



Enhancing mathematics teaching and learning in early childhood settings

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1. Aims, objectives, and research questions

Aim

The overall aim of the project was to engage early childhood teachers in investigating and improving their expertise in the teaching and learning of mathematics. The intention of the project was to develop a research environment through which researchers and kindergarten teachers worked collaboratively, using action research methodology, to explore *means* by which mathematical outcomes for children could be maximised. The research arose from the premise that within the field of mathematics education, while much has been written about mathematical experiences of both learners and teachers in the compulsory (school) sectors of education, very little is documented on mathematical learning and teaching in the early childhood sector from the perspective of the teacher, and particularly within Aotearoa New Zealand.

The project engaged the kindergarten teachers through one cycle of action research: from reconnaissance, through intervention, to evaluation. This provided them with opportunities to self-select a relevant issue in mathematics teaching and learning through exploration and reflection on their own mathematics knowledge, their personal dispositions towards mathematics, and their teaching strategies. It was expected that changes in practice would improve mathematical outcomes for children.

It was hoped that the findings from this project would:

- act as a useful learning tool for early childhood teachers across the wider early childhood education field by provoking them to consider the teaching and learning of mathematics in their own contexts;
- contribute to the body of knowledge within mathematics education research both within Aotearoa New Zealand and internationally; and
- broaden the action research field by increasing the possibilities for early childhood teachers to engage in action research.

Objectives

The overall objectives of the project addressed the strategic, research and practice principles of the Teaching and Learning Research Initiative (TLRI); specifically, through teachers' increased

understanding of the processes of mathematics teaching and learning; by building capacity through teachers' engagement in personalised and contextualised research; and through the teachers' evaluation of both the mathematical and the action research aspects of the project.

This was achieved through the kindergarten teachers applying a cycle of action research in order to improve their practice. An action research model was used to create, for each kindergarten teaching team, an independent framework for researching within their own kindergarten setting and community. Cardno (2003) describes how action research "creates the expectation that those involved will be researching a particular situation with the intent of taking action that will make a difference ... [that] will bring about change or improvement" (p. 1). The partnership kindergartens that participated in this project were involved in the planning, discussion, and decision-making, as occurs at all stages of an action research process, as each team of teachers self-identified a focus for their action research. Hence the research provided a base for self-review which, according to McLachlan-Smith, Grey and Haynes (2000), fosters not only improvement but also empowerment in early childhood teachers.

The objectives of each phase of the project were:

- *reconnaissance phase*: to investigate what research and practice reveals in relation to enablers and barriers that enhance the quality of mathematics learning and teaching, through
 - working in partnership with the teachers in each kindergarten through the formation of three action research groups;
 - conducting a review of relevant literature that informs the research problem;
 - examining issues and conditions for teachers that create barriers to mathematics teaching and learning in their kindergartens;
 - identifying strategies that are successful, and skills needed, to enhance effectiveness in the teaching of mathematics; and
 - facilitating each kindergarten to plan an intervention.
-
- *intervention phase*: to improve practice by intervening in the status quo, through
 - establishing a working theory of effective mathematics teaching and learning practice; and
 - involving whānau/families in an appreciation of conditions that support and enhance the possibilities for increased effectiveness in the teaching of mathematics.
-
- *evaluation phase*: to conduct an evidence-based evaluation of the effectiveness of the intervention, through
 - planning for the evaluation events; and
 - reflecting on the effectiveness of change in the teaching and learning of mathematics.

An action research approach to research does not aim for replication. However, in addition to documenting the mathematical journey for each individual kindergarten, it was also the

researchers' objective to execute a meta-analysis of the three site-specific cycles of action research in order to:

- establish similarities and differences between the findings in the three research settings;
- strengthen the transferability of new knowledge; and
- increase the rigour and validity of the project overall.

Rationale

In view of the ongoing government strategy to promote numeracy knowledge and skill development in the school sector in Aotearoa New Zealand, it is crucial that prestige be accorded to exploring issues that relate to effective mathematical learning and teaching in the years of early childhood education. It is important to undertake specific research within an early childhood pedagogy to establish guidelines for teachers that promote best, or wise, teaching practices: practices that improve the outcomes for children (Peters, 2001). Also, Savell and Davies (2001) emphasise how numeracy skills, and number competency in particular, are a necessary lead-in to further mathematical interest and achievement. They make the connection to *Te Whāriki* (Ministry of Education, 1996) by reminding us that in the early years children should “develop the expectation that numbers can amuse, delight, illuminate, inform and excite” (p. 78).

