatalyst programme that they can transfer to other learning contexts.

Learning and Listening

An Evaluation of Classroom Audio Distribution Technology for Enriching Teaching and Learning

Context and background

This report focuses on a research project that is designed to provide teachers with ideas to improve their strategies in both traditional and collaborative learning contexts. The aim is ultimately to assist schools in improving their achievement record by taking a fresh look at their professional practice based on research findings.

In this study researchers have provided teachers with frameworks to help them explore the impact of two innovative technologies in the classroom and to draw their own conclusions about what works and what does not. In the first stage of this research, from 2008-2014, REDCAT Classroom Audio Distribution systems were installed in classrooms where traditional teaching was being investigated. Both systems have been developed by Lightspeed Technologies.

The second stage of the research was undertaken by teachers who were sharing ideas about collaborative learning techniques and how to assess the result of group working. This second stage is still on-going but the emerging trends are also reported here.

Educational research partners

Because digital technology is becoming an important factor in improving achievement in schools, Lightspeed Technologies have partnered with the MirandaNet Fellowship, founded in 1992. This professional organisation with nearly 1,000 educator members in 80 countries has an international reputation for researching the value of digital technologies in teaching and learning.

These change management strategies are achieved through the iCatalyst programme a method of continuing development in which the MirandaNet team works with teachers as co-researchers. In this partnership with professionals, companies who are committed to learning, ensure that the research they commission is appropriately designed and executed, valid and reliable. In addition teachers and associates gain knowledge and experience through the iCatalyst programme that they can transfer to other learning contexts.

The underpinning technology

REDCAT provides Classroom Amplification Technology to schools that are designed to improve hearing in classrooms. The all-in-one audio system is to distribute sound evenly and intelligibly throughout a room. The elements of the system include a speaker, amplifier and receiver. The flat-panel speaker clarifies vocal-range frequencies that also help students to learn language.

Since 2011 the company has been developing a new audio distribution system that complements the REDCAT, called the REDCAT ACCESS/FLEXCAT that uses ACCESS Digital Audio Technology and supports the development of collaborative learning disciplines. ACCESS technology enables rich two-way communication and is scalable to meet evolving instructional and technology needs. The FLEXCAT retains

the high quality speech intelligibility achieved by the REDCAT whilst also allowing the teacher to support more effectively small group collaborative teaching and learning through the use of up to six small pod systems containing a microphone and speaker that are distributed to each group around the classroom. The pods allow the teacher to monitor student discussion, re-direct or compliment when appropriate and allow students to share their ideas with the whole class.

In 2013 small-scale research trials of the first models of the FLEXCAT were undertaken in the UK. Feedback from teachers and pupils led to the introduction of a second version of the FLEXCAT in February 2014. This new version has now undergone its preliminary trials that are now producing emerging trends.

Literature Review

The research literature demonstrates the critical importance of speech intelligibility and listening on learning and pupil performance in schools. Research studies over the last twenty years have shown that the learning of a surprisingly high percentage of children is impaired because they cannot hear their teacher well enough. Typically this is as a result of a range of affecting areas, the primary causes include:

- Teaching and learning being conducted in spaces with unsatisfactory acoustics and poor speech intelligibility, e.g. high reverberation and/or high levels of external and/or internal noise (Earthman, 2004);
- Teachers' with quiet voices with a reduced intelligibility critical distance who are unable to project across the classroom (MARRS, 1979–1993; Munier and Kinsella, 2008);
- Little awareness of the need for pupils to hear clearly in order to fix what they hear into long term memory– 'muddy in, muddy out' (Kilgard and Merzenich, 1998 reported in Doige, 'The Brain that Changes Itself', 2007).

Too little awareness:

- Of the level of signal to noise ratio (SNR) pupils require in order to hear intelligibly because of the immature neurological system they bring to the listening situation that is, in turn, due to their higher auditory brain centre not being fully developed until around 15 years of age (Crandell and Smaldino, 1987; Bhatnagar, 2002; Chermak and Musiek, 1997, Werner, 2007);
- That pupils have a developing rather than mature vocabulary and require a strong signal to hear new words clearly and to support them in undertaking complex tasks (Howard, Munro and Plack, 2010);
- That in lessons where the SNR is low pupils expend too much energy on trying to hear and understand leaving too little energy to apply to the set tasks (Howard, Munro and Plack, 2010; Baumeister and Tierney, 2011);
- Of the impact excessive noise has on pupil learning to the point of 'learned helplessness' (Dockrell and Shields, 2006 and 2008; Klatte, Lachmann and Meis, 2010, Gertel, McCarty and Schoff, 2004);
- Of the extent to which pupil hearing impairment is common, particularly in pre-school and primary pupils (MARRS, 1979–1993).

Research shows that this is not only a particular problem for pupils with intrinsic hearing difficulties or those caused by illness or infections, but also for others in the special needs cohort and those for whom English is an additional language and also many children in the normal ranges of hearing and language proficiency (MARRS, 1979–1993; Klatte, Lachmann and Meis, 2010).

What is becoming increasingly clear from the research is that even in classrooms with good acoustics, not all pupils receive intelligible speech all the time, and even those that are in close proximity to the voice

signal can enjoy a significant increase in the number of intelligible words they receive when CADs technology is installed in the classroom (Ostergren, 2011). For some years this deficiency has been easily rectifiable (other than where reverberation times have been extreme and acoustic materials have needed to be introduced initially), by installing classroom audio distribution systems (in the UK commonly referred to as 'soundfield' systems). A number of such systems are widely available from a range of manufacturers including Lightspeed Technologies, Phonak, Connevans and PC Werth. Systems commonly use either infrared or FM technology to transmit the teacher's voice and either comprise a single mobile speaker or four or more fixed speakers. For example, LightSpeed's REDCAT system at its simplest comprises a lightweight infrared microphone for the teacher and a portable distributed mode (Exciter Technology) flat-panel speaker normally placed towards the back of the classroom or in the ceiling (a Topcat version). Pupils can also use a second hand-held microphone. The microphone's infrared beams distribute the teacher's or pupil's voice across the classroom and the speaker re-distributes the signal from the back of the classroom thereby surrounding all pupils with a very clear and intelligible speech signal that is sufficiently louder than any background noise, i.e. +15-20db. The microphone user can be clearly heard even if they have their back to the class as when writing on the board.

Both quantitative and qualitative research into the effectiveness of soundfield systems has been going on for the past twenty years. The research has identified significant benefits to pupils and teachers in the following broad areas:

- Improved classroom management and efficient use of lesson time (Allen and Patton, 1990a; Rosenberg, 2004; Flexer, 2005);
- Improved language comprehension, listening skills and task completion (Rosenberg et al., 1999; Flexer et al., 2002);
- Improved speech intelligibility for HI (hearing impaired), SEN and EAL pupils (MARRS Study 1979-93; Crandell, 1994 and 1996; Klatte et al., 2002; Harmer, 2007);
- Improved academic achievement (Flexer, 2002; Chelius, 2004, Gertel et al., 2004);
- Improved teacher health and wellbeing (MARRS 1979-93; Gertel et al., 2004; Rosenberg, 2004).

An important aspect of this project has been to make these important research findings more accessible to mainstream teachers as well as LSAs (Learning Support Assistants), SENCOs (Special Needs Co-ordinators) and those involved with English as a Second Language.

Methodology

The methodology of engaging professionals in this research project has developed because Lightspeed Technologies are an associate of the MirandaNet Fellowship professional organisation founded in 1992. The 1,000 Fellows in 80 countries are researchers and educators specialise in partnering companies in the research and development of digital learning products.

At the core of this partnership is the MirandaNet iCatalyst programme, a bespoke professional development programme that focuses on strategies that support the leadership and the management of change. In the programme leaders of the schools are involved in the collaborative development of an action research programme to collect evidence of learning in the classroom working with their colleagues. The outcomes can include: accreditation for programme leaders of the programme; professional development for all the staff involved; local evidence of improved learning and other benefits to use in reports for Pupil Premium and Ofsted, key sources of funds in the UK; and case studies and articles for school publications as well as the MirandaNet website that enjoys international readership by teachers seeking to improve their professional performance and enrich classroom practice.

