SOUND CONCEPTS
DESIGN AND TESTING

Acoustics form development, testing and pilot installation in primary school classrooms

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SOUND CONCEPTS PROGRAM

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EXECUTIVE SUMMARY

The aim of this project was to produce and test prototypes of an acoustic baffle called the 'Tri-Form and an acoustic 'Igloo' design for acoustic treatment of primary schools.

The products are designed to reduce the medical, social and language issues associated with poor acoustic treatment of primary school classrooms which affects children's ability to learn. This project will:

> Raise awareness of the necessity for good acoustics in New Zealand classrooms for all children, particularly for those with hearing-impairments
> Raise awareness of flexible and affordable acoustic solutions for classroom environments

The research shows how the 'Tri-Form and 'Igloo' products impact the acoustics of five primary school classrooms tested.

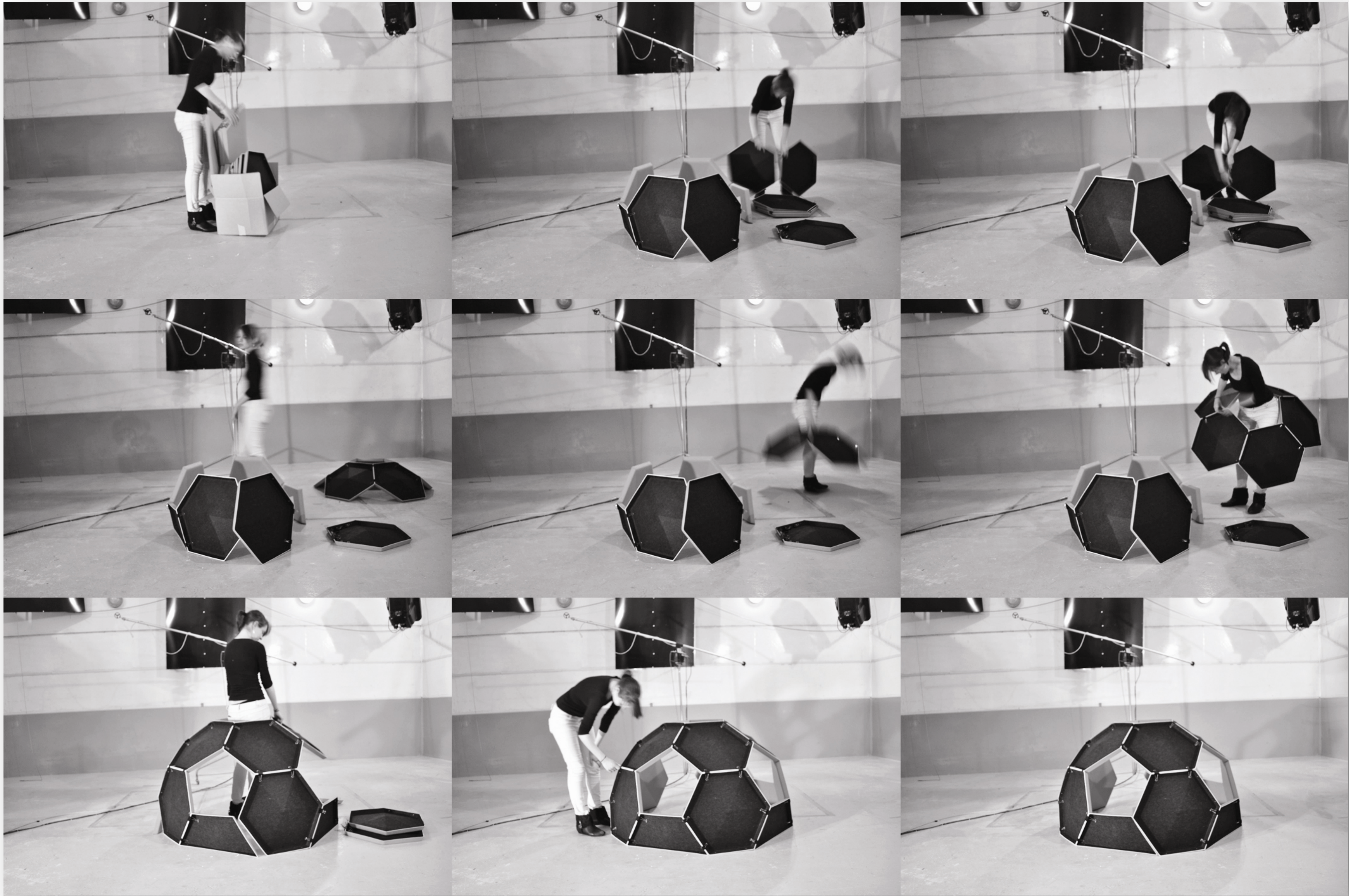
For the classrooms tested, four out of five had original speech and perception impairing reverberation times of longer than 0.4 seconds.

The Pod, nicknamed the 'Igloo', significantly affected the absorption of lower frequencies of sound within the classroom environments tested. It also decreased the reverberation times of some of the mid-range frequencies of speech and most of the high frequencies in the classrooms where it was tested.

The 'Tri-Form' consistently reduced reverberation times across most frequencies. This result is excluding 400-500Hz, where it is proposed that the product achieves a resonant frequency.

The research demonstrates how of putting form into the traditionally flat Autex 6mm Quietspace Workstation product improves the acoustic performance of the original product. The developed product exhibits a flexible acoustic product that has the potential to be used in a number of classroom and commercial applications.

Figure 1: installation of the Pod or 'igloo' in acoustic testing laboratory



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1. INTRODUCTION

1.1. AIM OF SOUND CONCEPTS PILOT TESTING:

The aim of this project is to develop, produce and test prototypes of an acoustic baffle called the 'Tri-Form and an acoustic 'Igloo' design for acoustic treatment of primary schools.

The products are designed to reduce the medical, social and language issues associated with poor acoustic treatment of primary school classrooms which affects children's ability to learn. Through this project it is hoped that the research will:

> Raise awareness of the necessity for good acoustics in New Zealand classrooms for all children, particularly for those with hearing-impairments
> Raise awareness of flexible and affordable acoustic solutions for classroom environments

The objectives and key outputs of the project are to:

> Produce prototype tooling at the School of Architecture and Design at Victoria University of Wellington; undertake a pilot production run with industry partners.
> Carry out technical testing of prototypes at the Acoustics Research Center of New Zealand.
> Identify classrooms and community spaces to undertake a pilot installation of prototypes.
> Undertake a pre and post installation acoustic survey review and technical testing.
> Review the outcomes with the objective of making recommendations to reduce reverberation time in primary school classrooms for improved speech intelligibility.
> Design a simple A3 poster that explains the basics of classroom acoustics- to be made available to teachers, parents and pupils, principals, schools boards, architects and designers.
> Make the results of the project available to key players such as the Ministry of Education and local government.

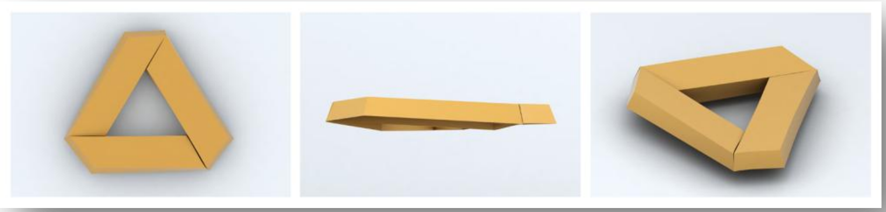
1.2. SOUND CONCEPTS PROJECT PRODUCTS

There are two Sound Concept products tested in this research called the Pod and nicknamed 'Igloo' and the 'Tri-Form'. Both products are made from an Autex Industries Ltd product called *Quietspace Workstation* which is a flat sheet acoustic panel made from virgin and 60% recycled Polyethylene Terephthalate (PET). This material has a felt-like appearance achieved through industrial needle punching. The original Autex product will be 'formed' by the project's product manufacturer-Calvert's Plastics Ltd into the projects two acoustic prototypes. By using this Autex product the project incorporates a material that is fire rated and not glued but thermally bonded. Most crucially, the material contains a minimum of 60% previously recycled polyester fiber which if uncontaminated, can then also be recycled at the end of the products life through Autex's stewardship program.

1.2.1. TRI-FORM

The 'Tri-Form' product is made up of a series of individual quadratic components which are joined with each other to form a geometric-based acoustic baffle. This system was designed to be incorporated into ceiling space of classrooms and provide a flexible solution when ameliorating the acoustic environment of a classroom. The 'Tri-Form', with its increased surface area and suspension flexibility is designed to absorb a range of frequencies of sound. It is hoped the product will act to reduce the critical reverberation times of the classrooms it is installed in.

Figure 3: Examples of configurations of the 'Tri-Form' tiles

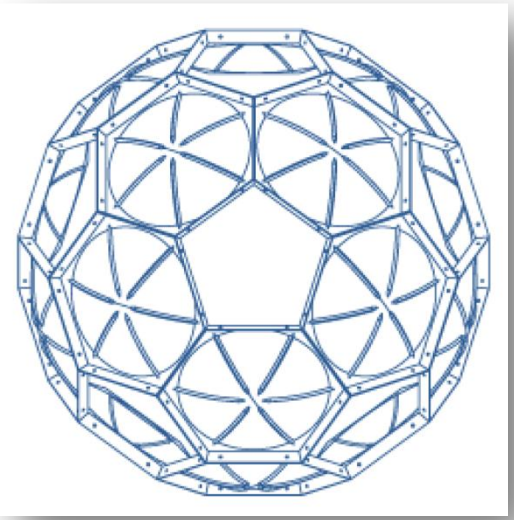


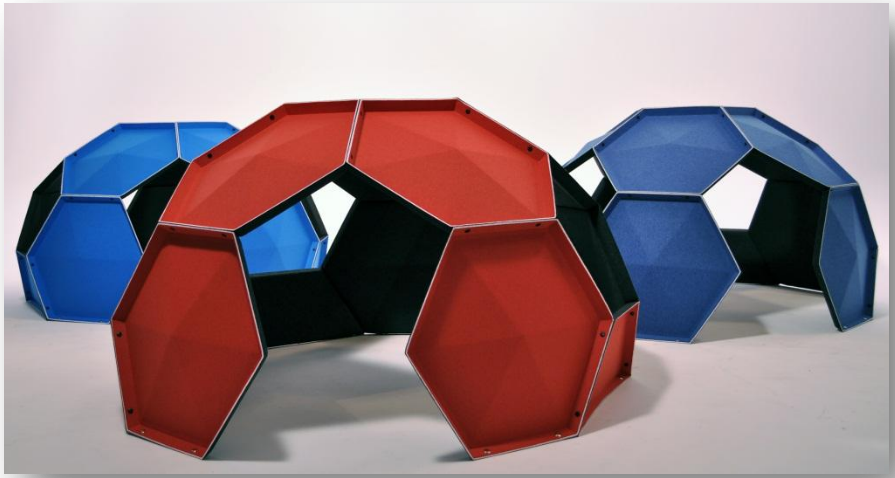
1.2.2. THE POD, NICKNAMED THE 'IGLOO'

The Sound Concept 'Igloo' was designed as a ground based acoustic product for early childhood classrooms in preschools and primary school education. The hexagonal panels of the 'Igloo' form an interactive geodesic dome that children can occupy and play in. The 'Igloo' panels are a composite of the Autex Quietspace Workstation product and Autex product called Vertiface which allows both sides of the panel to be produced in a range of colours.