Researchers such as Carr, Peters and Young-Loveridge (1994), Young-Loveridge, Carr and Peters (1995) and Wylie (2001) have for some time now highlighted the importance of young children's mathematical competencies in the early years and how these impact on the children's successes in learning mathematics later in the school years. Consequently, areas that need to be explored include: how mathematics teaching and learning is conceptualised in early childhood settings; what teachers' attitudes are to providing learning experiences that support and extend mathematical learning; what helps and hinders effective teaching and learning; and what can be done to improve practices that enhance the learning outcomes for children. The need for teacher knowledge to support these issues has been identified by Parsonage (2001) who explored her kindergarten setting through the lens of the mathematics component of the *New Zealand Curriculum Framework* (Ministry of Education, 1992; Ministry of Education, 1993).

The research described in this report built capacity for the kindergarten teachers by providing a framework within which they could investigate their capabilities: this included investigating their current knowledge and practice in the area of mathematics and ways of increasing this knowledge; their ability to undertake research into the teaching and learning of mathematics at their kindergartens, allowing them to examine a significant issue related to their practice; and subsequently transferring their findings into the learning environment by implementing and evaluating action designed to improve the mathematical learning experiences for the children. Furthermore, improved mathematical outcomes at the kindergartens would have the potential to benefit the wider community of each kindergarten. These wider benefits of shared mathematical activity within whānau/family settings were evident in the literacy and numeracy campaign

(Ministry of Education, 1999). This research project provided opportunities for teachers to involve the whānau/families in their children's mathematical thinking by making links to the home environment and involving the whānau/family in exciting opportunities to enjoy mathematical activity at home.

In seeking ways to investigate the enhancement of children's mathematical learning and development, the research was underpinned by the principles of *Te Whāriki* (Ministry of Education, 1996). Haynes (2000) identifies how the teaching and learning of mathematics in early childhood settings must remain firmly within the expected philosophical domain of early childhood education in Aotearoa New Zealand. This was reinforced by the teachers who were adamant that participation in the project would not jeopardise their normal philosophical and pedagogical practices. Thus this project enabled the kindergarten teachers to understand their own processes of teaching and learning and to view them from a mathematical perspective, to identify for themselves mathematical gaps in their own knowledge and to create forward-looking strategies for future possibilities in the teaching and learning of mathematics in their kindergartens as they relate to the values of the TLRI requirements.

Research questions

The overarching (macro) research question was: What do the participant kindergarten teachers know and practise in relation to the teaching and learning of mathematics, and how can this be improved? Research questions specific to each kindergarten were generated at each site, and are identified in the case studies (Section 3).

Each kindergarten teaching team self-selected a relevant issue in mathematics teaching and learning, and focused on strategies for improvement. The site-specific (micro) research questions that arose were:

- How can we establish a platform for making mathematics prominent? (Avondale Kindergarten);
- How can we enhance a collaborative mathematical partnership between teachers and parents? (Birdwood Kindergarten); and
- How can we grow teacher confidence in strategising for children's mathematical learning? (Don Buck Kindergarten).

2. Research design and methodologies

Action research defined

With its many and often contested definitions and applications, the action research knowledge base is “an arena of debate” (MacNaughton, Rolfe, & Siraj-Blatchford, 2001) in which much of the educational action research literature relates to the compulsory schooling sector. Very little appears to have been published on the specific nature or form of action research used in early childhood education contexts. However, in one study by Carr, May, and Podmore (2000), there is reference to a spiral approach derived from the work of Kemmis and McTaggart (1988). More recent reports of action research (for example, Bulman, Cubey, Mitchell, & Wilson, 2005; Podmore, 2004) refer to action research cycles and action research processes without elaborating on the details that support their claims to conducting any specific form of action research.

Action research is undoubtedly a form of practitioner research that has many meanings attached to it because it is used to describe a problem-solving approach that may be as simple as reflecting on and changing an aspect of one’s teaching practice, or as complex as embarking on a major evidence-based review of institutional management practice (Cardno & Piggot-Irving, 1996). In this project, a particular “developmental” form of action research was employed. This is described by Cardno (2003) as:

action research that is carried out by or for educational practitioners within their own organisation in response to some aspect of professional work that needs to be developed, either within the classroom, across the school, or in the management of the organisation.
(p. 1)

