Building a "vocabulary of experiences": Supporting children's learning in science centres

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Science centres[1] are designed to enable visitors of all ages to participate in fun, interactive experiences related to science. The biggest audience for New Zealand's small string of science centres is primary school children, visiting either with their friends and family, or on organized class trips. To what extent might these centres contribute to science teaching and learning in New Zealand schools, and how does a visit to a science centre actually contribute to classroom learning? What value do primary teachers see in bringing their students to a science centre, and what do teachers and students take away from their visit experience? This article reports some of the findings from a research project that aimed to document the role that a visit to one New Zealand science and technology centre played in the educational activities of six visiting primary school groups (Bolstad, 2000).

When it comes to thinking about what children enjoy and how they learn, science centre advocates and primary teachers have a lot in common. For example, one prominent science centre advocate suggests that good interactive exhibits should extend children's "vocabulary of experience" (Russell, 1990), giving them the opportunity to develop an intuitive understanding of various science-related phenomena. At this level of understanding, a child would have the ability to give a "hand-waving" explanation (Gregory, 1997), sowing the seeds for more sophisticated understandings and explanations to develop later. Most science centres describe a range of objectives for visitors that include: creating positive attitudes towards science; developing enthusiasm, wonder, and curiosity; encouraging people to think for themselves; developing intellectual self-confidence; and encouraging children to like science, or perhaps even want to become a scientist.

These goals seem to align nicely with some current international thinking about what primary science education should do for children. One influential report from the United Kingdom (Millar and Osborne, 1998) recommends that primary science should:

- provide a framework for developing children's innate curiosity about their natural environment;
- foster habits of careful observation and the use of precise language for descriptive purposes;
- provide opportunities to interact with the wide variety of natural phenomena that exist, to investigate their behaviour, and to learn how they are talked about;
- begin the process of developing the ability to produce and understand scientific arguments, using reliable and agreed evidence to support conclusions.

In New Zealand, recent findings from the Third International Mathematics and Science Study (TIMSS) have indicated a wide range in our primary science learners' achievement. Of particular concern is the low achievement of some children in low SES groups at Years 4 and 5. In the light of these findings, in 2001 the Ministry of Education commissioned a review of recent research in school science education to provide evidence for what might be effective pedagogy to raise New Zealand students' achievement in science (Hipkins et al., in press).

The review strongly suggested that, particularly for younger learners, having broad background experiences and a wide general knowledge of the world is an important factor in students' making links between their daily lives and their science learning. In other words, one feature of effective science pedagogy involves providing opportunities for students to have rich foundational experiences that they might not otherwise have outside their school lives. In short, a breadth of foundational experiences can be seen not only as supporting the further development of science learning outcomes for young learners, but also as in itself a valuable outcome of students' school science education.

Recent longitudinal studies of young children's learning in science also support the idea that concrete, personal experiences are an essential part of children's science learning. There is evidence that specific memories and experiences that young learners bring to their science learning can persist well into adolescence and continue to influence learners' ideas about scientific concepts and processes. For example, in one study, 23 Swedish students' developing understandings of ecological processes were traced over a period of 10 years (Hellden, 2001). When, at age 15 and 19, they listened to tape-recordings of their earlier interviews, the students could often recount concrete experiences from an early age that had led to them referring to certain concepts or processes over and over through the years. One student's description of the materials and processes involved in creating compost was remarkably consistent at ages 9, 11, 13, and 15 – he always described things like eggshells and coffee grounds breaking down into smaller pieces and mixing together. At age 19, the student recalled himself as a 7-year-old helping a neighbor to empty buckets of eggshells and coffee grounds onto a compost heap. The memory had stayed with him and become a part of his way of thinking about decomposition.

Thus, there seem to be many good reasons to think that the science centre learning environment could be an ideal conduit between the world of science and the world of the primary classroom.

Science centres can draw on special physical resources, and the knowledge of working scientists, with the specific purpose of translating this science knowledge and resourcing into interactive and engaging exhibits and programmes that appeal to primary school children. They can provide rich, memorable learning experiences that children might not otherwise encounter. These experiences can lay the foundations for learning that might extend well into children's future science education.