The iCatalyst programme is based on a variety of findings from research and development projects run by Fellow. Associate multinationals like Apple, Microsoft and Oracle as well as small and medium sized developers have also gained from the teachers findings (Preston 1995: 2005; 2013 a/b). What has emerged in these projects is the complexity of the ways in which teachers now learn and share. Action research has underpinned MirandaNet theory and practice from the first: Somekh (1995) developed Schön's action research approach (1983) with particular reference to professional learning in digital technologies. Somekh gave early MirandaNet workshops in action research emphasising the constructionist approach to teachers' learning that MirandaNet Fellows subscribe to. In the UK government funded research has shown how effective professional development can be if teachers are engaged in projects that relate to their own classroom (Davis, N. E., C. Preston and I. Sahin 2009 a/b). Over the years action research methodology has been refined and developed as informal professional learning, particularly in groups and on the internet, is beginning to emerge as a factor just as opportunities for formal learning become more fragmented (Daly Pachler, Pelletier 2009: Daly, Pachler, Pelletier 2010: Pachler, Preston, Cuthell, Allen and Pinheiro Torres 2011).

In this study MirandaNet Fellows provided advice on the methodologies used in observing teaching and learning and in data collection and analysis. A critical review and evaluation of progress was undertaken in April 2014 and has included a triangulation meeting with the Lightspeed and MirandaNet researchers and teaching staff at UCL Academy who were involved in the trial of the first version of the FLEXCAT. This evaluation has provided recommendations for phase two of the research programme in which qualitative methods like critical incident research will be employed (Preston and Cuthell 2007).

The timeline

Stage 1 research into the use of REDCAT was conducted between 2008-2014 in schools to investigate the impact on traditional classroom techniques of using Lightspeed Technologies REDCAT in England following on from its introduction into the USA and Canada and research carried out there on its impact on teaching and learning (see references in the Literature Review).

There were two phases to this research programme: Phase 1 quantitative data collection from 2008 – 2009 followed by Phase 2 qualitative case study work with the practitioners.
Stage 2 research into collaboration in learning using the new FLEXCAT CAD system overlapped with Stage 1, starting in the summer term 2013, and is on-going.

The research sample

The sample of schools used in this research included both primary and secondary and covered use with teachers, pupils, SENCOs (Special Needs Co-ordinators) and LSAs (Learning Support Assistants). In total, 22 schools were included in the research sample from 2008-2014, which consisted of 12 primary schools and 10 secondary schools. A total of 68 teachers were involved, which constituted 33 primary school teachers and 35 secondary school teachers. With respect to pupils, there were a total number of 715 pupils across the sample of schools, with 523 pupils from primary schools and 192 pupils from secondary schools.

The original Stage 1 REDCAT school-based action research programme undertaken in the academic year 2008-09 involved 7 primary and 7 secondary schools primarily from four west-London boroughs with one secondary school from Devon. Detailed feedback was received from a total of 58 teachers (28

primary and 30 secondary) who had trialled the REDCAT for at least one term and from 554 students (395 primary and 159 secondary).

Phase 2 of Stage 1 involved some of the same schools after Phase 1 had concluded. It involved post-trial teacher group and pupil group interview/discussions where their responses to the teacher evaluation questionnaire could be filled out and explored in more detail.

Stage 2 Phase 1 of the research into the effectiveness of the FLEXCAT CAD system in supporting small group collaborative learning involved 4 primary and 2 secondary schools from across England and Scotland. It ran from June 2013 until July 2014 and detailed feedback was received from 4 primary and 4 secondary teachers and a secondary special education needs coordinator (SENCO) and 128 primary and 33 secondary students.

Phase 2 of Stage 2 that is using the latest version of the FLEXCAT CAD system started in September 2014 and has involved three schools, one primary and two secondary Academies. Both secondary schools were involved in Phase 1 of the FLEXCAT research programme. A total of one primary teacher and six secondary teachers have trialled the system in the classrooms and detailed feedback has been received from all but two of the secondary teachers. Feedback has also now been received from 19 primary and 16 secondary students.

Methods of data collection

The research methodologies adopted in the Stage 1 REDCAT action research study and those used in the recent Stage 2 FLEXCAT action research studies have much in common and focused on classroom observations, teachers interviews and questionnaires undertaken with the teachers, pupils and where relevant SENCOs. The importance of lesson observation and post-lesson analysis with the teacher (respondent validation) become clear through the Stage 1 study resulting in greater emphasis being placed on this aspect of the research in the FLEXCAT research programme. Interview/discussions were conducted with teacher and pupil groups following completion of Phase 1 of the Stage 1 research programme. Some of the interviews were filmed as a means of collecting and saving information.

The methods that were selected to collect the data from each case study school increasingly involved the systematic use of classroom observations, teacher interviews and questionnaires, with the latter being distributed to both teachers and pupils. Also, where relevant, a questionnaire was also distributed to SENCOs and LSAs (learning support assistants). Stage 2 lesson observation reports once written were shared with teachers in order to reach agreement on their accuracy.

Questionnaires

Well-designed questionnaires were a good way of establishing base lines about the value of the technologies in traditional and collaborative teaching techniques. The questionnaires were distributed to teachers and pupils and collected during each case study visit to ensure maximum completion rates. The questionnaires were written as a type of evaluation form, which focused on the impact of the technology and how it supported the lesson activities. The questionnaire used Likert scales (originally devised by R. Likert in 1932), which provided a ranking system, which ranged from 1 to 5 and ranks the participants response to a statement that ranged from strongly agree, agree, neutral or satisfactory, to disagree and strongly disagree. The use of the Likert scale is a useful research device 'to discover the strengths of feeling or attitude towards a given series of statements' (Bell, 2005: 142). As the questionnaires are all worded the same this helps to build reliability in the research across the multiple case study schools.

The questionnaire, therefore, consisted of a series of statements, which the teachers and pupils were invited to rank, provided data that could be quantified concerning the impact of the technology on the lesson activities. This data enabled patterns to be identified and could be clearly presented in graph format.

Classroom observations

The opportunity to conduct classroom observations was important in that it provided direct access to viewing the use of the technology in a classroom setting and as a research method it provided the unique 'ability to spot significant events' (Nesbitt 1977, p15).

Denscombe (2002, p194-5) advocates the use of an observation schedule, which enables systematic observations across all lessons observed since it provides a framework for observation, which the observer can use every time and also other observers can use. An observation schedule can take the form of a checklist, a chart, a grid or critical incidents log, which is developed for the specific purpose of recording the impact of the technology in the classroom. The observation schedule then enabled the researcher to use a systematic recording process for each and every observation that was undertaken. As a participant observer, the researcher had to be aware and constantly look out for possible signs of bias. In order to overcome bias, one solution is to have another researcher also observe the lessons, which thereby offers investigator triangulation, as researchers can compare their observations and build more reliable data. With respect to this research this was partially achieved through the researcher comparing his observations with that of the teachers observations of the same lesson. This helped to build up reliability with respect to the data that was gathered during the lesson observations. This aspect was also enhanced in Spring 2014 when two more MirandaNet senior researchers conducted a school visit and were able to conduct teacher interviews and observations of classroom activities with the technology. This enabled the collection of data, which could then be triangulated against the data previously collected by the associate senior researcher from the same case study school, and was thereby able to enhance the reliability and validity of the research findings.

Three sets of observations were cross-referenced. As a result the key findings were verified and reported here in the findings section of this evaluation report of Phase 1 that was conducted between 2008 and 2014.

Types of Triangulation

The research adopted the strategy of triangulation in order to increase its internal validity, which is considered vital by academics (Yin, 1994). With respect to triangulation Denzin (1970) identified different types of triangulation, which guided the researcher:

- *Data triangulation*; involves data collected over a period of time, from more than one school and from more than one person. The longitudinal nature of the research combined with the variety of schools and numbers of teachers permitted the researcher to engage in data triangulation;
- *Investigator triangulation*; involves the use of more than one observer for the same object (lesson) and can also involve respondent checks (checking with the teacher after the observation). The use of respondent validation (teacher checks) was integral to ensuring investigator triangulation. The researcher undertook this with the teacher after every observation;
- *Methodological triangulation*; involves the use of more than one method of obtaining information. The researcher's use of interviews, observations and questionnaires ensured methodological triangulation. Hence the findings from one source were triangulated with alternative sources as a way of bolstering confidence in their validity.

Verifying conclusions

In verifying conclusions, triangulation is important for ensuring reliability and validity. The use of multiple methods, which has included lesson observations, teacher interviews and questionnaires conducted with both teachers and pupils, has enabled data to be collected that then can be triangulated.