This product is designed to act as a passive absorber of sound within the class environment and also as a piece of classroom furniture which can double as a calming, withdrawal or quiet space to aid children with central auditory processing disorder, hearing impairments, Autism etc.

Figure 4: Plan view and example of 'Igloo'





1.3. BACKGROUND

The following chapter describes some of the key theoretical discussions behind acoustics in education and what has traditionally been done to treat classroom spaces with acoustic issues.

1.3.1. NEW ZEALAND CLASSROOMS

In New Zealand primary school children will typically undertake four and a half hours of school activity in a day. These hours are spent between 8.30am and 3pm and children are legally required to spend 388 compulsory half-days at school in a year (Ministry of Education 2011). This is the equivalent of 873 hours a year at school, which is 22.5 hours a week. This means that children spend a significant amount of time in the classroom environment where they are expected to learn.

1.3.2. THE ROLE OF ACOUSTICS IN THE LEARNING ENVIORNMENT

Acoustics play a critical role in the learning environment of classrooms, particularly for younger groups of students. Psychoacoustics studies have shown that children are more affected by unfavorable acoustic conditions than adults (Larsen, Vega and Ribera 2008). This occurs because children are neurologically immature, lacking the experience to infer and predict speech in situations where they are unable to perceive the full quality of speech or sound. Evidence shows that poor acoustic environments in classrooms can significantly affect listening comprehension, identification and higher-order cognitive functions such as memory and mental processing (Jamieson, et al. 2004).

In classrooms sound sources include children, teachers, music, and in some cases services and background noise sources such as traffic and surrounding classrooms. These noises can range dramatically in sound level (dB) and frequency (Hz). An example of noise levels of typical sources in a classroom can be seen in Table 1 (Information sourced from BRANZ guidelines on classroom acoustic environments (2007)). It can be seen that the level of sound within a

Table 1: Typical sound levels in a school (BRANZ figure)

Sound Level (dB)	Source and Distance (where applicable)
16	Threshold of human hearing (person with good hearing)
20	Quiet recording room
35-40	Quiet unoccupied Classroom
60-70	Busy classroom-lots of students Normal voice at 1 meter
80-90	Vacuum cleaner Person shouting at 1 meter
100	Very loud music (maximum recommended by World Health Organization)

Table 2: Terms and meaning

Term	Meaning
dB	Or decibel, unit indicating the power or intensity of a noise. The larger the dB the larger the larger the intensity of the sound
Hz	The unit of frequency, the larger the Hz the greater the frequency. The greater the frequency the higher the pitch of sound.

classroom ranges depending on the activity being done in the space and that some of these activities can be quite loud.

The frequency of this sound represents the pitch at which the sound is heard and determines how much noise can be absorbed by the acoustic treatment of the classroom. As shown in Figure 5 human hearing ranges from 20 to 20,000Hz (Binggeli 2003), this is excellent hearing, commonly associated with young children with no hearing impairment. The frequency spectrum of speech ranges from 300 to 5,000Hz with the lower frequencies being sounds such as 'B's and the higher frequencies being the higher consonants i.e. 's' and 'f' (Seep, et al. 2000).

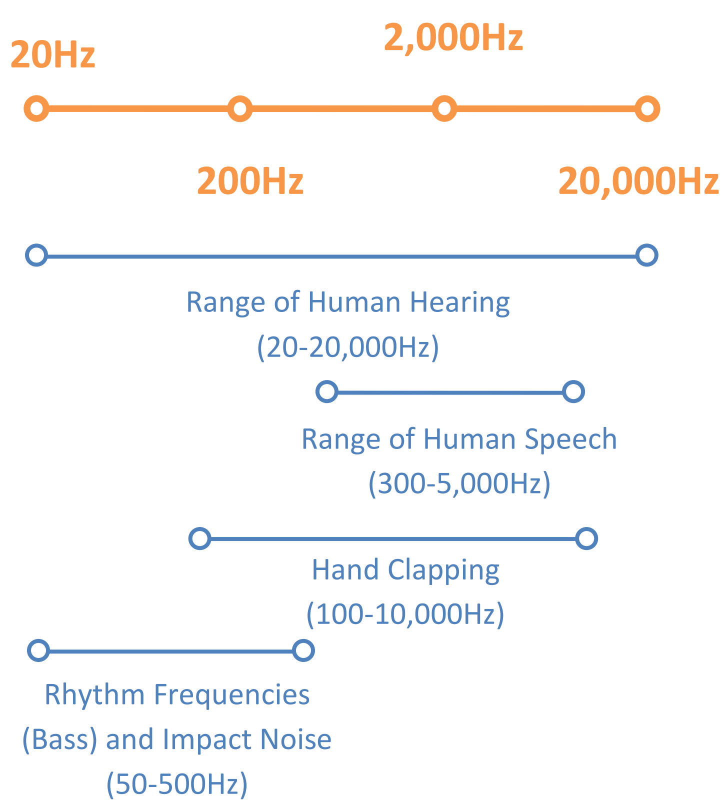
Our brains are capable of selecting certain sounds out of the sound spectrum we perceive; combinations of sound level (dB) and frequency. However, in classrooms with poor acoustics the perceived magnitude of sound waves and sound directionality can make it difficult to comprehend one sound source from another leading to difficulties in speech perception and understanding.

Factors that can affect the quality of the acoustics in a classroom include background noise, excessive reverberation times and a low signal-to-noise ratio.

REVERBERATION TIME

The reverberation time of a room describes how long it takes sound to decrease by 60dB after the generation of the sound has stopped. Reverberation time is typically measured over 160-6,300Hz and is a generally good measure of how much sound is 'bouncing' around in a space. Studies done internationally have found that a reverberation time of 0.4 seconds is satisfactory for a primary school classroom environment ((Seep, et al. 2000), (Kailes 1999), (Wilson, et al. 2002)). '*Certain teaching spaces, included those intended for primary school students, students with learning difficulties and students with English as a second language, should have reverberation times at the extreme low of the recommended scale*' (Wilson, et al. 2002).

Figure 5: Comparison of Audible frequencies of speech and sound



BACKGROUND NOISE

Background noise in the classroom environment can prove a disruptive problem in the classroom environment and come from a number of sources. AS/NZS 2107:2000 states that a classroom should have a satisfactory unoccupied noise level of 35dBA and maximum of 45dBA. This means that the background noise level is controlled and will have a minimal impact on the acoustics of the classroom environment.

SIGNAL-TO-NOISE RATIO

Background noise of a classroom is critical as it has a direct impact on that of the signal-to-noise ratio. The signal-to-noise ratio describes how loud source sound is compared to ambient noise and can be a good indication of how clear a sound is for the person listening. For a primary school student the signal-to-noise ratio at a student's ear should exceed a minimum of +15dB (Wilson, et al. 2002). This will allow clarity of sound or speech and allow optimum chance of perception and understanding.

1.3.3. STUDIES OF ACOUSTICS IN NEW ZEALAND

For a good record of studies done on New Zealand classrooms please refer to: *Classroom Acoustics: A New Zealand Perspective.* This provides a good summary and point of reference and is available at:

http://www.oticon.org.nz/grantRep.htm

Figure 6: 'Igloo' installed in school hallway

2. RESEARCH METHODOLOGY

2.1. METHODOLOGY FOR TECHNICAL LABORATORY PRODUCT TESTING

Initial technical acoustic testing of the Sound Concept products was conducted in the Acoustic Research Centre of New Zealand laboratories in Auckland to obtain measured absorption coefficients for the products.