The context for the research

My research was conducted during one school term in 2000 while a temporary exhibition called *Maze Daze* was installed at a small New Zealand science and technology centre. *Maze Daze* featured a number of large bright floor mazes, tessellation tables, and puzzles. Although it was not a particularly science-laden exhibition, the centre had boosted the science and technology content of *Maze Daze* by developing a workshop session to go with the exhibition. During this session, the science and technology centre's education officer presented a number of exciting activities and demonstrations of scientific phenomena such as air pressure, lasers, motion, and force, all built around a maze theme. The demonstrations included a labyrinth which a Ping-Pong ball could be blown through, a laser maze with smoke and mirrors, and strategy "tilt" mazes which children had to tilt to roll a ball through. A typical visit to *Maze Daze* lasted an hour and a half, with about half this time spent on the exhibition floor and the other half in the education workshop.

The strategy for my research was to investigate and compare the views of science and technology centre staff, teachers and students about class visits to the science and technology centre. Interviews and observations with teachers and students before and after the visit enabled a picture to be constructed of the way the visit fitted in with the school-based activities of the classes concerned.

The study schools

A sample of six classes from three schools was chosen, based on the science and technology centre's list of bookings at the beginning of the term. Table 1 outlines the six classes involved.[2]

The six teachers from the three schools were each interviewed at their schools a few days before their visit to *Maze Daze*, and interviewed again approximately a week to 10 days after their visit. Each teacher chose a sample of five children of mixed sex, age, and ability to participate in group interviews one day before and about 10 days after their visit. The science and technology centre's director and education officer were also interviewed, and all six classes were observed during their visit to *Maze Daze*.

TABLE 1. SAMPLE OF SIX CLASSES INVOLVED IN SCIENCE CENTRE RESEARCH, 2000

	Class level	*Age range of children*
School A Teachers 1 & 2	Year 1 & 2	5 years 7 months – 7 years 1 month
School B Teachers 3 & 4	Year 3 & 4	7 years 1 month – 9 years 8 months
School C Teachers 5 & 6	Year 3 & 4	7 years 1 month – 9 years 2 months

TABLE 2. HOW THE MAZE DAZE VISIT FITTED IN WITH SCHOOL ACTIVITIES AT EACH SCHOOL

	Relationship between Maze Daze visit and school activities	*Activities which occurred after the visit*	*Curriculum objectives*
School A	*Maze Daze* visit was part of a teaching unit with specific science and technology achievement objectives.	Children: • worked in pairs to design and build their own 3 dimensional marble mazes using cardboard, tubes and other found materials. • practised giving each other directions to get through a maze laid out in masking tape on the floor.	**Science**: children to describe different types of motion to move a marble through the maze. **Technology**: children to describe ways in which the maze could have been modified for improvement. **Mathematics**: direction and position: children to give each other direction commands to get through a floor maze.
School B	*Maze Daze* visit was part of a wide teaching unit which crossed several different curriculum achievement objectives.	Children: • wrote, drew and discussed ideas for creating their own mazes. • created a collage maze as an art activity. • looked at maps, drew a map of their classroom and asked peers to navigate using their map.	**Art**: using drawing and collage to design a creative maze. **Science**: discussing the properties of different materials which could be used to build their mazes. **Health and PE**: extending map-drawing skills to larger areas: school grounds, local neighbourhood, and using these as the basis for an orienteering exercise.
School C	*Maze Daze* visit was not linked to any specific teaching unit.	A few ad-hoc activities related to mazes, mainly drawing and discussing ideas for fantasy mazes.	No specific curriculum objectives.

Broadening children's experiences: the teachers' perspectives

The relationship between the *Maze Daze* visit and specific classroom activities was different across the three schools, but was very similar among classes within each school. In all three schools, teachers planned within syndicates, to teach and assess the same general curriculum areas across the syndicate over the course of the year. Table 2 summarises, for each school: the relationship between the visit and school activities; the main trip-related activities which occurred in classrooms after the visit; and which curriculum objectives teachers said these activities were intended to cover.

As Table 2 shows, the teaching context for each school's visit was different. **School A** had gone to *Maze Daze* specifically because they had planned a teaching unit incorporating science and technology achievement objectives, and the teachers felt that the maze theme would be a good way to do this.

School B viewed the visit as one component of a whole-day trip from their rural town to the city that was home to the science and technology centre. Their day included a visit to look around the campus of the local university. These teachers had rather holistic objectives for the trip, many of which related to extending the children's awareness of the possibilities outside their small town:

> To realise that education goes further than [name of School B] (Teacher 3, school B).