The conclusions drawn from the data were verified in accordance with the guidelines (tactics) provided by Miles and Huberman (1994, p28). The guidelines for ensuring reliability and validity were employed in the following ways:

- *Check for representativeness*: When a category, theme or issue had been identified, checks for representativeness were conducted by looking for evidence of the category across more than one data source;
- *Check for research effects*: in order to minimise the effects of the researcher, a variety of data collection methods were established;
- *Triangulation of data*: the cross-checking of data from interviews, observations and questionnaires bolstered the study's internal validity;
- *Weighing the evidence*: Analysis of the data proceeded by simultaneously examining different forms of data, and identifying the relationships between them. Hence, evidence was 'weighed up' in the light of data from other sources.

Teacher interviews including critical incidents

The use of teacher interviews enabled triangulation to occur with respect to the other methods that were also employed. It also enabled the collection of qualitative data and provided more in-depth responses from teachers. Bell (2005, p157) argues that the major advantage of the interview is its adaptability, which means that the interviewer can follow up ideas, probe responses and investigate key issues in more depth than is possible with a questionnaire. In addition, it is the case that questionnaire responses have to be taken at face value, but responses to interview questions can be probed and developed to gain a deeper understanding in a way that is not possible with a questionnaire. In addition critical incident responses have been requested in which the teacher offers an anecdote about a significant moment in teaching that was a turning point in reflection and practice (Preston and Cuthell 2007)

Case study schools: foci for research

In each case study school the following aspects needed to be considered and then systematically recorded. First, the **space** in which the technology was installed, with a view to identifying the key characteristics of each learning space in which the technology was used. Second, the **curriculum** areas in which the technology was used which refers to the subjects being taught by the teacher. Third, the **pedagogic framework** that was implemented with regards to the learning and teaching activities that were undertaken in the lesson using the technology.

Case study research design

Each school that was used in the research constituted a case study, which is an appropriate approach for researchers as it provides an opportunity for focusing on one specific aspect in depth.

Multi-site case study design

The research design that was developed was that of a multi-site case study. The case study approach is the most effective research strategy to use when the aim is to understand in depth a situation, or aspects of a situation and the interactions of people, technologies, events, structures and processes (Yin, 1994; Marshall and Rossman, 1995; Gomm, Hammersley and Foster, 2000; Denscombe 2003).

The purposes of the multi-site case study in this research were:

- Analysis, explanation and the development of an in depth understanding of an issue (implementation of Lightspeed technology) in one setting, i.e. the case (school);
- To use multiple case studies of similar contexts (schools) to develop understanding across several cases, which is to engage in the 'constant comparative method' (Glaser and Strauss, 1967).

The decision to use the case study approach was a strategic decision and Denscombe (1998, p32) argues it 'does not dictate which methods must be used'. Indeed, the strength of this research strategy is the variety of methods that can be used. This case study approach incorporates a qualitative approach to data collection with a range of methods namely, teacher interviews and classroom observations, alongside the use of questionnaires, whereby the latter has a quantitative element (Denscombe, 2003).

Denscombe (2003) identifies three key reasons for the adoption of the case study approach. Firstly a case study can offer an in-depth study, secondly it enables a focus on processes and, it can provide multiple sources and multiple methods.

What the survey approach cannot do, but case study can, is to study things in detail. The main benefit is to deal with the subtleties and intricacies of complex social situations (Denscombe, 1998, p39) such as classrooms and learning.

The case study enables understanding of processes that is denied to the survey approach. The real value of case study is that it offers the opportunity to explain why. In this case, why the technology was adopted and was successful and why, when it wasn't successful, this occurred.

The seminal work of Yin (1994) on the case study approach also informed the research design with respect to data collection. Yin (1994) identified three principles of data collection, which can help to establish validity and reliability of a case study: principle 1, use multiple sources of evidence; principle 2, create a case study database and principle 3, maintain a chain of evidence.

Yin's (1994) first principle was adhered to in the following way: the research design built in multi-site case studies, which allowed for evidence from more than one case to be collected namely, multiple examples of cases (technology implementations across schools), and also multiple sources of evidence collected within each case study; from teacher interviews, questionnaires and observations. This allowed for a level of triangulation necessary for establishing validity and reliability in the research. Then a case study database was established in order to adhere to Yin's (1994) second principle. Next, the research was carefully recorded and data analysed, in the spirit of an audit trail, in order to maintain a chain of evidence, which adheres to the third principle.

Learning spaces

Throughout the research the technology was installed in classrooms that were average in size. There were two exceptions with respect to two newly built secondary schools, one of which had a super studio learning space. This space was an innovative learning area that comprised of a tiered lecture theatre in the central area with two 'break-out' teaching spaces each with 7-8 tables around which 6-7 pupils could sit. The super studio also incorporated the main corridor for teacher and pupil movement, which resulted in visual and noise distraction at times during lessons. The second was comprised of a very large teaching area where up to four classes can be taught at any one time. As with the first example, the

corridor for teacher and pupil movement to either side of the large space was through the middle of the teaching space.

In addition, some teachers used the technology beyond the classroom: some teachers had groups of pupils working outside of the classroom, for example, working in corridors or in adjacent rooms. Most importantly to the teachers, FLEXCAT enabled them to place pupil groups outside of the main classroom without losing oversight of what the groups would be doing.

In the next two sections the differing arrangements for the REDCAT and FLEX CAT set ups are described.

Application of research methods

The data collection methods outlined above were used in different combinations in Stages One and Two that are described here.

REDCAT research design

All fourteen schools, seven primary and seven secondary in the REDCAT study trialled the mobile systems for a minimum of a full term, with many trialling the equipment for two terms. REDCAT audio systems were set up in four separate classrooms in each school and teachers were encouraged to use the technology on a daily basis whenever they were engaged in whole class teaching.

Teachers were given detailed questionnaires in the form of 'evaluation forms' from the outset in order to help them focus on the impact using the system had on both their pupils and themselves. Lessons in all the schools were observed on a regular basis by an education researcher with each observation followed by a discussion with the teacher on their developing views about the impact the technology was having in the areas highlighted in the evaluation forms. The observer elicited the views of pupils at appropriate times during lessons as did the teachers throughout the trials.

The key impact evidence was sought in the following areas: quality of speech intelligibility in all parts of the classroom, class management and control, frequency of repetition of instructions, pupil learning behaviours, pace of learning, learning outcomes, maximising use of lesson time, pupil confidence when addressing the whole class, teacher's vocal comfort and energy levels.

Towards the end of the school's involvement in the research programme each of the 58 teachers was required to grade the statements of impact of the REDCAT on their pupils and themselves as set out on the evaluation form provided. The majority of the 554 pupils involved in the study also completed shorter evaluation forms. At the end of the research study teachers and pupils from two of the primary schools took part in videoed post-research discussions in which they were encouraged to say in their own words what they felt were the advantages and disadvantages of using the REDCAT system.

All statistical data and written and spoken evidence generated from the completed trials was used in the writing of a short research report.

All subsequent trials of the REDCAT in schools over the following five years involved the collection of feedback from teachers on the audio distribution system's impact on teaching and learning. On-going consultation with expert MirandaNet researchers throughout this period informed new ways to interpret

the results of the original research study and significantly influenced the shaping of a more sophisticated research model for the subsequent FLEXCAT research programme.

FLEXCAT research design

When the FLEXCAT research programme started in June 2013 only two Model 1 FLEXCAT systems were available for school trials in the UK. As a result once the first set of trials was completed in the summer term 2013, further trials were limited to approximately four weeks.

Once the findings of the trial evaluations of the version 1 FLEXCAT were completed, Lightspeed started work on an improved version in response to the teacher's views. Trials using Model 1 Flexcats continued whilst the new version was being developed.

Model 2 of the FLEXCAT became available in March 2014 and it was decided at that time to identify three regional Hub Schools where medium to long-term research could be carried out. The first of these, Manchester Communications Academy (MCA) was equipped with a version 2 FLEXCAT system in March 2014.

As with the REDCAT study, once installed teachers were encouraged to use the system as often as possible using all its modalities - whole class instruction, small group instruction, monitoring and intervention and small group sharing with the whole class. A revise evaluation form was used as the basis for collecting qualitative and quantitative data and opinion on the impact of the FLEXCAT system. Lesson observation and post-lesson discussion was a key feature of the research programme with observation and discussion notes being formally written up and distributed after each visit. Towards the end of each trial teachers were again required to complete the evaluation form and this, together with all other evidence, formed the basis of two quarterly reports.