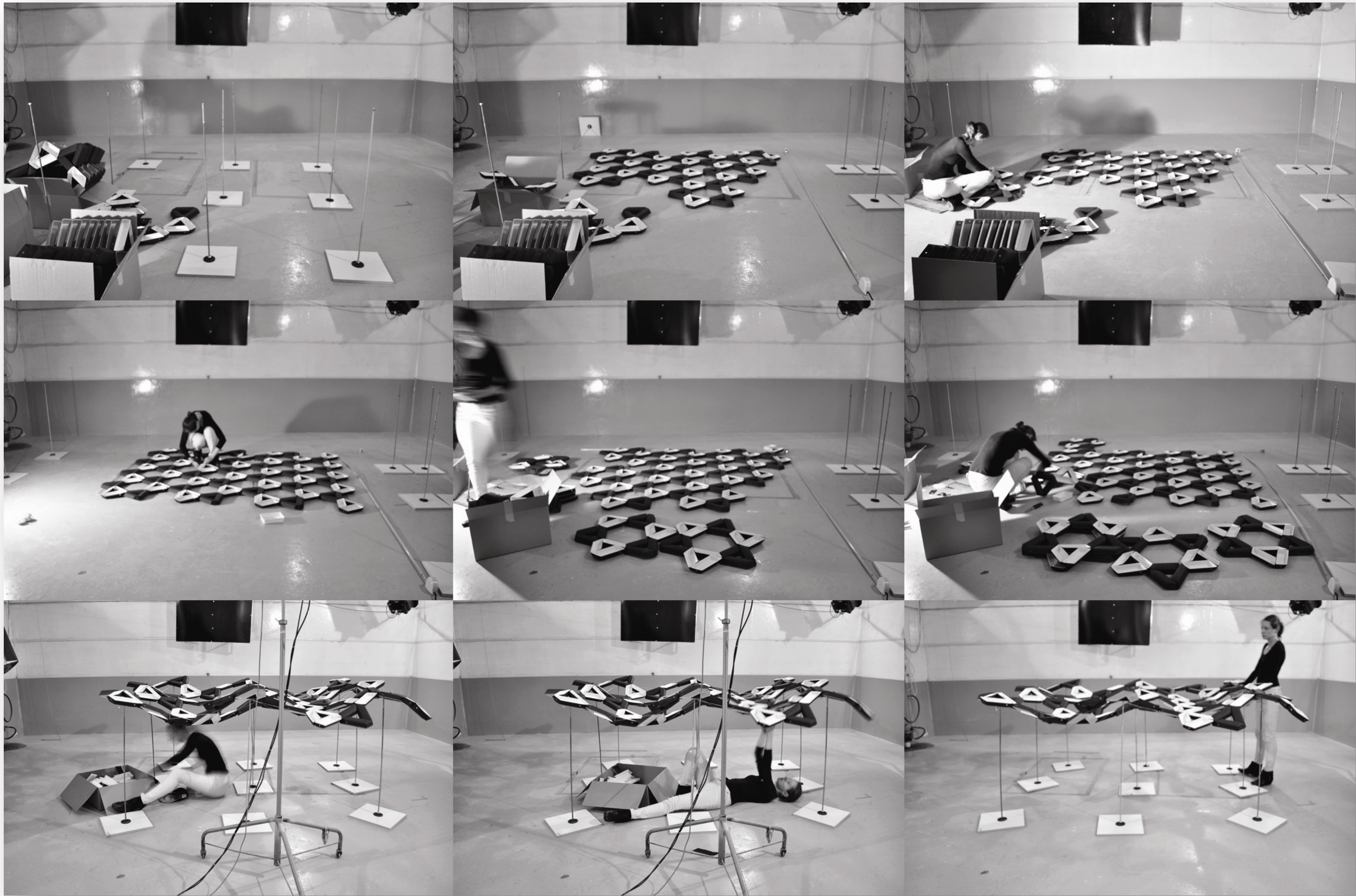
Essentially the absorption coefficient of a building element can be measured in a standardized reverberation chamber by comparing the reverberation time in the chamber with and without the product sample. The absorption coefficient is then calculated by substituting the values into the relevant formula. This method gives an average value of the absorption coefficient for the different angles of incidence across a sound frequency spectrum of 100Hz to 5000Hz via the use of a standard reference curve with a 'best fit' method. Time and space averaged sound pressure levels in both the reverberation chamber are measured by sampling the sound pressure levels as the boom rotates through one cycle (taking 64seconds). This is repeated when the product sample tested is place in the reverberation chamber. The ceiling of the reverberation chamber correlates to the floor plane in reality and, inversely the floor plane correlates to the ceiling.

The Acoustics Research Centre's reverberation chamber A was used for testing. The chamber may be described as a hexagonal prism with 6 vertical walls perpendicular to the floor. It has a rotating vane diffuser in a central position with an area (both sides) of about 53m^2 and the vane has the shape of two cones with their bases joined, with the two opposite quadrants of one cone open and the complementary quadrants in the other cone open. The reverberation chamber is vibration isolated and the chamber has been accredited by International Laboratory Accreditation Cooperation.

Both products were tested for their sound absorption performance. The 'Igloo' design, positioned in the middle of the reverberation chamber for testing, was measured for the total absorption coefficient of the whole structure. The 'Tri-form' was then suspended from the floor (upside down with the floor representing the ceiling), correlating with it being hung from the ceiling in reality. The 'Tri-Form' was tested with and without the AUTEX AAB Blanket inserts. The 'Tri-Form' was also tested at two suspension heights to test the impact of the restriction on suspension heights by different classroom stud heights.

Figure 7: 'Igloo' outside the Acoustic Research Centre of New Zealand Reverberation Chamber

Figure 8: The 'Tri-Form' being assembled in the Reverberation Chamber of the Acoustic Research Center of New Zealand Laboratory



2.2. SURVEY OF CLASSROOM ENVIRONMENTS

A request was made via media releases (newspapers and magazine articles) for Wellington Schools to participate in the Sound Concepts research project.

Five interested school were further briefed on the project. Teachers within the schools were asked for their interest in participating in the research and their classrooms were surveyed for appropriateness.

Appropriateness of classrooms for the research product(s) was assessed against:

- The age of children to be taught in the classroom (younger ages (years 1-3) were required for the 'Igloo' product); and
- Availability of space for the product(s); and
- Estimated reverberation time of the classroom (unoccupied) – the larger the reverberation time within the space, the easier it is to assess the impact of the Sound Concepts acoustic products.

One Classroom was selected from each school for the pilot testing of the Sound Concepts Project's products. Two were selected for the 'Tri-Form' and three were chosen for the 'Igloo' Product in accordance with material availability. The seating arrangement, activity areas, dimensions, surface finishes, construction types and materials were recorded for each classroom. Each classroom's interior and exterior was also photographically recorded.

2.3. DETAILED ASSESMENT OF CLASSROOM ACOUSTIC ENVIRONMENTS AND IMPACT OF PRODUCTS

Each of the selected classroom environments was assessed in terms of its acoustic environment before and after the installation of the Sound Concept products to correlate the impact of the product on the classroom's initial acoustic environment.

The acoustic environment was assessed for changes in:

- Reverberation Time
- Live Noise
- Qualitative Change (Questionnaire)

2.3.1. SUBJECTS

Classroom occupants consisted of the children of the classroom and the allocated classroom teacher(s). In some cases classroom occupants included a small number of children and teachers with known learning disabilities. i.e.: central auditory processing disorder, hearing impairments, Autism etc.

The normal number of classroom occupants was recorded during the period of acoustic measurement, this included fluctuations in numbers over time.

2.3.2. EQUIPMENT CALIBRATION

Measurements of reverberation time were taken using a portable loudspeaker generating pink noise. The sound meters used in both reverberation and sound level measurements were Brüel & Kjær 2250's. The sound level meters are calibrated to conform to IEC60651 for 'type 1 sound level meters' and IEC 61672-1 for 'Class 1 sound level meters'. The meter used for reverberation time measurements also conforms to ISO 3382 for measuring reverberation time and ISO 354 for measuring absorption of materials in a reverberant room.

2.3.3. REVERBERATION TIME MEASUREMENTS

Reverberation time measurements were done in all five classroom test environments. These measurements were done pre and then post Sound Concepts product installation.

The reverberation time measurements were taken using Brüel & Kjær 2250 Sound Meter. A series of five reverberation time measurements were taken in each classroom from a variety of points on the floor plate when the classroom was unoccupied. Reverberation time measurements were taken across a 150-6300Hz spectrum and the measurements for each position were averaged to give a representative reverberation time for each frequency band in each classroom.

The series of unoccupied classroom reverberation time measurements were taken using loud speaker generating pink noise which was located in the middle of the classroom's floor plate.

The set of reverberation measurements were done pre and post installation was compared. This allowed an assessment of the impact of the products on noise absorption within the classroom environments.

2.3.4. LIVE NOISE MEASUREMENTS

The live sound levels (dB) within each classroom were recorded over a period of three days to assess noise fluctuation within the classroom environment. The sound level measurements were taken both pre and post product installation to measure the impact of the product on internal sound levels. These measurements were correlated to a simultaneous activity log and a qualitative sound questionnaire completed by the classroom teacher(s).

The sound levels were measured using a logging sound level which was hung from the ceiling with a minimum suspension of the microphone of 0.5m from the closest physical surface(s).

The L10, L50 and L90 results pre and post installation were then statistically analysed for change as a consequence of the product's installation.

2.3.4.1. ACTIVITY LOG

The activity log was used to correlate recorded sound levels to the activities of classroom occupants at the time (example in appendix).

To compare sound levels pre and post installation a series of comparable activities were repeated both before and after installation. This consisted of either a morning (9.00am-12.30pm) or an afternoon (12.30pm-3.00pm) worth of activity. This was done in collaboration with the classroom teacher and was determined before initial recording.

2.3.5. QUALITATIVE QUESTIONNAIRE

A qualitative questionnaire was administered to the five teachers of the selected classrooms. This was to determine the acoustic environment in their classroom. The questionnaire was administered both before and after installation of the Sound Concepts products. The questionnaire was developed from the survey used in *Classroom Acoustics: A New Zealand Perspective* (Wilson, et al. 2002). Teachers were introduced to the questionnaire in a briefing session. See appendix for a copy of the pre and post questionnaire.

3. CLASSROOM SURVEY AND PRE-QUESTIONNAIRE RESULTS

A range of classrooms were assessed from schools chosen for the study. The classrooms selected ranged in age, size and use. All of the classrooms had been renovated over time, remodeled and had layouts changed from their original format.

The classroom chosen from School A for 'Tri-Form' testing was one of the biggest in the study. The classroom is L-shaped and is connected to other classrooms via an interior hallway at its rear which was separated from the classroom by a thin sliding door. The classroom building itself was timber construction with a tilted MDF ceiling resting on glulam beams and had three walls of head height single-glazed windows. The room, a learning space for Years 1 and 2, had a carpeted floors and was occupied by the usual classroom equipment; chairs, tables, books, shelving, bags etc. The teacher reported in the pre-installation questionnaire, for this classroom that the room was 'echoic' and that there was a concerning amount of loud noise. The teacher noted that she was aware of the impact the 'L'-shaped classroom had on her voice and made sure to locate herself in the middle of the 'L' where all her students could see and hear her.

The remaining rooms chosen from the rest of the schools were 'box' shape and had basic timber construction. All had the usual classroom equipment but School B and C had larger quantities of sound absorbing furniture with extra couches and sitting cushions. All of the classrooms were connected to other classrooms through walled off interior corridors accessed through a timber framed doors. Most of the classrooms had hard wall surfaces, with the exception of School E whose walls were treated with an Autex-like Composition Board.