The activities which occurred in school B after the trip reflected these broad goals and were intended to span several curriculum areas, including science, art, and health and physical education.

School C viewed the visit experience itself as sufficient reason for attending *Maze Daze.* The visit was not incorporated into a specific teaching plan on this occasion, partly because the school was engaged in rehearsals for a drama production that term. The activities that occurred after the visit were of an ad-hoc nature and were not intended to cover specific curriculum objectives.

The activities that followed the visit in all six classes seemed to divide into two main categories: first, those designed to cover specific, assessable curriculum achievement objectives (listed in Table 2), and second, those which did not cover assessable achievement objectives but were considered valuable learning opportunities by the teachers. Although the specific "curriculum-linked" activities associated with the visit were quite different at each school, the six classes also shared many similarities. For example, all six teachers shared similar attitudes about the value of trips out of the classroom. Their view was that out-of-school trips could extend the children's education by giving them new experiences, and enabling them to experience things that could only be talked about in the classroom:

> You know it's just providing something which we can't do on our own, and so it's an extra opportunity for the kids to go there and learn (Teacher 1, School A).

Class trips were often used as a focus for developing children's language skills. In all six classrooms, teachers had followed up the trip by having students talk, write and/or draw about the visit and the things they had enjoyed. All the teachers felt that this was an important follow-up for any class trip, particularly as it caused the children to reflect on their experience and put this into language:

> I usually get them to write something about the experiences that they've had as well…what can you remember, what did you enjoy, what did you learn. (Teacher 2, School A)
>
> I mean for example one thing that we've done is build up lists of vocab. from that visit. From there it's improving spelling … it's improving oral language because they have to start explaining words and how they put it in context and how they would use it during the day…. There's the written language part…The letter to our parent helper, we had to include also two or three sentences about the things we enjoyed doing throughout the day….then they had to write about *why* they enjoyed it, so it's good expressive language. (Teacher 4, school B)

These activities appeared to be part of the normal classroom routine for following up on new learning experiences. In addition to the language-based activities, at least two teachers used the trip to stimulate group work or social interaction in the class. Another teacher had videotaped the trip and viewed it with his class afterwards. This served to extend the trip experience, and was also intended to reduce the novelty of being "on-camera" in preparation for a video-making unit the following term.

All six teachers felt that the trip had been very worthwhile and that the science and technology centre was an appealing and appropriate destination for their classes. The teachers made excellent use of the informality and exploratory nature of the science and technology centre environment, using parents to help monitor the children's movements, allowing children the freedom to explore exhibits themselves, and making themselves available to answer questions or be shown what the children had discovered in their explorations. Teachers saw the science centre visit as an opportunity to broaden and enrich children's "vocabulary of experiences" – *and*, in a literal sense, their vocabulary for speaking and writing about the experience. The teachers noticed what the children enjoyed, and reinforced the visit experience back in the classroom through a variety of activities, many of which had been loosely planned to meet particular objectives from a variety of curriculum areas.

However, the science and technology centre's philosophy was to provide fun, hands-on, and interactive experiences specifically as a medium for learning science and technology. From this perspective, providing rich experiences for children is a first step in a road leading to the development of cognitive understandings in science. Did the science centre therefore have other possible learning goals in mind for their primary visitors? And if so, did these match up with the teachers' teaching and learning goals for the trip?

Designing science experiences for children: the science and technology centre's perspective

In designing the *Maze Daze* workshop session, the science centre's education officer had begun with a mental list of science areas, such as air pressure, light and reflection, force and motion, and from there considered how to turn these ideas into fun, interactive demonstrations of phenomena that would relate to the maze theme. To demonstrate some phenomena related to the science of light, he decided a few weeks before *Maze Daze* was due to open that he would create a maze through which a laser beam could be directed by reflecting it off a series of mirrors:

> So I thought a light beam then brings in angles of reflection, it brings in scattering and so forth, particularly if it's a laser; if it's a laser I can bring in monochromatic light, single wavelength. I can bring in reflection versus transmission versus absorption of the light…(Education officer)

A few weeks later, the education officer had obtained a suitable laser, constructed the maze, and mounted it on the wall of his workshop classroom. In one of the most dramatic parts of his workshop session, the blinds would be drawn, the lights turned off, and the education officer would direct the laser beam through the maze, and then introduce smoke from a burning mosquito-coil into the maze to render the laser beam visible. Another of the resources he had developed was a large block of polystyrene into which a classic seven-ring labyrinth had been carved. The labyrinth was covered by a clear perspex sheet and was designed so that a ping-pong ball could roll though its channels. One way to do this was to get a group of children to cooperate to tilt the whole labyrinth in the right sequence to get the ball through. Another way was to blow the balls with a hair dryer (see Figure 1).