In the summer term 2014, a research triangulation visit took place at UCL Academy involving the three MirandaNet senior researchers who were involved in the trial of the first version of the FLEXCAT. Lesson observations and subsequent teacher interviews were conducted with data written up by the project directors. Their report was then cross-referenced with the senior researcher's previous research reports, the result of which provided confirmation of the reliability and validity of both Stage 1 and Stage 2 research findings.

Stage 2 of the FLEXCAT action research study started in September 2014 in three Hub schools (Manchester Communication Academy, Manchester; UCL Academy, London; Greenfield Primary, Stourbridge, Dudley).

Summary of the methodology

The data collection methods were substantially the same although subjects in which the technology was used varied across the schools, however, these were predominantly either cross curricular or used for literacy plus English, maths, science and MFL (modern foreign language) lessons.

The pedagogic framework in which the researcher was working was important as the project was about different kinds of teaching and learning: traditional techniques and collaborative methods.

The types of teaching and learning activities that were predominantly used with the REDCAT and FLEXCAT technologies were whole classroom instruction, with the teacher leading from the front; small group work and discussion-based learning, which is referred to as a dialogic pedagogy. The use of a dialogic pedagogy is dependent upon multiple interactions between pupils with one another and between

pupils and the teacher. As a consequence, speaking and listening are the key skills and characteristics of this pedagogic approach. In the FLEXCAT research the pedagogical approaches are classified as 'whole class instruction' (WCI mode), 'small-group instruction' (SGI mode), 'small group monitoring' (SGM mode), 'small group redirection' (SGR mode) and 'small group sharing' (SGS mode).

The aim of the methodology section was to carefully describe the methods selected for the research and to outline a rationale for the methods chosen. This was a multi-site case study approach that utilized classroom observations, interviews and questionnaires, with both pupils and teachers, in order to conduct qualitative research aimed at understanding the processes and experiences of teachers implementing the Lightspeed technology in classrooms to enhance speech intelligibility. This has necessitated a detailed description of the methods used, in order to provide an audit trail, which would enable other researchers to replicate the research study. This triangulated research design and approach to data collection thereby enhances the validity and reliability of the research.

Findings

The key findings from the first piece of research with the REDCAT technology in 2008-09 have been incorporated into the following Whole Class Instruction (WCI) Mode section as they are in essence the same or very similar to the FLEXCAT research findings outlined below.

Key findings: model 1 FLEXCAT 2013

Through the deployment of the data collection methods outlined in the methodology section, the following findings for the research conducted on the use of the technology can be reported:

Whole Class Instruction (WCI) Mode

- Teachers and pupils recognized the immediate improvement in speech intelligibility.
- Fewer repeated instructions, with more time for small group learning and targeted support.
- 66% secondary to 77% primary pupils heard and understood instruction more clearly.
- 45% secondary to 53% primary pupils settled to work more quickly.

Small Group Instruction (SGI) Mode

Teachers rarely used this feature during the trial period.

Small Group Monitoring (SGM) Mode

76% secondary / 58% primary pupils remained much more on-task knowing the teacher could listen to their discussions.

- Teachers valued this feature but picking up a high quality speech signal through the earpiece from the Pod was unreliable and often of poor quality, usually dependent on the general classroom noise level generated by group discussions;
- Teachers and SENCO reported that they heard dialogue that they would never have heard without the FLEX CAT;
- Listening to group discussions from a neighbouring classroom resulted in higher quality speech signals being received;
- Teachers could more effectively monitor groups working and increased their confidence in placing groups of pupils outside the classroom.

Small Group Re-direction (SGR) Mode

- 64% secondary / 48% primary pupils less distracted when teacher was talking to other groups;
- Allowed the teacher to provide timely support and challenge to groups;

- Only useful when teacher was clear what pupils were saying and so able to respond appropriately (see SGM Mode).

Small Group Sharing (SGS) Mode

- 58% secondary / 54% primary pupils benefited from clearer speech intelligibility when colleagues were feeding back;
- 36% secondary / 35% primary pupils confidence in speaking to whole class improved;
- Pupils talking into the Pod can be counter-intuitive depending on where they are sitting in terms of distance from the Pod and the pupil's line of sight to the teacher. Student voices often lacked sufficient clarity to be intelligible to all – usually as a result of the pupil not being close enough to the Pod.

Innovation in pedagogy

Some teachers were very positive about the potential for innovation as a result of having a FLEXCAT system available. One said that as teachers became fluent in the use of the system they would experiment in the use of different styles of teaching and learning and would lead to better use of small group discussions, particularly in large teaching spaces. Other teachers reported that improvements in the system were necessary before they could envisage innovation.

Pupil increased lesson engagement

59% of primary school pupils reported that they enjoyed their lessons more when the FLEXCAT was used, with 65% of them wanting it to be used in every lesson. However, only 24% of secondary pupils enjoyed their lessons more and only 36% wanted the FLEXCAT in all their lessons. Also teachers reported that pupils stayed 'on- task' more.

Teacher voice strain

All teachers reported that they experienced less voice strain when using the FLEXCAT.

Ease of use and wish to keep equipment

Whilst some teachers found the equipment easy to use, others struggled with the equipment, which led to their reluctance to consistently use the system in its SGI, SGM and SGS modes. These teachers reported that they would not have wanted to continue to use the equipment whilst the problems they identified were unresolved.

Evaluation of equipment

The challenges and solutions for the technology developers are recorded here:

Remotes: Most teachers found the remote 'clunky' to some degree with slow button responses disrupting lesson flow during rapid Q&A sessions. The need to re-press the central button and new group Pod number each time a switch between groups was required became too frustrating for both teachers and pupils. One teacher reported that on occasions, when buttons were alight the associated signal did not consistently function. Some of these problems can be attributed to teachers' lack of remote control facility. Teachers need to devote sufficient time to practicing with the remote so that quick changes in settings become automatic. Teachers were happier with the remote when speed of reaction was not critical. Also, when both remotes were being used the second teacher had to be careful not to counter the remote settings of the lead teacher. Only when the lead teacher was not using the whole class button could the second teacher switch freely between groups to monitor and provide support.

Recommendation: Teachers would also welcome having some form of wrist strap for the remote control, allowing them to have both hands free when necessary without having to dispense with the remote.

Pods: Teachers and pupils liked the design of the Pods, as they took up only a small space on each table. Teachers needed to set out the Pods logically so that they knew the number of each Pod on each cluster of tables. Setting effective Pod volumes was judged to be tricky. Too high a volume could result in spillage of input to neighbouring groups, whilst too low a volume made it more difficult for the teacher to pick up pupil conversations sufficiently clearly to be able to monitor activity or for sufficient volume to be broadcast from the speaker when put in SGS mode. Also the number of pupils working together in a group resulted in differing levels of audition: a group of 4 pupils enjoyed better quality Pod activity than did groups of 6-7 pupils who were sitting further away from the Pod.

Recommendation: Improvements in the consistent quality of pupil voice pickup through the Pod microphone was seen as critical and would be greatly welcomed by teachers.

Also, attaching wheels, felt pads or ball bearing rollers to the base of the Pod might help in facilitating the movement of the Pod around table clusters was suggested.

Speaker: This was judged a very effective component of the FLEXCAT system by both teachers and pupils, delivering, as it did, a very clear and consistent teacher speech signal and, on occasions, a clear pupil speech signal. Dispensing with the wired connection to the base station will allow for greater flexibility in the placing of both pieces of equipment.

Headsets and belt pack: Whilst, in general, the headset worked well, teachers tended to 'fiddle' with it during lessons. Keeping the microphone boom close to the mouth meant regular readjustments were being made during lessons and the primary teacher reported soreness and some ear pain from wearing the earpiece for more than 90 minutes at any one time. This teacher feedback resulted in a much-improved microphone and earpiece in the V2 FLEXCAT that has resolved all the above issues.

No issues or negative comments were raised concerning the belt pack. however, teachers welcomed the plan to replace the headset and belt pack with a Redmike and earpiece solution.

Base station: The base stations functioned well throughout the trials.

Teacher professional development: Setting-up the equipment although relatively easy, may not always be the case, i.e. depending on the location of power sockets and space to set-up the base station and speaker, particularly whilst still needing to be wired together.