The selected School D classroom housed the oldest group of students (Years 4 and 5) amongst the classrooms selected and the other 'Tri-Form' product was tested in this classroom due to the age of the students and the stud-height of the classroom. The School D classroom also had the largest number of students. The room has one wall of windows, is carpeted and has a significant patch of linoleum. The teacher of School D attributed most of the sound in her classroom to noise generated by students and identified that children, who were 'far from the teacher/speaker', had difficulty hearing instructions.

The 'Igloo' selected rooms were limited to the early aged group of students. The classroom selected in School B had high stud room and had a mix of carpet and linoleum floor surfaces. The classroom in School C was also a high stud room but the floor was fully carpeted with two walls of full height windows. Comments from the pre-installation questionnaire for both School B and C noted a concern with the loud volumes of noise in the classroom generated from the children at some times due class activity.

Lastly the room chosen for the study of the 'Igloo' in School E was a recently renovated room with new wall coverings and carpet. It has one wall of windows and the teacher uses voice amplification hardware throughout the day because she 'goes home with a strained voice if she doesn't use it'. The teacher commented that she did not think her classroom was 'echoic' and rated her listening environment as 'good' but had concerns about background noise caused by the close proximity to road traffic.

Across all the rooms there was a common grouping of desks and chairs for workspace with the use of a central mat area and the use of hanging ropes or string to suspend children's pictures and images across the roof space.

Note: Full photos are available for reference in the Appendix

4. ACOUSTIC TESTING RESULTS

4.1. TECHNICAL LABORATORY RESULTS

The laboratory results describe the performance of the products using absorption coefficients as defined in Chapter 2.1. For reference, when discussing absorption coefficients a larger result is generally better. An absorption coefficient of 0.3 rather than 0.8 means that the same product would be absorbing 30% of the critically incident sound waves rather than 80%, and therefore absorbing less sound.

4.1.1. 'IGLOO' RESULTS

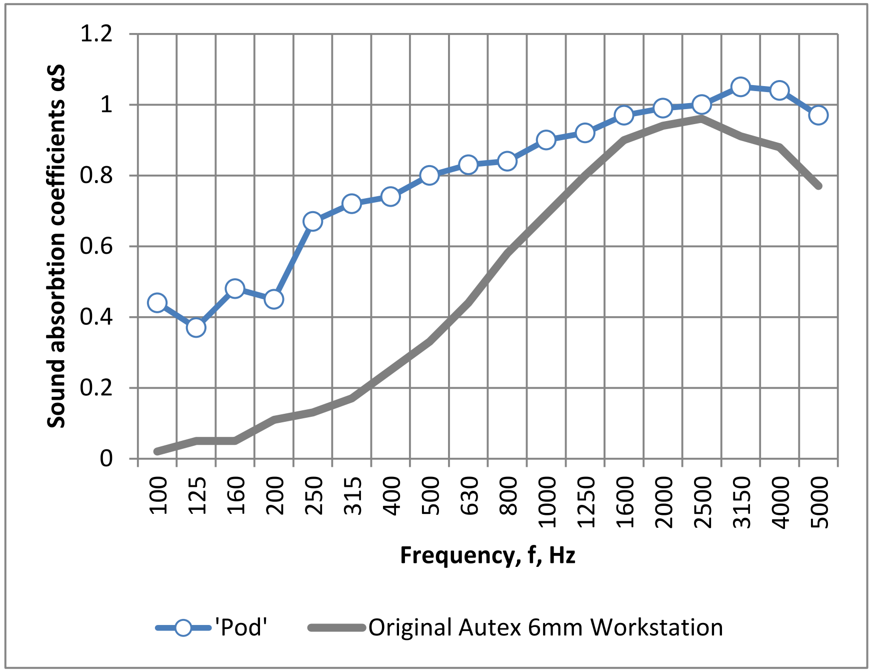
The 'Igloo' performed better than the 'Tri-form' and indeed better than its original material –Autex Quietspace Workstation, in the Laboratory tests in terms of its initial weighted absorption values.

The laboratory tested the 'Igloo' as a whole for the test specimen. The resultant absorption coefficient was of the entire surface area of the 'Igloo'- inside and outside with the test area being 1/2 the total surface area of the material used because of the window holes. Figure 9 shows the absorption coefficients the 'Igloo' achieved for the frequency spectrum of 100-5000Hz. The performance of the original product without form can also be seen, indicated by the grey line.

The 'Igloo' line shows a positive trend increasing toward higher absorption coefficients in the higher frequencies peaking with 1.05 at 3150Hz. The frequency for speech ranges from 300Hz to 5000Hz (Crocker 2007). With the 'Igloo's absorption coefficients ranging between 0.72-1.05 at these frequencies, the 'Igloo' is shown absorb sound at these critical frequency bands.

In Figure 9 the molded 'Igloo' panels can be seen to significantly improve the lower frequency performance of the original unmolded product (without form). The Noise Reduction Coefficient (NRC) of the product has improved from an original 0.20-0.30 for the original unmolded product to 0.85 for the 'Igloo' panels.

Figure 9: Absorption coefficients of 'Igloo'



Ratings according to ISO 11654

Weighted sound absorption coefficient: α_w =0.85

Sound absorption class: B

Rating according to ASTM C423-99

Noise reduction coefficient (NRC) =0.85 Sound absorption average =0.82

4.1.2. 'TRI-FORM' RESULTS

The results of the laboratory test of the 'Tri-Form' showed that it performed better with the AAB Blanket inserted (See Figure 10 and 11 over the page). This has occurred in tests for both suspension heights tested (1m and 0.6m).

This increase in performance can be seen in the higher frequencies in both Figure 10 and Figure 11 with the line indicating 'with AAB Blanket' (Orange) sitting above that of the 'without AAB Blanket' line (Blue). The maximum absorption coefficient was significant increase of 0.11

It was hypothesized that decreasing the height of the suspended 'Tri-Form' would reduce performance of the 'Tri-Form'. However the difference between the results of the two suspension heights tested were not significantly different. The difference between the absorption coefficient results ranged only between 0.07 and -0.06 across the results, which shows little variation due to a significant change in height.

Both Figure 10 and Figure 11 exhibit the increasing acoustic performance of the 'Tri-Form' as the frequency of sound increases. The absorption coefficient performance plateaus around 2000Hz. With the frequency of human speech ranging from 300- 5000Hz the 'Tri-form' can be seen to have a significant effect on areas of critical frequency but not on that of bass frequencies.

Because the 'Tri-Form' is a heat-welded combination of two Autex products; the 6mm Workstation and the Vertiface acoustic paneling it cannot be directly compared to any one of its composite parts.

The 'Tri-Form' achieved an NRC of 0.45 and 0.5 (without and then with AAB Blanket) applying to both suspension heights.

While the absorption coefficients achieved by the 'Tri-Form' are lower than those of the Autex 6mm Quietspace Workstation with a 25mm air-gap in higher frequencies (Autex Industries Ltd n.d.) (See Figure 10 and Figure 11) the 'Tri-Form' out-performs the absorption coefficients of the 6mm Workstation with a 6mm air-gap (indicated by the lighter grey line in Figure 10 and Figure 11) which only has a 0.5 different NRC from the 25mm air-gap product and the Vertiface product

Ratings according to ISO 11654

Weighted sound absorption coefficient: α_w =0.35/0.4 (H)

Sound absorption class: D

Rating according to ASTM C423-99

	With AAB Blanket	/	Without AAB Blanket
1m & 0.6m Noise reduction coefficient:	0.45	/	0.5
1m Sound absorption average:	0.44	/	0.47
0.6m Sound absorption averages:	0.43	/	0.47

Figure 10: Absorption coefficients of 'Tri-Form' suspended 1m with and without AAB Blanket (One-third octave)

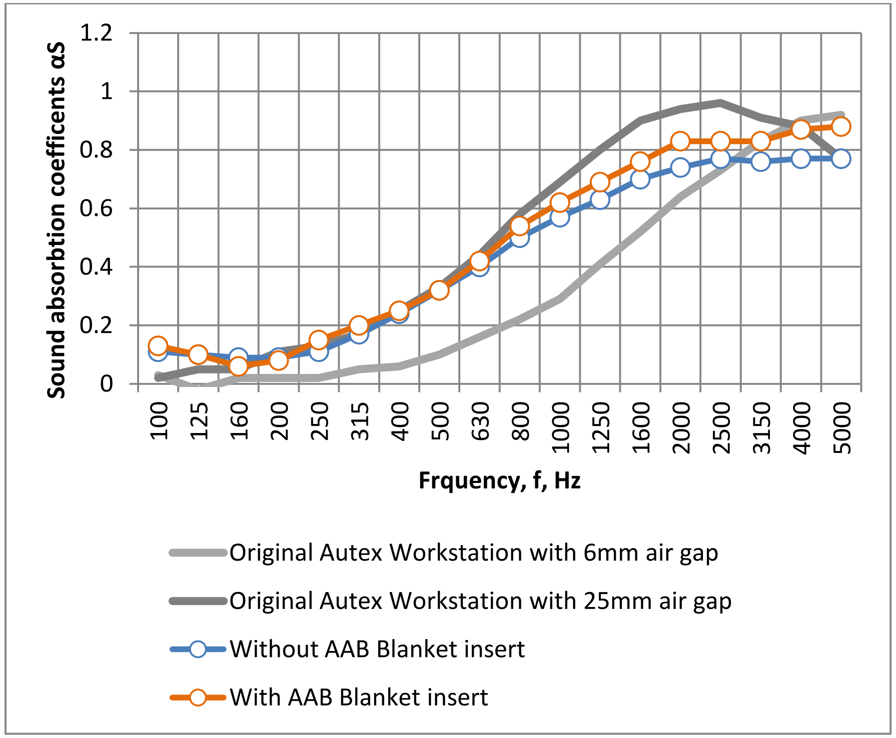
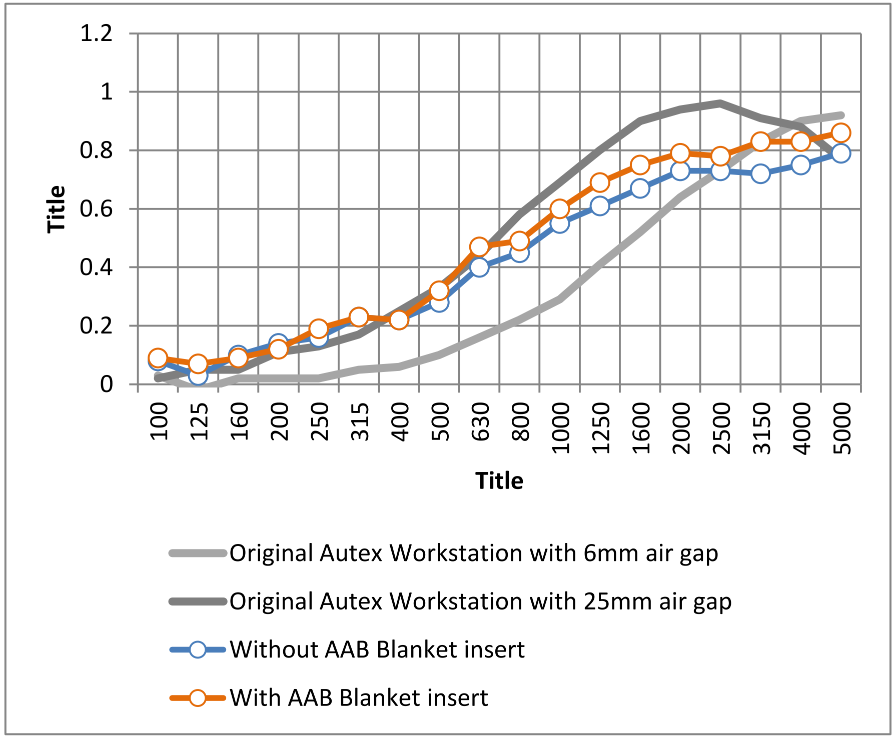