The educator felt that the range of resources he had developed meant that he could tailor his workshop sessions to cater to multiple levels of ages and abilities in his audience. With young children, the education officer would concentrate on the fun aspects of moving the ball around the maze, while with older children he would begin to concentrate on describing the forces that were acting on the ball:

> I try and draw out the scientific principle while we're discussing the fun side of what's actually happening. (Education officer)

The educator always used the correct scientific terminology to describe the phenomena he was exploring. He felt that it was important to use the correct terminology, but said he tried also to explain and demonstrate the meaning of the words as he was using them. The educator acknowledged that some of the terminology he used was probably beyond the children's comprehension; however, he felt that using scientific language to describe what he was doing was also a way of earmarking for teachers the particular aspect of science that was being demonstrated. He recognised that a visit to a science and technology centre was just one of many experiences in a student's school year. Therefore, he hoped to make a connection with teachers which would enable them to extend or develop, back in the classroom, the concepts which he had initiated in the workshop session:

> … When they leave my workshop the teachers would take away with them a full set of notes [a teacher resource manual] that explores that workshop in a great deal of depth, …it gives the teacher the background to go beyond what we went in the workshop to whatever depth she wants to explore as part of their learning experience. So I see that as going beyond the experience and back into the classroom. (Education officer)

What children said about the workshop

Interviews with both teachers and children indicated that aspects of the workshop had stimulated interest and excitement from the children. For the Year 1 and 2 children at school A, this tended to be the activities they had been able to physically participate in – for example, cooperating to roll the ball through the labyrinth. By and large, these children's comments tended to confirm their teachers' impression that the children had not understood much of the explanation and terminology used by the education officer. A week later, few could recall what had been said during the session, although they could vividly describe things they had seen and done.

The Year 3 and 4 children at schools B and C tended to remember more of the phenomena that had been demonstrated. A week to 10 days later, they were able to describe these using some of the words and explanations that the education officer had used. For example, two students from school C remembered the educator explaining the phenomenon shown in Figure 1A as the result of a competition between two forces: the upwards force of the air pressure, and the downwards force of gravity:

> The man just had a little bit of the air blower on it, and then he pushed it and all the air kept going through, he had it just there and gravity was holding it down but air was going with it so they were having a fight, who was going to get away with it (Male student aged 8).
>
> He holded it until it had a balance. It stayed up there spinning and spinning (Female student, aged 8).

A student from school B described the phenomenon illustrated in Figure 1B:

> We saw this ball maze and the guy put a blowing thing on it and he put it on the end and it went nyeh-nyeh-nyeh – out [shows movement of ball with hand]. And when he put this big maze on its side, it did the same and it popped out the end that the [blower] was on (Female student, aged 8).
>
> R: *Oh yeah, tell me about that, 'cause that was a bit different eh?*
>
> It went in the place it was meant to get up to, and it just went backwards and then it popped out the end! (same student).

Many of the Year 3 and 4 students were also captivated by the demonstration of the laser beam maze. One teacher said she was surprised to hear her students use words like "reflection" and "changing the angle" of the laser beam during subsequent classroom discussions.

> I was quite surprised that they remembered! Remembered all that, from everything else. (Teacher 5, School C)

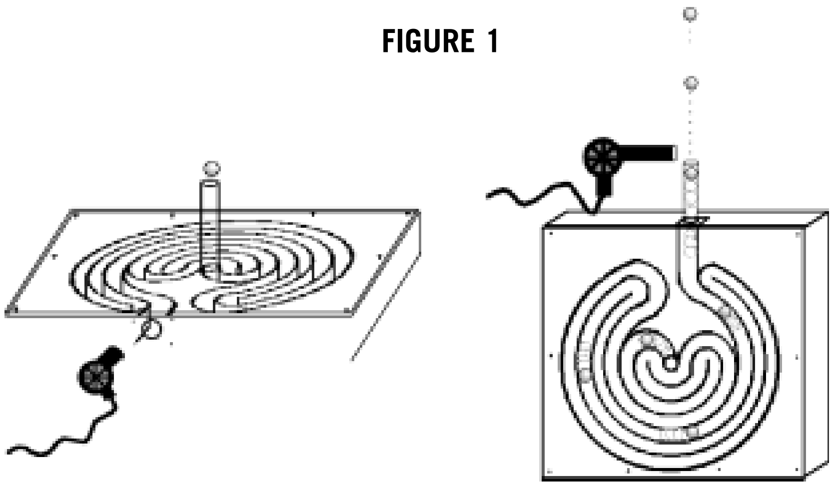
Several students in the class of Teacher 6 class had an interesting idea about the laser beam maze:

> The mosquito coil thing, well the smoke it's a special kind of smoke to keep the mosquitoes away and that kind of smoke makes lasers light up so you can see it, and it heats it up (Female student, aged 8).

These students had said the same thing to Teacher 6 in classroom discussions after the trip. Actually, any smoke would have made the laser beam visible, but mosquito coils are a good safe way for producing smoke indoors.

It would have been nearly impossible for a demonstration like this to happen in a primary classroom. But in a primary classroom, with a teacher's guidance, students might have been able to further develop their ideas about this

FIGURE 1



A. Bernoulli effect B. Low-pressure suction effect

This diagram shows two exciting demonstrations of the effect of air pressure. In example A on the left (the Bernoulli effect), a Ping-Pong ball hovers in mid-air when air is blown through the labyrinth and up a Perspex tube. In example B on the right, air blown across the top of the tube has the unexpected effect of causing the Ping-Pong balls to be sucked backwards through the labyrinth and come flying out the top! The scientific explanations for these results are a bit more sophisticated than many people might think. They are both the result of moving air that creates a zone where the air pressure is lower than the pressure of the air in the rest of the room. The principles they illustrate help to explain things such as flight and the weather. An education officer with specialist knowledge in science and access to some unusual resources dreamed up this truly exciting way to show air pressure principles in action. But a primary teacher is the best person to help children to talk and think about this exciting experience afterwards.

interesting experience. From a science education perspective, the classroom discussions provided a useful opportunity for the teacher to find out what children think about light and what makes us able to see light. Of course, if learning about light and vision was not already a part of the teacher's purpose for visiting the science centre, chances are that an opportunity like this would not be followed up, because there would be so many *other* valuable learning experiences to follow up! It appeared that many of the science concepts did not go beyond the science centre experience and back into the classroom for two reasons–first, they were not all matched to the children's readiness to learn; and second, they were not matched to teachers' readiness to teach.

Matching opportunities to learn with children's readiness to learn

Of the three schools, only school A had specifically directed the visit towards achievement objectives from the science and technology curricula. Teachers at school A commented that the hands-on experiences of moving balls through the mazes in the *Maze Daze* workshop had given children ideas about motion, which resurfaced during later classroom maze-making activities. Although the *Maze Daze* visit offered the opportunity for children to experience lots of things that they might never had been exposed to in a normal classroom, all six teachers felt that a significant amount of the workshop had gone "over the children's heads". The Year 1 and 2 teachers suggested that children "switched off" at the parts they didn't understand, and sat waiting patiently for the next fun thing that they could get involved in. The children's lack of interest or understanding at these moments might not be visible to another observer:

> Those are just little things that you notice when you're coming from a different level, and you know what level your kids are coming from. (Teacher 2, School A)

Matching opportunities to learn with teachers' readiness to teach

Teachers sometimes expressed a lack of readiness for some of the concepts or explanations that were given:

> It just seemed a bit, I felt I didn't really know what [the education officer] was talking about to start off, he sort of jumped right into it and we weren't really sure what was happening, and then they [the children] cottoned on a bit and so did I. (Teacher 5, School C)

Even though they had been sent a resource pack beforehand, some of the teachers were not sure what was going to happen in the workshop before they went to the science and technology centre. The six teachers were highly selective in their use of the resource manual, generally looking through it during their pre-trip or post-trip lesson planning for things which were directly relevant to their teaching plans at that time:

> R: *Did you use anything out of that resource pack?*
>
> No, I didn't, I'd actually forgotten that I had that…yeah I know when we actually sat down and did our unit planning, we sat down and looked through it, to set up what we were going to do, but I didn't actually refer to it during the teaching. (Teacher 1, School A)

All six teachers said they appreciated the resource and thought it might be useful at some future point in their teaching, but not all the specific curriculum links seemed appropriate for them or their students at that time.