Whilst some training in the use of the equipment was provided at the time of setting up the systems, it was quickly apparent once the trials had started that teachers would have benefitted from more. Insecurity in the range of modes available, together with awkward handling of the remote control could all have been minimized if teachers had been clearer in these areas before they started using the equipment in lessons.

It is essential teachers recognize the need to practice using the remote control if they are not to struggle in lessons. Advice in limiting the use of the equipment to one or two modes at the start of the trials might have given teachers greater security and confidence from the outset. Giving simple tips such as being

methodical about the order in which to place the Pods and to have the Pod numbers facing the teacher would also have been beneficial.

Training: Teacher proficiency in using the technology was observed in order to discover simplifying techniques. Once installed in the teaching spaces a brief period of training of approximately 20 minutes in the use of the FLEXCAT system was given to the lead teachers in each school. This has subsequently been judged to be too short a time to ensure teachers fully understand the range of uses of the system, specifically the efficient handling of the remote control and the placing of the Pods. Subsequent trials have provided more in-depth introductions on the FLEXCAT system and this has reduced the concerns teachers have expressed in the handling of the technology in the early stages of the trials.

Trends: phase 2 model 2 FLEXCAT 2014

Whilst only two teachers, one the HOD in a MFL department in a secondary school and the other a Y2 class teacher in a primary school, have trialled the Model 2 FLEXCAT as part of the research programme, interview feedback and completed evaluations from both teachers are very positive.

The secondary teacher identified the following strengths of the improved system, 'Being able to listen to pupils speaking in the target language and when team teaching, being able to manage the class/deal with 'interruptions' without them needing to become interruptions to the lead teacher.' As reported pupils benefited from 'being able to ask questions without disrupting the flow of the lesson or having to wait for a teacher to come over to them'. Also, 'targeted intervention, differentiated input and broadcasting what tables say without a microphone' were all identified as positives.

The teachers valued being able to have conversations from far away without having to raise any voices. The 'general classroom noise level has decreased' and teachers reported the benefit of not needing to shout. Also, teachers said that 'the quiet pupils who are reluctant to put their hands up have been able to ask questions much more easily.' One teacher reported that, 'the hand control system is challenging for a teacher working without a colleague as it is one more thing they have to think about whilst trying to teach.'

The Y2 primary school class teacher reported that the biggest gains from the system were, 'being able to talk to small groups whilst working with another group during independent tasks to move their learning on further, or to help them to remain on task. Being able to listen to any groups working in the shared area, to check they are on task.' Her pupils benefited from, 'being able to use the feedback to the rest of the class clearly, especially to the hearing impaired child.' The 'children who needed reminders to stay on task and the hearing impaired child' particularly benefited from having the system in their classroom.' The one drawback she identified was, 'Children playing with the speakers on the table and being distracted by them e.g. trying to talk into them. As children become older, this will become less of an issue.'

Most importantly for Model 2 is that the problems associated with the Model 1 headset and teacher microphone, the lack of mobility of the system and the inability of students to draw the attention of the teacher when needing help are no longer issues being reported. Improvement in pod and headset technology have helped teachers hear more distinctly what pupils are saying in small group discussions and pupil's voices are clearer when addressing the whole class although teachers would welcome further improvement in these areas. Teachers are still reporting that the speed of reaction of the remote control when switching between pods is too slow.

Discussion and analysis

The system delivers very good speech intelligibility to all pupils through the speaker when they are in a typical to above average-sized classroom when using the REDCAT or in large open plan classrooms when using the REDCAT ACCESS/FLEXCAT in WCI mode. The FLEXCAT is also very effective in supporting the monitoring of pupils who are outside the classroom and two-way dialogue between teacher and such groups when in SHI, SGM and SGR mode.

Whilst there is an awareness of the limitations of the FLEXCAT research to date, which concern the size of the sample and the fact it is only a small number of schools and teachers there are, however, some clear conclusions that can be drawn from the data. First, there is evidence of a positive impact that improved speech intelligibility has for pupils, particularly those with SEN, sensory impairment and English as an Additional Language [EAL].

The additional features of the FLEXCAT, facilitating unobtrusive monitoring and assessing of group discussion, intervention in group discussions in a timely fashion without disturbing the whole class, the allowing of students to address the whole class without having to deliver a microphone and being able to remain in contact with groups working outside the classroom are all greatly welcomed by teachers. It would appear from the latest data that on-task behaviour during small group discussions has increased significantly with the introduction of the FLEXCAT; much to the pleasure of the students. They also report that the call button has meant that they no longer have to wait so long to get help when they hit a problem. From these results it is clear that the quality of small group collaborative working is improving as a result of installing FLEXCAT systems and that teachers are more confident in using this highly effective learning strategy more regularly in lessons.

Many of the features designed into the FLEXCAT system were strongly supported and welcomed by the teachers. However, the Model 1 system didn't always deliver on all of them and that operating the system was not as smart as teachers would have liked was a disappointment and sometimes a frustration for teachers. This is to be expected with innovative technology, and consequently the technology is continually researched and developed with the users, who are teachers and pupils working in the challenging space of noisy classrooms and newly built 'open plan' environments in schools under the BSF (Building Schools for the Future) programme.

Whole Class Instruction (WCI) mode

The strongest benefit reported by teacher and pupils alike was the immediate improvement in speech intelligibility delivered by the FLEXCAT speaker. Teachers and pupils reported several important subsequent benefits, e.g. improved understanding of instructions, less repetition, a faster settling to work, pupils more confident about what they had to do, enjoying their work more and less vocal strain experienced by teachers.

The delivery of the FLEXCAT speaker was the same that a REDCAT would have delivered in the same learning spaces and, as with the REDCAT, its limitation was the system's restriction to only broadcasting through the speaker rather than the Pods when in WCI mode, so the teacher was unable to talk to the whole class when one or more groups were positioned outside the classroom.

When question and answer sessions formed part of the whole class lesson introduction, teachers gave up on switching between Pods to capture the pupil's voice because the remote control was too slow in responding, the quality of speech intelligibility transmitted from the Pods was not always high and the flow of lessons was interrupted. This was as a result of a number of issues including the teacher's lack of

skill in moving fluently around the remote (improved pre-trial training could help), the response time of the remote to a change of button, the position of the Pod in relation to the pupil and the pupil not consistently leaning into the Pod when speaking.

Small Group Instruction (SGI) mode

Throughout the FLEXCAT 2013 trial period teachers did not work exclusively with one group for extended periods of time, so teachers only very occasionally used the system's SGI mode. Much more common, once the WCI had finished and the class had settled to small group collaborative discussions, was for the teacher to move between each group physically staying in close proximity to each group for only short periods of time. Rather than teaching in-depth, the teacher engaged in checking understanding and, if necessary, providing brief additional guidance before moving on. Future research would need to explore more fully the SGI mode.

Small Group Monitoring (SGM) mode

This facility was very much welcomed by all teachers and yielded particular pedagogic benefits as reported by both the teachers and the pupils, which concerned enhancing the learning activity by effectively keeping pupils on task.

Staying on task for the duration of the activity was effectively enhanced as pupils stated that the thought of the teacher being able to listen in meant that they remained more on-task than they might otherwise have done, with 76% secondary and 58% primary pupils responding positively: "*My group remained more on task when the FLEXCAT was used as the teacher could listen to see if we were working effectively and give help when necessary*".

Similarly, teacher judgments on the effectiveness of this mode by the lead primary and secondary teachers were that the FLEXCAT allowed them to give more intensive support to groups whilst remaining aware of progress in all groups.

Specific challenges: however, other teachers reported that with group work they struggled at times to hear individual pupil comments clearly enough to be able to make sense of what was being said. The researcher also experienced the same difficulties when he tried to listen in to group conversations using the second teacher headset. In the teacher interview, which was conducted after the lesson observation, the researcher and the teacher analysed that it was the level of general background noise generated by six groups of 6-7 pupils engaged in discussions that prevented the Pod picking up sufficient distinctive speech to be interpretable. This view was further supported by the feedback received from the school SENCO.

Benefits for SENCOs and SEN pupils

From the interviews and questionnaires completed by the SENCOs, their feedback clearly illuminated the ways in which the technology can support SEN pupils, alongside how the technology can help the SENCOs role, in terms of management - including that of LSA's and how they work with SEN pupils.