Figure 11: Absorption coefficients of 'Tri-Form' suspended 0.6m with and without AAB Blanket (One-third octave)



4.2. CLASSROOM TESTING

4.2.1. SOUND LEVEL RECORDINGS

The sound level recording measurements for this Pilot testing did not show any change in sound levels following the installation of either of the products.

The results for each classroom were analysed for changes in L10, L50 and L90 sound levels from the pre to the post-installation.

No statistical change could be determined due to some L90 results showing a sound *reduction* after installation, while others showed a sound *increase* for the same product. This also happened in the L50 and L10 measurements. This inconsistency between results made for unreliable data and made pilot testing conclusions impossible.

What can be seen from the sound levels recorded both pre and post installation however is an incredible variation in sound level across times and classrooms. The highest sound level recorded during classroom time was an incredible 90.95dB in School B, taken during a 'Group Work' session. This is consistent with extensive yelling. The sound levels recorded ranged from this to the minimum recording of 32.06dB, also measured in the same classroom. The L90 measurements which indicate what the sound level was for 'most' (90%) of the time showed results ranging from 78.64dB to 90.05dB. These sound level measurements show a dramatic level of classroom noise being produced during class time when the class is being used as a teaching space.

Note: Complete summary results for the sound level comparison can be located in the Appendix for reference.

Figure 12: Preparing the ceiling of School A for suspension of the 'Tri-Form'

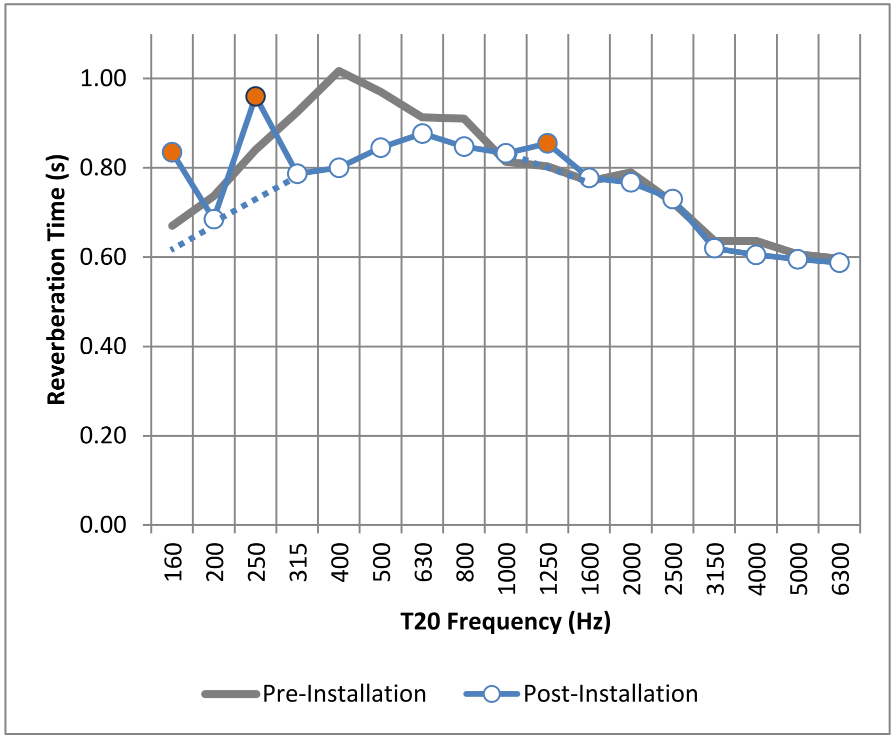
4.2.2. REVERBERATION TIME RESULTS

These results show the reverberation times measured in the test classrooms, pre and post installation. A number of studies identify 0.3-0.4 seconds as the ideal reverberation time for a classroom learning environment (Seep, et al. 2000), (Wilson, et al. 2002). This allows for clear transmission of sound throughout the class space and heightened speech perception for the children.

4.2.2.1. POD RESULTS

School B had, for the most part, the longest reverberation times of all the classrooms tested. Its original (pre-installation) maximum reverberation time of 1.02 seconds at 400Hz and average reverberation time of 0.79 seconds, were well over the recommended level of 0.4 seconds needed to allow unimpaired speech perception. The impact of the installed 'Igloo' on the reverberation within the School B classroom can be seen in the blue line in Figure 13. The three anomaly results the post-installation line of Figure 13 around 160, 250 and 1250Hz (indicated by) are probably caused by exterior sound interference during measurements and so can be ignored. Taking into account the consequent adjusted dashed line, the 'Igloo' appears to significantly reduce the peak reverberation times around 250-500Hz with changes up to 0.22 seconds. The impact of the 'Igloo' reduces in the higher frequencies with the post-installation reverberation times echoing those of the pre-installation times from1600Hz.

Figure 13: School B classroom reverberation tests; before and after installation



The same mimicking reverberation times can be seen in the results from School C. School C had the lowest original reverberation times of the classrooms tested, only ranging from 0.29-0.46 seconds with an average of 0.33. These reverberation times are, for the main part, appropriate for a classroom learning environment and allow should allow good speech indelibility. The 'Igloo' installed in this classroom therefore had less of an affect. It can be seen in Figure 14 that the 'Igloo' did affect the lower frequencies, reducing the reverberation times between 200 and 500Hz by as much as 0.09 of a second. The mimicking occurs when the post-installation tests show reverberation times returning to the original reverberation time trend lines of the classroom around 1600Hz (See right side of Figure 14).

The tests of the School E classroom (Figure 15) showed a reverberation time that decreases as the frequency increases. The original reverberation time of the room was a maximum of 0.93 seconds at 160Hz and an average of 0.53 seconds. The decreasing of reverberation time can be seen as the pre-installation line (Grey) in Figure 15 trends downwards from its maximum at 160Hz to its minimum at 6300Hz of 0.35 seconds. The impact of installing the 'Igloo' within this classroom, indicated by the blue line in , can be seen to reduce some of the peaking reverberation times at 160, 315 and630Hz.

The 'Igloo' acting to flatten out the reverberation times of the room is a common result across all these 'Igloo' results. It can be seen that the 'Igloo' has consistently reduced the peak reverberation times across the three classrooms in the frequency range between 160 and 1000Hz. From 1000-6300Hz the reverberation time impact of the 'Igloo' seems to also consistently lower, with the results commonly mirroring those of the original space with little-to-no change.

Figure 14: School C classroom reverberation tests; before and after installation

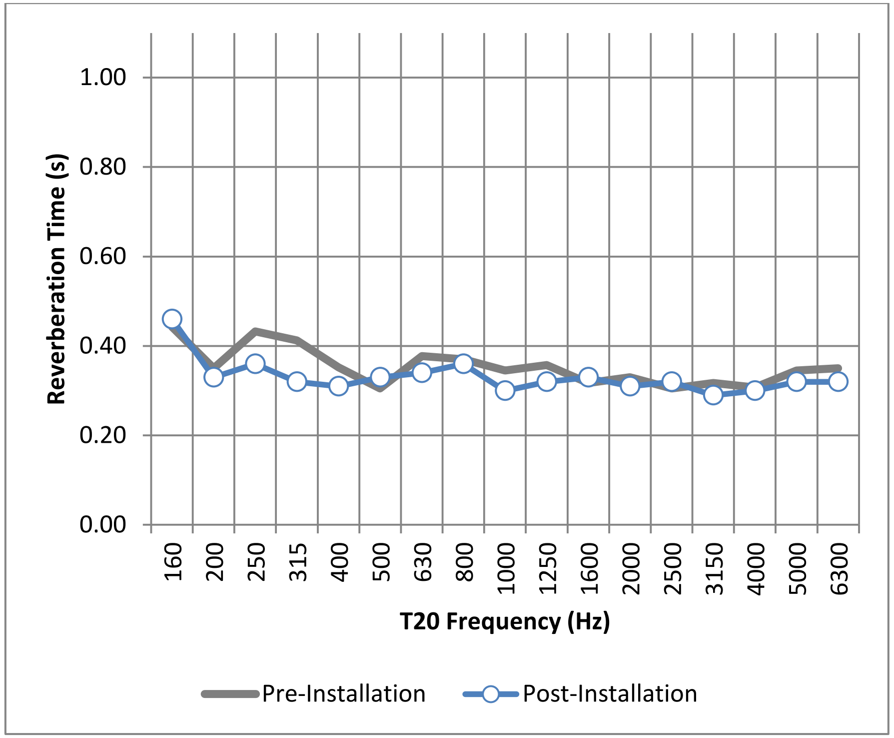
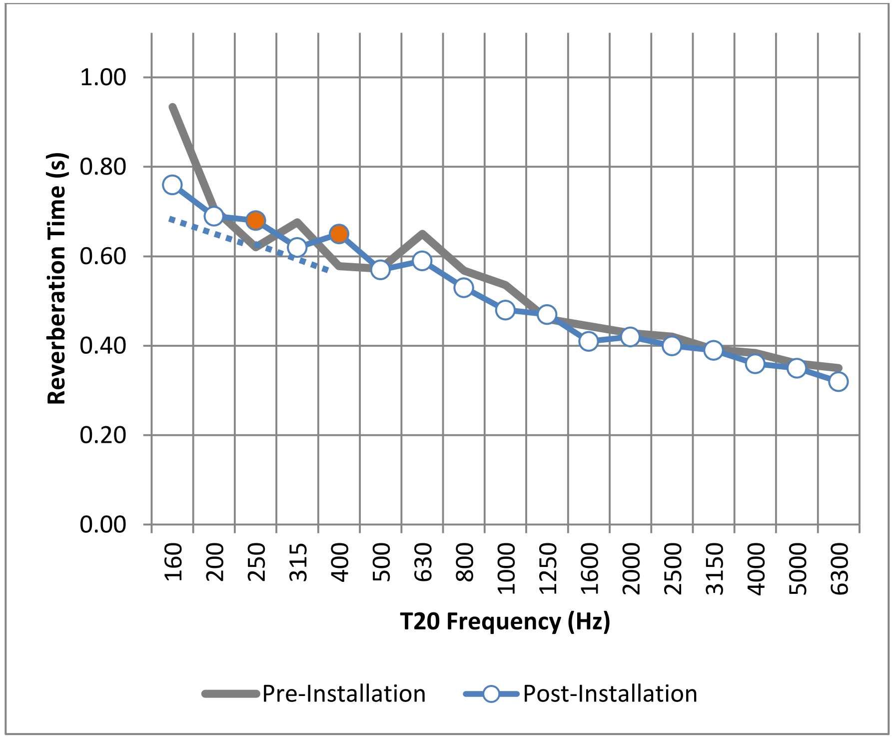