What can add value to school science centre visits?

Research literature which relates to bridging the gap between science centres and school science learning says that the science ideas and experiences which students encounter during the visit must be scaffolded back in the classroom if successful science learning is desired (Russell, 1990; Wellington, 1990; Rennie and McClafferty, 1995; Griffin and Symington, 1997). This presumes that science learning is a desired objective. However, if teachers have other kinds of learning outcomes in mind, then the follow-up activities they engage in may focus on other aspects of the trip experience.

One of the foremost reasons that teachers in this study brought their classes to the science centre was the special child-oriented nature of the environment. While the teachers saw an engaging science-related experience as just one possible outcome of the science centre visit, the science centre staff viewed science concept learning as the *raison d'etre* for the way they designed the exhibition and workshop. The science centre's educational resource manual was prepared with careful attention to the New Zealand Curriculum Framework, and particularly the science and technology curricula, with the intention that they would enable teachers to make a wide range of possible curriculum links with their visit.

However, the six teachers in this study were very selective about which links they actually followed up, because the links had to fit realistically into their current teaching plans and programmes. These plans depended on the particular circumstances of each class, including: the teacher's long-term teaching plans; the ages and abilities of the students; the teacher's own perceptions of their students; and what they hoped to achieve with their students over the course of that year. The teachers and students in the six classes in this study had been impressed by the science demonstrations they had encountered in the workshop session, but the science concepts themselves were rarely followed up after the visit unless they coincided with the teachers' own teaching plans.

The findings of the research described in this article suggest that science centres and primary teachers could work together to make stronger connections between the science centre's potential to support primary science learning, and its actual impact in the primary classroom.

Unless teachers are specifically thinking about ways to expand their students' repertoire of experiences with science concepts or phenomena, they may not use opportunities to build on the scientific concepts that may develop from these experiences, because these are not integrated into the teachers' teaching plans in advance.

On the other hand, unless science centre staff receive feedback and input from teachers, they may present science concepts or explanations that are not pitched at quite the right level for their primary audience, or which teachers are not yet ready to teach. Whether or not children have a chance to build and develop on their "hand-waving" science explanations in the classroom may end up being a matter of hit-or-miss. As one teacher noted:

> … in some ways I think we don't utilize [the science centre] enough in advance…Because you realise we have certain objectives that we have to fit in a year for science, and social studies and all those things, and if there comes an objective that we know we haven't covered, and [the science centre] will be able to help fill that gap, then that will be really good. But sometimes we plan almost too far in advance, and something's already set and then we find out there's this really good exhibition. (Teacher 5, School C)

Because of the centre's small staff and modest funding, the support which the science centre was able to provide to schools at the time of this study was limited. Overseas research suggests that science centres which are able to provide more intense or longer-term support to teachers are more successful in enhancing school science education. Reviewing findings from 35 evaluation studies of school science programmes at institutions such as museums and science centres in the United States, Price and Hein (1991) found that teachers were most enthusiastic when they received pre-progamme orientation, had input into the design of the programmes, were actively involved by institution staff running the programme sessions, and participated in teacher-only workshops. Price and Hein's evaluation of teachers involved in a long-term collaborative programme at a science museum concluded that participation in the programme led many teachers to increase the amount of time they spent on science and also provided teachers the opportunity to learn from each other. Teachers involved in a programme spanning two to three years described both increased confidence in handling the curriculum material, and an increased ability to integrate programme materials and classroom science.

Science centres are a rich environment where young learners can have unique foundational experiences in science, as well as in other areas of learning. However, whether or not the science aspects of the visit are followed up in the classroom depends on whether teachers are able to plan for this in advance so that it fits in alongside their other intended teaching plans. By planning together, science centres and teachers could pool their expertise to develop rich science experiences for children that teachers are ready to build on further in the classroom environment.

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Notes

1 In this paper "science centre" also refers to science and technology centres and interactive science museums.

2 The ages of the children in the sample were fairly representative of the total school audience for *Maze Daze*. Of 29 school bookings, eighteen (62%) were primary school or primary-aged home-school groups, six (21%) were preschool groups and only five (17%) were secondary school groups (two of which were special-needs classes).

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