The SENCO used the SGM mode in two different ways to support her monitoring activity. First, she listened into group discussions where learning support assistants (LSA) were supporting SEN pupils in order to judge the quality and appropriateness of the LSA's help. The SENCO did this whilst sitting in the main teaching room and on another occasion, she moved into one of the neighbouring classrooms in order to monitor the quality of SEN pupil discussion contributions. The SENCO reported hearing comments from pupils that would never have been heard without the system and they were surprised at the quality and regularity of contributions made by some SEN pupils.

SEN use: SEN is one area in which the system is regularly used. The system is used to observe teachers and pupils interactions with respect to monitoring SEN; the SEN pupils have the kit on the table, and at the same time the SENCO can hear the interactions, although the SENCO is in a different room. This allows the SENCO to monitor the interactions between teacher and pupil and also to provide feedback to the teacher, with a view to improving teacher interactions with SEN pupils.

From a SENCO's management role, the benefits of the FLEXCAT system, is to use it to record evidence, particularly with respect to capturing the dialogue that learning support assistants (LSAs) have with pupils. This enables a quality assurance process to be undertaken with respect to the work that LSAs do with pupils, as the SENCO can monitor the LSA's interactions with pupils and provide feedback and even target CPD were required.

The teachers reported that they were also able to provide professional development to the learning support assistants, once they had had the opportunity to listen into the dialogue between the LSAs and pupils. As the teachers could hear what the LSAs were saying there was a specific focus on looking at how LSAs ask questions and give feedback. For example, the teachers were able to identify where LSAs were only asking closed questions. This led to a professional development opportunity, where the teachers could share with the learning support assistants, the importance of asking open questions.

The SENCO was very enthusiastic about the FLEXCAT for monitoring pupils learning. She judged her experience of listening and talking to SEN pupils using the FLEXCAT from the main classroom and a neighbouring classroom gave her knowledge about these pupils she would not otherwise have discovered and resulted in her being able to improve LSA's and subject teachers support to these pupils.

Benefits for teachers of monitoring pupils dialogue

In addition, teachers also reported being pleasantly surprised by some of the comments they heard from pupils, some of whom were not normally enthusiastic contributors to class discussions. Teachers consequently felt better able to provide appropriate, more targeted feedback to groups having listened to their discussions.

Small Group Redirection (SGR)

Teachers reported being able to intervene promptly when a group was off-task or needing support and teachers reported that their pupils were significantly less disturbed when they spoke to an individual group using the FLEXCAT. This view was strongly supported by the feedback from the secondary school pupils where (64%) reported that they were less disturbed when teachers intervened with other groups. Whilst the judgment of the primary school pupils was favourable overall (48%) there was, however, a significant minority (25%) that disagreed.

Small Group Sharing (SGS)

Teachers used the small group-sharing (SGS) mode when groups were invited to report back on their work rather than during more rapid Q&A sessions. The slower pace of switching between groups during group feedback sessions meant that teachers did not experience the same level of problems that they reported with the remote control and were able to maintain the flow of the lesson.

Challenges

In terms of the quality of the signal teachers reported on the value of the Small Group Sharing (SGS) mode particularly when groups located outside the classroom fed back to the whole class. Pupils no longer needed to leave their workstation and come into the class in order to talk to the teacher and the other pupils. However, the quality of signal through the speaker varied significantly depending on where the pupil was in relation to the group's Pod. The secondary pupils recognised the problem and, unprompted,

would move the Pod closer to the pupil speaking. This would immediately result in an improved speech signal. Teachers and observers recognised that pupils instinctively spoke in the teacher's direction, which meant for those in a group with their back to the teacher, they turned around and, therefore, away from their table and their group's Pod when speaking. This problem would likely be overcome through training and experience.

Overall, pupil questionnaire data showed that pupils liked the fact that they could hear their peers as clearly as the teacher and that everyone could hear them when they contributed to feedback. 58% of secondary and 54% of primary pupils felt that they benefited from the improved clarity of peers contributions and 36% of both secondary and primary pupils experienced an increase in confidence when talking to the whole class using the FLEXCAT.

Overall the research demonstrated that speech intelligibility is enhanced by the use of the technology. A key finding regarding the use of the FLEXCAT is that it has been able to provide teacher clarity, with respect to the spoken word, in the didactic teaching parts of the lessons. This is very important in an open learning space, like a super-studio, when the pupils are sitting in a large, tiered, open area and the teachers are delivering master classes. The use of the FLEXCAT has meant that the teachers are able to speak and know that they are being heard clearly across the large space.

Similarly it was found that the FLEXCAT could facilitate teacher intervention to refocus the learning. It greatly enabled teacher intervention into pupil group discussion work when the discussion was off task; so the intervening of teachers into pupil's dialogues had a striking impact in one group without the rest of the class being interrupted. The teachers particularly valued this opportunity that the technology afforded.

The fact that the teachers can listen in and also intervene with teacher questioning to facilitate and improve pupil discussion was highly valued by the teachers. In team teaching MFL lessons the supporting teacher used the FLEXCAT to monitor pupil engagement with the lead teacher and to intervene when pupils either were confused or drifting off task without disrupting the flow of the lesson. In a Year 10 call lesson pupils reported that when engaged in individual or paired working they could maintain progress by alerting the teacher to their need of support by using the call button on the FLEXCAT Pod and subsequently receiving more rapid help.

Another key feature that teachers referred to was the opportunity to be able to listen in at any time, which the teachers referred to as "*tapping into the moment*", this was seen as a key benefit of the system, so that teachers could keep tabs on discussions at all times; teachers are able to walk around in a group work situation and still be able to listen into all the groups, which enabled the teachers in turn to facilitate group work across the class during the lesson.

The teachers commented that it helps with formative assessment, and that it was useful for peer and self-assessment for written work and for pupil presentations. Teachers recognised the potential for improving the quality of formative assessment of pupils' language development and their skills in contributing to discussion and collaborating with their peers. A SENCO and school Education Psychologist both reported much improved monitoring of the performance of SEN pupils when engaged in collaborative group work with their peers and were able to inform Learning Support Assistance of how best to support their SEN pupils in their discussion work.

By being able to listen to pupil talk at a distance helped teachers get a more accurate picture of pupil's performance, performance that is often changed when a teacher is seen to be listening into pupil discussion.

Behaviour management was identified as a key benefit of the technology. The pupils were aware that the teacher is listening in at all times and the teacher knows when the group is off task. The teachers welcomed the ability to be heard clearly without having to shout and reported that this helped create a calm atmosphere for the outset of the lesson, which in turn supports positive behaviour throughout the lesson.

Another important benefit of the technology is that it allows for quieter pupils, who are more shy and more reserved and don't willingly speak up in front of the whole class, the opportunity to offer feedback using the system. The teachers said in fact that quieter pupils were more likely to give feedback because they had the system.

Key factors for technology adoption

Teachers who trialled the Model 1 FLEXCAT system reported the key to the adoption of the system was the need to improve the strength of speech signal that the Pod microphone can consistently transmit to either the teacher in SGM mode or the speaker in SGS mode. Also, with improvement of the teacher's microphone and earpiece headset already in hand, teachers would greatly welcome an improvement in the responsiveness of the remote control allowing them to switch quickly between pupil's speaking in different groups during rapid Q&A sessions.

It is clear that without these improvements teachers are unlikely to recommend purchase of the FLEXCAT system and, if purchased, make regular use of the system.

Suggestions for further improvements

- The teachers also requested the need for a 'record button', to help record the pupils dialogue and for the pupils to hear back their own work, which in turn would help pupils self assessment and self reflection;
- Sound quality: the teachers did think it would be possible to improve the quality of the sound;
- To improve the handsets, that the teachers hold, and to improve the pods, that sit on the pupils tables;
- The teachers wanted user-friendly technology, that was intuitive and easy to use with respect to the handsets, pods and headsets;
- The teachers wanted the technology to be able to capture, replay and record (so that it was then possible to analyse the speech, either by the pupils analysing their own speech or the teachers analysing the pupil's speech);
- When the pupils speak to the rest of the class, it is broadcast through the central speaker, and not through the table pods, in this sense it is not easy to hear and the teachers wondered if it was possible for it to be broadcast through the pods?

Conclusions on traditional teaching issues

Lightspeed undertook school-based action research in 2008-09 to investigate the impact of the Lightspeed REDCAT soundfield system on teaching and learning. This system represented a major development of Lightspeed technology in this area. This was followed up with the development of the FLEXCAT system, which was implemented in schools in 2013 and led to the next stage of research from 2013-14.