Figure 15: School E classroom reverberation tests; before and after installation



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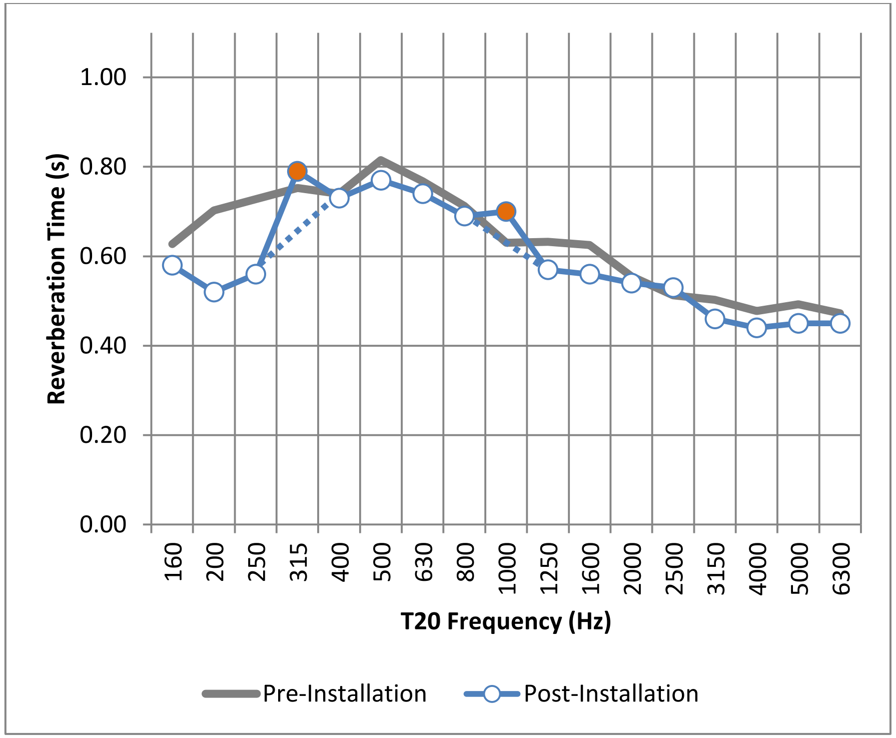
4.2.2.2. ‘TRI-FORM’ RESULTS

The reverberation time results for the ‘Tri-Form’ showed similar pattern results to that of the ‘Pod results.

Tests done in the classroom at School A showed original reverberation times ranging between a maximum of 0.82seconds at 500Hz to a minimum at 0.47 seconds at 6300Hz. The average reverberation time of the classroom was 0.63 seconds. This sits well above the ideal reverberation time of 0.4 seconds especially with the original reverberation time of the room sitting above 0.6 seconds for over 50% of the frequency range tested and its peak reverberation time located in the critical frequency range of human speech and perception (See Figure 16).

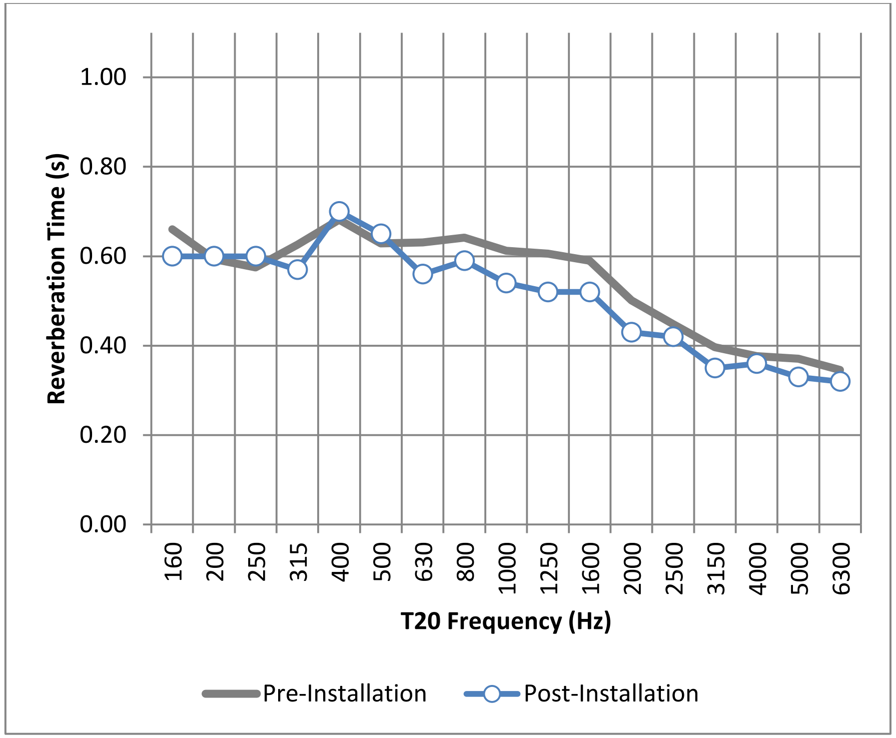
The impact of the installation of the ‘Tri-Form’ in the School A classroom can be seen in Figure 16, indicated by the blue line. Even allowing for the two anomaly results of the post-reverberation measurements (indicated by), it can be seen that installing the ‘Tri-Form’ has resulted in some significant changes in bass frequency reverberation times. The biggest of these changes is a 0.18 second decrease from the original reverberation time at 200Hz. From this maximum reduction the post-installation reverberation times increase and join the same trend as the reverberation times of the original room, peaking and troughing along the same paths.

Figure 16: School A classroom reverberation tests; before and after installation



A different pattern of affect can be seen in School D classroom's post-installation test results (Figure 17). The *pre*-installation reverberation times of the School D classroom decrease as the frequency increases. The *post*-installation reverberation times, shown in Figure 17, follow the same pattern as the original times but at a decreased level. The exception to this pattern is where the post-installation reverberation times of the 'Tri-form' extend marginally beyond that of the original classroom- for the frequencies 400 and 500Hz. This could be an anomaly, but because it so closely follows the pattern of the original reverberation times it is more likely to represent a resonant frequency due to the 'Tri-Form's suspended height or acoustic properties, a frequency where that 'Tri-Form' has no effect on a frequency. The same decrease in performance can be seen in the School A results (Figure 16) around 400 and 500Hz.

Figure 17: School D classroom reverberation tests; before and after installation



5. DISCUSSION

The following discussion considers the results of the pilot study in the light of interactions with the product, teachers, students and school caretakers with some of the theoretical discussions around classroom listening environments.

5.1. SOUND CONCEPT PRODUCTS AND THE CLASSROOM

Our initial findings from the pilot testing indicate that the two Sound Concepts products have some significant effects on the acoustics within the classroom environment.

The original measured reverberation times in the classrooms tested raises some interesting and potentially important issues for the study. For four out of the five classrooms the measured reverberation times of the original room exceeded the recommended cap of 0.4 seconds. This reverberation level is compromising to the potential speech clarity and perception for students within these classroom environments and was one of the key targets for the products to reduce.

The results have shown that the 'Igloo' has a critical impact on the reverberation times in these classrooms in the lower frequencies (<800Hz) but has a limited effect on the higher frequencies within the classroom space. Potentially this can be attributed to its limited size and density along with its position on the classroom floor rather than covering an entire surface. The largest impact of the 'Igloo' was found in the School B classroom; one of the largest in the study and had the longest average reverberation time of the classrooms studied. The 'Igloo' in this classroom reduced the reverberation times up to 0.22 of a second.

The 'Tri-Form' product was shown to generally decrease reverberation time within the classrooms, across all frequencies tested. It was found that the 'Tri-Form' had weak performance around 400 and 500Hz but still made a measured difference of nearly 0.2 seconds in some frequencies and classrooms.

Figure 18: Kids playing in the 'Igloo' installed in Kaori Normal classroom

The impact of the products was clearly affected by how extreme the reverberation time of the room was. In a classroom with a long reverberation (>0.6 seconds), like that in School B, the 'Igloo' had a larger impact. This differs from a result like that of School C, whose reverberation time was low, and more ideal (0.4 seconds+/- 0.05), the product had less of a difference. This was true too of the 'Tri-Form' classroom tests, the higher the original reverberation times, especially in the lower frequencies, the larger the impact of the 'Tri-Form' on reverberation times' post-installation.

This phenomenon can most likely be attributed to the fact that for longer reverberation times the energy of a sound wave is able to travel around in a space for a longer time without its energy being absorbed by classroom surfaces (Binggeli 2003). When an absorbent acoustic product like that of the 'Igloo' or the 'Tri-Form' is put in a reverberant space it acts to increases the energy absorbing surfaces and so decreases the sound reflections per unit of time, increasing the rate of the sound decay (Turner and Pretlove 1955). For a room with a low reverberation time there is already a fast rate of decay so the products are less likely to make contact with sound waves at the angle of incidence and therefore less likely to make an impact on the reverberation time.

5.2. USER INTERACTION- A BREIF ANALYSIS OF COMMENTS AND POST-QUESTIONNAIRE RESULTS

The application of the 'Pods' and 'Tri-Form' into the different schools and classrooms resulted in some interesting discussion on the products with their users and potential installers.

The main concerns of the teachers were that the products improve the level of sound within the space and that the product should benefit the children. Though a change in sound level could not be determined the results of the reverberation tests show that the product will have had an impact of the acoustic environment of the classrooms. By improving the reverberation times in the rooms the products reduce the persistence of sound within a space and as a result have improved the intelligibility of speech and perception of music; improving learning perception within the tested space.

Following installation the teachers had a number of comments on the products and their impact on the classroom.

'Igloo' classroom teachers had been concerned with how much ground space the 'Igloo' was going to occupy with the limitation of space a key issue for all of the classrooms tested. Following the 'Igloo's assembly a number of teachers commented that the 'Igloo' was not nearly as big as they had thought it would be. Others said that it would now be incorporated into the classroom furniture; in all classrooms the 'Igloo' was integrated into an unoccupied floor-space, in a reading area, up against a wall and window space and in School E- in a corner of the classroom. Children interacting with the 'Igloo' referred to it by a number of names; 'a bees nest', 'hut' even by its product name the 'Igloo'. Across all classrooms the children's first experience of the 'Igloo' was an exploratory one, with the children entering through the door-space, standing up in the center and then often using the window holes to exit.

The suspension of the 'Tri-Form' from the ceiling meant that there was a lack of direct play and continued attention given to the product by the children in the class. In both classrooms where the 'Tri-Form was tested the teachers commented that the 'Tri-Forms' were initially an item of interest but as time passed on the first morning they were seen they were less of a 'distraction'. Teachers in both classrooms inquired if classroom artwork could be hung from the suspended 'Tri-Form', and it was discussed that while art work most probably could be hung it was discouraged that too much be attached in case the system should be pulled from its supports.

Overall the comments were positive on the products especially on their 'look' and 'feel'. There was however one issue highlighted by the School A teacher of dust and the capture of it by the product over time. It was identified that this would need to be addressed, possibly through education of installers and users.

5.3. SOUND CONCEPT PRODUCTS IN THE MODERN LEARNING ENVIRONMENT

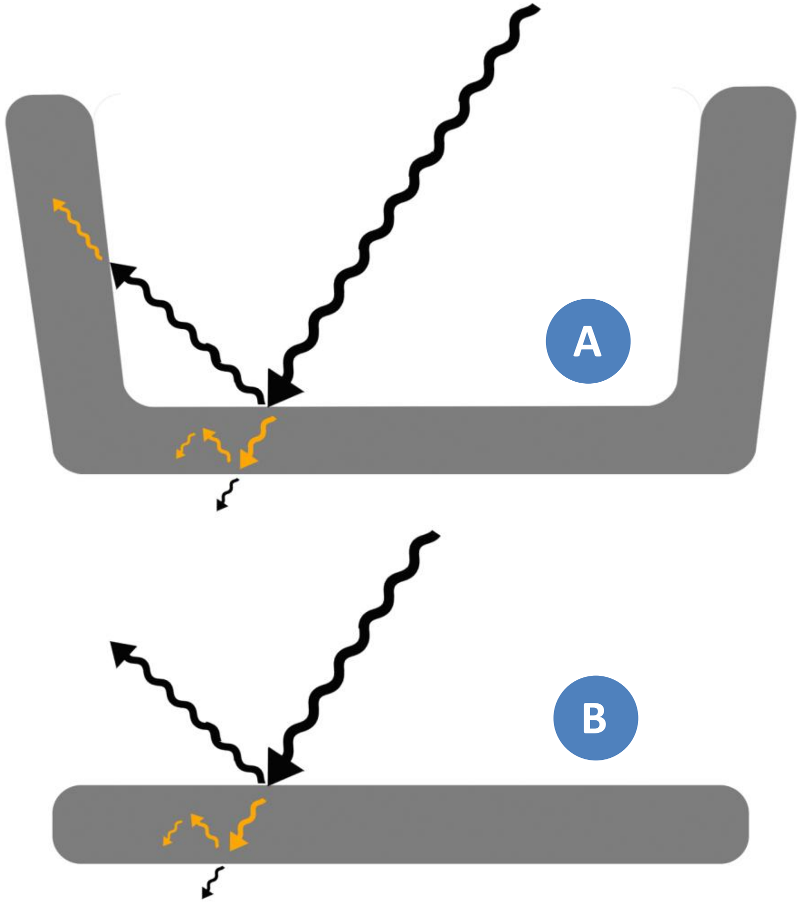
The pilot test has revealed that forming/shaping the flat Autex acoustic products can increase their acoustic performance.

The results from the laboratory tests of the two products show that both products improved the sound absorption performance of their original product counterparts. This change can be attributed to the newer 'form' of the material increases the amount of surface area exposed therefore the attenuation of sound. Figure 19 shows an example of the 'Tri-Form' baffle 9A) and how it acts to absorb more reflected sound because of the cupping shape of the product and increased exposed surface area. The flat baffle (B) does not do this and instead the sound energy not absorbed on incident is returned into the space. Figure 19 also shows how sound can be absorbed within the material with trapped sound waves decreasing in energy over time.

Another benefit of 'forming' the original, flat product is that the heat molding process increased the product's rigidity and allows the product to support its own weight. The rigidity and design of the Geodesic 'Igloo' meant it could stand up on its own and allowed the 'Tri-Form' to be suspended. It also meant that the baffles did not need to be anchored to a sub-straight and therefore both sides of the material could be exposed- increasing sound absorbing surface area.

It was found in the assembly and installation stages of the project that the 'Tri-Form' baffles, when suspended 'draped' rather forming a rigid platform. While this was not dramatic enough to affect its acoustic performance it does affect how it can be used and how high it needs to be hung. The 'draping' of the Tri-form (Seen in Figure 20) meant that, though it was suspended at 1m from the ceiling, at its lowest point the 'Tri-form' hung at 1.2m +/- 0.05m. This was a limitation to the pilot 'Tri-Form's' use in the primary schools. The draping of the 'Tri-Form' meant that it couldn't be used in low stud classrooms. It also meant that the placing of the installation for testing had to consider the numerous

Figure 19: Diagram of sound absorption; formed baffle verses a flat baffle



hanging artworks of the students to ensure the classroom was minimally disturbed from its normal format.

Some of this flexibility of the suspended ‘Tri-Form’ was caused by the pivoting 6mm ratchets that were used to connect the ‘Tri-Form’ baffles. The rest of the flexibility was attributed to the way the ‘Tri-Form’ was assembled; with a wide pattern used and large gaps between ‘Tri-Form’ stars. It is possible to increase the density of the ‘Tri-Form’ pattern by securing the baffle tiles against their longest horizontal edge and therefore significantly improve the rigidity of the structure. This pattern would increase the density of the ‘Tri-Form’ system meaning more tiles will be used in the same flat area. This would most likely increase the acoustic performance of the system by with a significant increase in the available surface area.

The element of flexibility needs to be incorporated into any denser and therefore more rigid ‘Tri-Form’. The current ‘Tri-Form’ system exhibits an acoustic baffle which can flow over and around surfaces, ceiling structure, services and in-amongst sprinkler heads. Potentially this application also extends the use of the ‘Tri-Form’ beyond that of the classroom and into use in the commercial, industrial and appropriate residential situations.

Another potential development of the products is a move of the ‘Igloo’ and ‘Tri-Form’ panels into a wall and corner-based acoustic baffle system. This system would utilize the increased performance of a normally flat acoustic product and create a series of fixed designs away from the normal wall-structure. Like normal acoustic wall-panels these baffles would act to absorb mid-range frequencies (Binggeli 2003) but designed carefully the structural rigidity of the panels can be used to create a layer of air in amongst the individual forms that could also act to absorb the bass frequencies of sound (See ‘Pod and ‘Tri-Form’ results). This system would need the design of fixture methods and considerations of a sub-straight.

Figure 20: Draping 'Tri-Form' suspended in School A

6. SUMMARY AND RECOMMENDATIONS

6.1. CRITICAL FINDINGS

- > Of the classrooms tested, four out of five had speech and perception impairing reverberation times of longer than 0.4 seconds.
- > Placing 'form' into an originally flat acoustic product can significantly improve its performance due to increased surface and impact of changed shape
- > The 'Igloo' Sound Concepts product had a significant effect on the absorption of lower frequencies of sound within the classroom environments tested. In addition it decreased the reverberation times of some of the mid-range frequencies of speech and most of the high frequencies.
- > The 'Tri-Form' consistently reduced reverberation times across all frequencies excluding 400-500Hz where a resonant frequency was achieved.
- > Both products have a design flexible enough to be used for a number of other applications including new arrangements, increased density of panels for the same horizontal area, wall and corner-based systems and acoustic treatment of and around services etc.

6.2. SUMMARY

This research has shown how the 'Tri-Form and 'Igloo' products have positively impacted the acoustics in a set of five primary school classrooms. The research demonstrates how of putting form into the traditionally flat Autex 6mm Quietspace Workstation product improves the acoustic performance of the original product. The developed product exhibits a flexible acoustic product that has the potential to be used in a number of classroom and commercial applications.

7. FURTHER STUDY

The 'Tri-Form' system has been identified to perform better with the insert of the Autex AAB Blanket. The design team recommends developing the 'Tri-Form' so it doesn't rely on an insert, but rather on its own structure. This will enable the product an increased versatility.

This research has shown that putting form into the original product through the developed designs has increased their acoustic performance. An analysis of cost verses material and performance benefits of the 'Tri-Form and 'Igloo' product's design will underpin how successful these products have been.