The key findings of the Stage 1, Phases 1 and 2 REDCAT research that investigated the impact the technology had on traditional teaching and learning activity were:

- 91% of teachers agreeing that their students are able to hear and understand instructions better;
- 79% of teachers agreeing that their students learn faster;
- 84% of teachers agreeing that their students' attention increases;
- 78% of teachers agreeing that their students' overall achievement improves;
- 71% of teachers agreeing that classroom management is easier;
- 77% of teachers agreeing that their students benefit from using a microphone when speaking to the whole class;
- 55% of teachers agreeing that they experience less vocal strain;
- 88% of teachers wanting to keep the REDCAT system in their classroom.
- The large majority the 554 students involved in the trial also valued the system highly:
- 70% of students agreeing that they can hear and understand their teacher better;
- 64% of students wanting to keep the REDCAT system in their classroom.

In the next phase focusing on traditional teaching techniques researchers concentrated on qualitative case studies of changes in professional practice. In the results, teachers agreed that students learnt more in the traditional sessions underpinned by the REDCAT device in five important areas:

- Improved hearing and understanding of teacher instructions;
- Improved on-task behaviour;
- Improved attention and engagement in discussion activities;
- Improved ability to follow directions;
- Improved self-confidence of pupils when speaking to the whole class.

For teachers, the professional benefits of the REDCAT system were judged to be:

- A need for fewer repetitions of instructions;
- Less vocal fatigue and tiredness;
- Improved ability to control and manage the class; leading to better behaviour;
- More time to support individual and small groups of learners.

The findings across Stage 1 from 2008 – 2014 strongly support those of previous research studies carried out in the USA, Canada and Europe showing that the large majority of teachers and students who trialled the REDCAT recognised the positive impact the technology had on their teaching and learning.

Trends in collaborative learning techniques

Stage 2 of the research concentrates on improving collaborative learning techniques though the use of the FLEXCAT CAD system. These techniques will now be more important in schools because new PISA criteria for the International Organisation for Economic Co-operation and Development (OECD) emphasises the value of group learning and collaborative problem solving alongside scores for individual achievement.

In the first phase, FLEXCAT, the new audio distribution system that complements the REDCAT, was trialled in 6 schools across England and Scotland. This device retains the high quality speech intelligibility achieved by the REDCAT whilst also allowing the teacher to support more effectively small group collaborative teaching through the use of up to 6 audio pods that can be distributed to groups of students working inside and outside the classroom.

The key findings of this Stage 2, Phase 1 FLEXCAT research were:

- Teachers and students enjoyed the immediate and on-going improvement in speech intelligibility throughout the classroom;
- Classroom management was improved with students settling to work more quickly as a result of hearing instructions clearly the first time;
- Increased on-task behaviour was achieved as a result of student's knowing that the teacher could unobtrusively monitor their group discussions at any time;
- Teachers reported that they heard contributions from students that they would not have expected from them, helping improve the quality of their feedback and lesson planning;
- Teachers were able to provide timely interventions to individuals and small groups without disrupting the whole class;
- Students were more able to share their ideas and progress achieved with the whole class;
- Teachers were able to maintain contact with groups working outside the classroom thereby making maximum use of the space available for learning;
- Difficulties with the design and performance of the prototype technology prevented teachers and students from gaining the full potential from the FLEXCAT systems.

The conclusions drawn from all these research studies indicate how critically important managing the environment is in promoting learning. The results indicate that by equipping classrooms with appropriate audio distribution technology senior managers will be able to make an impact on levels of achievement throughout the school. These results indicate potential for the raising of measurable achievement that could also be used by senior managers as evidence of learning in Pupil Premium and OFSTED reports.

The Stage 2, Phase 1 results have informed the Phase 2 research model, the full results of which will be reported at the end of the research programme. Whilst research in Phase 2 of Stage 2 is not yet completed, it is clear that the Flexcat system is bringing improvements to the quality of small group collaborative working in schools. Teachers and students as well as the researchers are recognizing the following trends and the on-going research will investigate the extent to which these and other trends continue to establish themselves:

- Assured high quality speech intelligibility and the use of six pods is allowing teacher to make maximum use of learning spaces including those outside the classroom;
- Students are increasingly remaining on-task when engaged in small group collaborative activity as a result of the teacher being able to unobtrusively monitor discussions. This is increasing teachers' confidence in the frequency they can employ this highly effective learning style;
- The flow between whole class and small group working is easily managed;
- The quality of formative assessment of student contributions to small group discussion has improved significantly and teachers are increasingly able to provide more specific well-targeted feedback to individuals and small groups of students;
- The speed at which well-targeted intervention can be given is raising the quality of group discussions and the pace of learning overall;
- Teacher use of the pods is resulting in fewer disturbances to students not needing to hear interventions;
- Use of the pod call button is minimising the time when students waste time waiting for teacher support;
- More frequent use of student reporting to the whole class is occurring because of the availability of the pod microphone;
- There is growing evidence that students with profound hearing loss are benefiting from the use of the FLEXCAT system;
- Trial schools are beginning to invest in the technology as they see the results of its use to support effective teaching and learning.

Many of the technical challenges of the FLEXCAT system identified in Phase 1 have been overcome. However, further work is being carried out to improve the areas where teachers have suggested the need.

A pilot using version 2 of the FLEXCAT was conducted in a primary and secondary school in the summer term 2014 to establish the research tools required before a second, more wide-ranging study will be undertaken. The teachers were identified through discussions with senior managers who were keen to extend their teaching and learning strategies. Installing the FLEXCAT, supporting the teachers and working with them to develop research tools were the key tasks in this stage. The aim was to test for strategies and tools that will inform the rest of the study.

It is proposed that from September 2014 three hub schools, one primary and two secondary, undertake the Stage 2, Phase 2 research programme as they offer a range of different teaching styles, cohorts and scenarios, across primary and secondary schools. The research will use the tools determined most appropriate from the pilot.

The research in the three hub schools will seek to establish the system's effectiveness in securing enhanced speech intelligibility for all pupils as well as supporting teaching and learning in a range of situations that will aim to include:

- single whole class and differentiated small group working in average and large teaching spaces;
- single whole class and differentiated small group working in average teaching spaces with some groups working at distance from the teacher, including outside the classroom;
- multiple class differentiated small group working in large teaching spaces using one FLEXCAT system;
- multiple class differentiated small group working in large teaching spaces using 2-3 FLEXCAT systems;
- innovative scenarios suggested by the teachers, the pupils and the requirements of different environments.

Classroom Acoustics: the acoustic characteristics of each of the teaching spaces used will be accurately measured in order to judge the effectiveness of the systems in relation to the prevailing classroom sound environment.

Ethics: the ethical code of the British Educational Research Association will be applied and ethical approval will be gained through the university ethics committee. Once the permission of the teachers is given, it is hoped to install video camera technology developed by IRIS Connect Isis, into the participating classrooms to record the lessons when the FLEXCAT is both in use and not in use. This equipment provides the opportunity to gather data about the use of the FLEXCAT and for the participating teachers to annotate the video for use as a teaching resource for new users if this is practicable.

Staffing: All the participant teachers and senior staff from each of the four schools will be inducted into the research protocols and agreed scenarios. Time has been budgeted for data gathering specifically observing the classrooms. Additional time has been allotted to the collation and analysis of data and the writing of a report on the findings.

From January 2015 it is hoped to increase the number of schools trialling FLEXCATS with a focus on determining the impact on learning for students with profound hearing loss in mainstream education. Thereafter it is hoped to focus research on a wider sample of primary and secondary schools, with a view to also including early years settings and special schools.

Lightspeed is also intending to commission a larger independent study of the FLEXCAT in the USA so this study would be expected to extend the value of the American one.

Overall conclusions

Most of the teachers in this research project were unaware about how poor the sound field is for many learners in classrooms, not just those with identified hearing challenges. Installing the REDCAT CAD system is shown here to have significant impact on achievement in all kinds of classrooms. The trends that are emerging so far suggest that not only traditional teaching can be improved but also the skills of collaborating and sharing can be enhanced by the judicious use of systems that extend and enrich teachers' access to classroom exchanges.

Dissemination

During the REDCAT and FLEXCAT Phase 1 research Lightspeed have been associates of the MirandaNet Fellowship of educators (www.mirandanet.ac.uk) who are experts in the potential impact of digital technologies on effective teaching and learning. This professional organisation ensures that practising teachers have access to research findings that are presented in an accessible style that helps them to implement the findings in the classroom.

As a result of this association Lightspeed have already had some dissemination of these significant findings. This could be increased as the new study gets underway so that trends and development are all reported, for example, through a MirandaNet research publication and web report.

Lightspeed can be sure of a keen interest in their research publications because currently the MirandaNet website attracts 6,000 unique visitors a month and the numbers are growing at about 12% per year. The indexing is efficient and the site features prominently in Google. Many visitors return and read up to eleven pages, which is unusual. The design for the new website based on visitors' established pathways will be launched in November 2015.

MirandaNet is now developing exciting ways of communicating the research findings at interim points as well as at the end of the study. Companies can opt for social media forms of publicity as well as a range of assets like video. In addition MirandaNet has access to about 15,000 educators through their professional organisations and social networks. Fellows present papers and give keynotes at conferences.

Further research

In this section we strengthen the approach to securing future qualitative findings and outline how to enhance quantitative data, which specifically links to achievement, particularly SEN. In order to do this it will be necessary to secure pupil performance data from schools and to examine monitoring and progression data on those SEN pupils who are working with the technology in their lessons.

Lightspeed's new FLEXCAT audio distribution system is designed to improve hearing in group learning and thereby support and improve differentiated learning strategies. In the FLEXCAT system the teacher microphone feeds into a REDCAT ACCESS speaker and up to six module speakers (Pods) that are positioned in the centre of a small group of pupils. The teacher can control which speaker is active, thereby speaking to the whole class or to just one chosen group of pupils leaving the other groups to get on with their work undisturbed. With the Pod operating as both microphone and speaker, when active, pupils are able to address the teacher or the whole class from their table when presenting their ideas and the outcomes of work in progress or when completed.

The proximity of the speakers is designed to ensure that all pupils, including those with hearing difficulties, those within the special needs cohort and those for whom English is an additional language receive an excellent speech signal. The system is designed to be fully compatible with cochlea implant and hearing aid technologies and to provide a much-enhanced signal to the many children suffering both permanent and intermittent hearing loss. Equally, the individual pod speakers are designed to restrict the spread of sound to the immediate area thereby preventing spillage of unnecessary noise between speakers.

The FLEXCAT system is designed to allow teachers to provide concentrated supported to one group of pupils whilst remaining alert to the progress being made in the other groups in the classroom and providing support when necessary without having to leave the group of pupils with whom the teacher is working. Improved concentrated support to a single group and greater effective and efficient use of lesson time should result. When the teacher's microphone is muted the system is designed so that they can use the Pod system to unobtrusively listen in to individual groups to judge more effectively the quality of contribution each pupil is making to collaborative study. The quality and accuracy of teacher formative assessment should be enhanced as pupils, who might modify their behaviours when the teacher is physically present (e.g. say what they think the teacher wants to hear, stop speaking through shyness) will remain natural through the unobtrusive assessment process. This should in turn improve the feedback and re-direction the teacher can give and, also possibly the quality of teacher lesson planning, based as it would be on improved knowledge of the learning standards individual pupils have reached and their rate of progress.

The FLEXCAT technology is designed to allow groups of pupils to work in adjoining rooms or in the corridor whilst remaining in contact with the teacher through the Pod speaker. Each pod is equipped with a button that the group of pupils can use to alert the teacher that they need support. Equally, it is designed to allow teachers to maximise the use of the learning space they have available, including very large teaching spaces, without the pupils struggling to hear the teacher or fellow pupils when addressing the whole class.

The Phase 2 research study is designed to collect and analyse both quantitative and qualitative data in order to present the potential benefits of the new system. Consequently further research should be designed to test the effectiveness of this technology in a variety of learning environments.

In identifying the benefits for pupils and teachers this proposed new study would have three main aims: to develop more knowledge about the trends in facilitating information transmission pedagogies as illustrated in the first study;

- to generate more knowledge about developing dialogic, interactive pedagogies through small group work;
- to explore the potential to improve the value of learning collaboratively and to reduce the opportunities for the group to lose focus.

The investigation will be facilitated by introducing the FLEXCAT classroom audio distribution system into a variety of teaching and learning spaces in schools. The focus of the study will be the impact on the facilitation of differentiated group work as well as making the teacher voice always intelligible in traditional, larger and very large classrooms.

In the first phase the study will explore existing practice. Working with teachers, the researchers will seek to record preliminary evidence of improvements in pupil hearing and understanding; rates of progress; their ability to follow directions and retain attention; improvements in self-confidence from using the pod

microphone. The study will also record impact on the teacher's ability to manage the class, especially during small group collaborative learning activities; their delivery of differentiated learning, and their need to repeat themselves; their ability to more effectively target support through intervention and re-direction to individuals and small groups; any increase in the efficiency and effective use of lesson time; any improvement in assessing formative and summative pupil attainment and progress and, any reduction in vocal fatigue and levels of tiredness overall.

In the second phase innovative practice will be the focus. Teachers and pupils will be encouraged to experiment with the FLEXCAT system in order to test the full capability of the system in supporting innovative teaching and learning styles. Curriculum content and integration will form a crucial part of this pilot study.

Critical to the study will be to ascertain whether or not the system reduces interference between groups in normal classes and between groups and whole classes when working in large teaching spaces. A key aim of the research will be contributing towards the school development plan in improving teaching and learning excellence and curriculum choice and innovation in the selected schools. For this reason the views and ideas of both teachers and pupils as co-researchers will be central to the evaluation of the FLEXCAT system.



The research team

Dr Christina Preston, has been at the forefront of education and technology for over 25 years. She founded MirandaNet in 1992 to research and advise clients in the impact of technology and learning. The professional organisation has become a global thought leader with over 1,000 members in 80 countries. Knowledge sharing and creation and managing the change process to ensure impact is at the core of MirandaNet's philosophy. A full programme of events is held in partnership with the London Knowledge Lab, Institute of Education. As Professor of Educational Innovation, Christina also advises the Future Learning Centre at the University of Bedfordshire. She is also the Chair of Trustees of World Ecitizens charity established by the MirandaNet Fellows in 2002 after the events of 9/11 in New York. This charity provides a web space where learners across the world can publish for an international audience.

Dr Sarah Younie, MirandaNet Research and Innovation Director, has brought her significant research experience to MirandaNet Projects over many years. She is currently working on several research project with MirandaNet associates including the EU LLL HandsOn project.

Sarah has been involved in international research on educational technologies and teaching for twenty five years. She has been involved in the use of digital technologies in educational settings for UNESCO, the EU, UK Government Agencies, Local Authorities, educational charities and other funders. She has worked as a teacher and researcher in secondary schools, universities and as UK Chair of the national subject association of IT in Teacher Education (ITTE) she has conducted research, including gathering evidence for the Parliamentary Select Committee Inquiry into Education.

Sarah is also a visiting Senior Research Fellow at University of Bedfordshire and Principal Lecturer at De Montfort University, where she is Programme leader for the MA in Education Practice. She has published widely on educational technologies and is the Associate Editor-in-Chief for the international Journal of Technology, Pedagogy and Education. Dr Younie's latest book published by the Open University Press is entitled 'Teaching with Technology: the essential guide'. Dr Younie is a founder member of MESH (Mapping Education Specialist knowhow) and is the Editor-in-Chief of the MESHguides for ICT.





Roger Turner, MA, is a Senior Research Associate, MirandaNet Fellowship as well as an independent education consultant and researcher who for the past six years has been undertaking on-going research into the impact on teaching and learning in schools of Lightspeed Technology's Redcat and, more recently, new Flexcat audio distribution systems.

Previous to this Roger was Assistant Director of Children Services in the London Borough of Hillingdon, having been the borough's Chief Inspector of Schools and a Registered Ofsted inspector of secondary schools. He spent fourteen years as a teacher educator, seven of which were as Head of Music Education and Chair of the PGCE Secondary Panel at the Roehampton Institute of Higher Education. During this time he was external examiner for the University of London, Institute of Education Secondary Music PGCE course. Prior to this he was Head of Music in three central London secondary schools and a tutor at the Pimlico Centre for

Young Musicians. He is a graduate of the Royal Academy of Music, was subsequently awarded Associate status for services to music education and winner of the Young Composer of the Year Award in 1966

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