With the measurement of sound level in this research inconclusive it would be beneficial to attempt a long term study of the sound levels pre and post product installation. Additionally the number of classrooms tested needs to be increased to achieve an appropriate sample size. This extended testing would allow thorough assessment of whether the 'Tri-Form' and 'Igloo' affect sound levels or 'café effects' within primary schools instead of just reverberation time.

Other product development ideas include:

- Development of fixtures –for the systems themselves and to surfaces
- Development of the Tri-Form into a wall-based acoustic baffle
- Instructions for assembly and installation

Figure 21: Pod or 'Igloo' awaiting use

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Sound Concepts Research
Pre/Post-Installation: Activity Log

Please note down your classroom activities over the day in the appropriate timeslot for the three days agreed to with the researchers. Only note down when an activity changes; you do not need to put something in every box if the activity remains the same just draw a line around the appropriate time slot(s)

School:
Classroom:
Teacher:

Timeslots	Activity		
	Day 1	Day 2	Day 3
8:30am-9.00am			
9.00am-9.30am			
9.30am-10.00am			
10.00am-10.30am			
10.30am-11.00am			
11.00am-11.30am			
11.30am-12.00pm			
12.00pm-12.30pm			
12.30pm-1.00pm			
1.00pm- 1.30pm			
1.30pm-2.00pm			
2.00pm-2.30pm			
2.30pm-3.00pm			

Any additional notes:

Sound Concepts Project

Classroom Acoustics Survey: Pre-Installation Questionnaire

Thank you for completing this questionnaire. We are investigating the opinions of teachers on the acoustics and noise levels of the classrooms that you teach in. We are particularly interested in the effects of reverberation in classroom environments which has been linked to students' ability to hear and learn.

To protect privacy and maintain confidentiality the classrooms will only be identified by a study number when any of the research findings are presented.

Date ________________________________

School_________________________________

Classroom Number ______________________

Age range of students in your class ________

School Year _____________________________

Number of students in your class _________

How many students in your class have a hearing loss that you are aware of? ______________

✐ **Please place a cross in the box of the appropriate answers.**

✐ **Please note this questionnaire is printed in a double-sided format.**

✐ **Thank you for your time and cooperation in completing this questionnaire**.

Please return it to the school office by the date noted on the attached letter.

Classroom Acoustics Survey

Room Characteristics:

1. In your opinion what aspects of your classroom are the most important? Rank those categories below with 1 being the most important and 5 the least important.

- ☐ Lighting (state example if known)________________________________
- ☐ Ventilation (state example if known)______________________________
- ☐ Acoustics (Listening environment) (state example if known) ____________
- ☐ Equipment (state example if known)______________________________
- ☐ Sufficient room space (state example if known) ______________________

2. How do you experience the listening environment in the classroom?
(Please choose all the words that best describe your present room)

- ☐ Comfortable
- ☐ Confusing
- ☐ Echoes
- ☐ Harsh
- ☐ Clear
- ☐ Irritating
- ☐ Relaxing
- ☐ Other (please specify) ____

3. How do you rate your classroom listening environment?

- ☐ Very good (go to next section Noise Sources – Inside the Classroom)
- ☐ Good (go to next section Noise Sources – Inside the Classroom)
- ☐ Acceptable (go to next section Noise Sources – Inside the Classroom)
- ☐ Poor (continue to Q4)
- ☐ Very poor (continue to Q4)

4. If you answered “poor” or “very poor” why do you think that it is hard for students to hear well in your classroom?
- ☐ Open plan style room
- ☐ Too much echo in room
- ☐ Too much noise from outside room
- ☐ Noise level produced by students too high
- ☐ Other (please specify) ____

Noise Sources – Inside the Classroom:

1. Do you have any problems with noise created inside the classroom (this includes the noise the students themselves make)?
- ☐ Yes (continue to Q2)
- ☐ No (go to the next Section – Noises outside classroom)

2. What proportion of noise generated inside the classroom is student generated?
- ☐ None
- ☐ Some
- ☐ Most
- ☐ All

3. Please identify all other sources of noise inside the classroom?
- ☐ Equipment, e.g. Computer, fish tank, clocks.
- ☐ Air conditioning
- ☐ Heaters
- ☐ Lights
- ☐ Fans
- ☐ Other (please specify) ____

4. Which is the most intrusive noise from the list in Q3 above?___________________________

Noise Sources – Outside the Classroom:

1. Do you have any problems with outside noise entering your classroom (this includes noise from adjacent rooms)?
   - ☐ ☐ Yes (continue to Q2)
   - ☐ ☐ No (go to the section on Vocal Effort)

2. Identify the sources of the outside noise?
   - ☐ Traffic noise
   - ☐ Lawn mowing
   - ☐ Noise from other classrooms
   - ☐ Noise from sports fields
   - ☐ Corridors
   - ☐ Student traffic on decks
   - ☐ Other (please specify) ____

3. Which is the most intrusive noise from the list in Q2- sources of outside noise? ___________________________

4. How important do you think it is to eliminate or reduce these external noises for the students?
   - ☐ Critical
   - ☐ Important
   - ☐ Not very important
   - ☐ Unimportant

5. What could be done to eliminate these noises from outside your classroom?

____

____

6. Which is the worse source of noise problems for you?
   - ☐ noise made inside the classroom
   - ☐ noise coming into the classroom from outside?

Vocal Effort:

1. When teaching would you consider yourself to have?
   - ☐ A soft speaking voice
   - ☐ A normal level speaking voice
   - ☐ A loud speaking voice

2. How often is it necessary for you to elevate your voice to be heard clearly?
   - ☐ Always
   - ☐ Often
   - ☐ Sometimes
   - ☐ Never

3. Does the level at which you need to speak seem to strain your voice?
   - ☐ Yes
   - ☐ No
4. From where in the classroom do students appear to be able to hear your instructions best?
   - ☐ Easy everywhere
   - ☐ Near the teacher
   - ☐ Far from the teacher
   - ☐ In the center of the room
   - ☐ Near the back
   - ☐ At the sides
   - ☐ Have not considered this

5. From where in the classroom do students seem to have most difficulty hearing?
- ☐ Difficult everywhere
- ☐ Near the teacher
- ☐ Far from the teacher
- ☐ In the center of the room
- ☐ Near the back
- ☐ At the sides
- ☐ Have not considered this

Teaching Style:

1. Approximately what percentage of time do you spend in the classroom teaching in each of these styles?
- ☐ Mat Work _____
- ☐ Group Work _____
- ☐ Blackboard/Didactic _____
- ☐ Other (specify) _____

Total 100 %

2. In what situations do you find it is necessary to elevate your voice to be heard clearly?
- ☐ Mat work
- ☐ Group work
- ☐ Blackboard
- ☐ Other (please specify) ____

3. Where is your usual position in the class?
- ☐ At the center
- ☐ In the front
- ☐ Walking around
- ☐ Other (please specify) ____

4. Do you think the acoustics in your classroom have a direct effect on the student's learning ability?

- ☐ Yes (go to question 5)
- ☐ No (go to question 6)
- ☐ Don't know (go to question 6)

5. Please explain in detail, why you think the acoustics in your classroom have a direct effect on the student's learning ability. Continue overleaf if more space is required.

____

____

____

6. Please note any further comments you would like to make on the subject of this questionnaire.

____

____

Sound Concepts Project

Classroom Acoustics Survey: Post-Installation Questionnaire

1. What is the number of the classroom you taught last year? ___________________

2. Please describe in your own words how your classroom listening environment has changed since it has been modified.

____
____
____
____

3. Have the acoustics improved in your classroom since the ceiling was modified?
   - ☐ No
   - ☐ Slightly
   - ☐ Significantly

4. Have the ceiling modifications created any new problems for you?
   - ☐ Yes
   - ☐ No

   If `Yes' Please describe;

   ____
   ____

5. With respect to the two issues listed below, please rate your classroom for the different teaching styles **(Circle appropriate place on scale)**.

A. Inside Noise Levels	**Same……….Better……….Worse**
Group work	├──────┼──────┤
Mat work	├──────┼──────┤
Blackboard / didactic	├──────┼──────┤
One to One	├──────┼──────┤

B. Student’s Hearing Ability **Same……….Better……….Worse**

Group work

Mat work

Blackboard / didactic

One to One

6. Have any of your colleagues (or student’s) made any comment about the modifications?

____

____

THANK YOU

Figure 22: School A, view of the inside from the doorway

Figure 23: School C, view of the inside of the building from the door

Figure 24: School E, view from the back of the classroom with the door to the left and right

	Island Pre	Island Post	Khandallah Pre	Khandallah Post	Petone Pre	Petone Post	Raumati Pre	Raumati Post
	Duration: 3.07:11:17	Duration: 4.21:33:26	Duration: 4.00:00:05	Duration: 4.00:00:00	Duration: 3.09:03:09	Duration: 4.00:00:02	Duration: 4.00:00:14	Duration: 06:10:03
	Start: 13/03/2012 10:37:27 a.m.	Start: 16/03/2012 5:51:30 p.m.	Start: 8/03/2012 3:28:26 p.m.	Start: 13/03/2012 8:39:52 a.m.	Start: 27/02/2012 8:56:08 a.m.	Start: 6/03/2012 8:16:26 a.m.	Start: 7/03/2012 3:38:08 p.m.	Start:13/03/2012 3:26:25 p.m.
	End: 16/03/2012 5:48:00 p.m.	End: 21/03/2012 3:24:00 p.m.	End: 12/03/2012 3:28:00 p.m.	End: 17/03/2012 8:39:30 a.m.	End: 1/03/2012 5:59:00 p.m.	End: 10/03/2012 8:16:00 a.m.	End: 13/03/2012 3:24:00 p.m.	End:13/03/2012 9:36:00 p.m.
Maximum Level Recorded (dB)	78.64	81.3	80.35	90.05	90.18	80.54	81.35	0
Minimum Level Recorded (dB)	32.98	32.91	26.02	27.26	32.08	29.73	38.59	0
L90 (dB)	49.348	53.204	32.739	43.958	52.522	34.418	44.482	Not enough Data
L10 (dB)	70.694	70.756	67.364	77.833	77.73	66.035	73.742	Not enough Data
L50 (dB)	63.77	63.29	55.005	69.71	70.29	57.12	64.57	Not enough Data