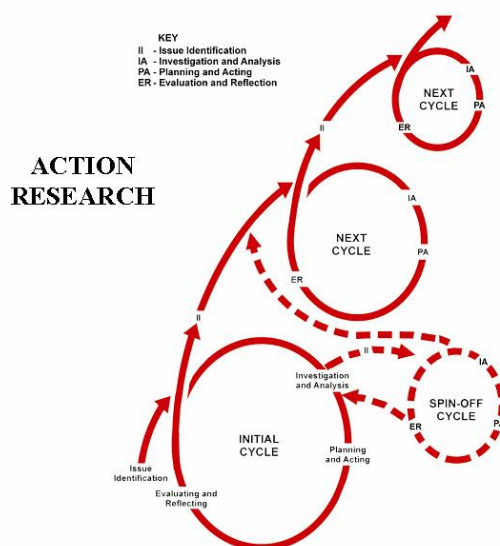
In this research project, the broad problem that attracted both researcher and practitioner attention related to the need to enhance the teaching and learning of mathematics in early childhood settings. Action research was chosen as an appropriate methodology because its fundamental principles value professional practice and collaborative research partnerships between practitioners and researchers. Additionally, it enables theory building that acknowledges the primacy of the critique and generation of new knowledge in the practice context with a view to improving that practice (Elliott, 1991; Lomax, 2002; McNiff, 1988; McNiff & Whitehead, 2005; Mills, 2000).

As Cardno (2003) asserts, “the aims of action research are twofold: to enquire into professional practice, and to use the knowledge and understandings thus gained for developmental purposes” (p. 21). Action research of this type is inherently collaborative and critical: collaborative because

it requires all the people associated with the issue to be involved as active participants; and critical because it requires practitioners to adopt a critically reflective stance in relation to their own theories of practice and consequently generate new knowledge that has both theory and practice value (McNiff & Whitehead, 2005).

The process of action research is intended to be planned and systematic, proceeding in a cyclic process that moves through stages of investigating and analysing a problem, to planning a change strategy and then implementing this, followed by an evaluation of the effectiveness of the change. This end-point reflection could lead into a reclarification of the problem, or revelation of deeper or further dimensions of the problem that warrant another formal cycle of investigation (research), intervention (action) and evaluation (in the form of monitoring or review or more research to collect data for these processes), and so on. Hence, action research is often depicted as an ongoing spiral (Cardno, 2003, p. 13) and participants could well embark on another cycle of research and action as a consequence of identifying new or recurring issues related to the original problem they set out to solve. This cycle is depicted in Figure 1.

Figure 1 **Action research spiral**



The collaborative learning process and research rigour

Facilitated action research of the type employed in this project engages the action research group in action learning. Zuber-Skerritt (1993; 2002) notes that the term ‘action learning’ (often used synonymously with the term “experiential learning” because of shared philosophical assumptions about adult learning) is associated with reflecting on personal practice:

It offers us a method of raising our learning from the unconscious to the more conscious levels through techniques of questioning that probe and illuminate what many of us assume or ignore about our own prefiguring of what we learn. This conscious use of the learning process can thus make tacit knowledge more explicit. (Zuber-Skerritt, 2002, p. 118)

This is what is needed to understand problems/challenges in action research and to negotiate changed action. Because action researchers in educational settings work with adults (key practitioners and their professional colleagues), the principles of action learning are acknowledged to be at the heart of the process. In the case of this project, the researchers were expected to be familiar with the general principles of both action research and action learning. In this project, each meeting of the action research group was an action learning episode.

However, action research demands more than action learning. According to Zuber-Skerritt (1993), action research involves action learning but the process is “more deliberate, systematic and rigorous, and it is always made public” (p. 46). She asserts that the rigour of action research demands explanations of the methodology and use of methods for gathering data so that it can be scrutinised (Zuber-Skerritt, 2002). Similarly, Wallace (1987) contends that action research requires a formalised approach to data gathering and must be published to achieve its status as research as opposed to other forms of organisational development. It is this consistently identifiable standard of reporting the research project that distinguishes action research from the less formal processes of action learning.

Action researchers are also concerned with strengthening the rigour and credibility of their studies. As Janesick (2000) asserts:

Validity in the quantitative arena has a set of technical microdefinitions, and the reader is most likely well aware of those. Validity in qualitative research has to do with description and explanation and whether or not the explanation fits the description. In other words, is the explanation credible? In addition, qualitative researchers do not claim that there is only one way of interpreting an event. There is no one “correct” interpretation. (p. 393)

In essence, what counts in establishing validity in this kind of research is “the extent to which what you say is credible and trustworthy” (McNiff & Whitehead, 2005, p. 91) is borne out by the evidence displayed and its authentication. An aspect of internal rigour (or validity) relates therefore to efforts to assure verification by the practitioners themselves of the evidence included in reports to confirm the integrity of the project. In this project, the practitioners were asked to provide feedback on their particular case study draft and this was incorporated into the final version of each case.

Each case reported in this research report is unique in terms of the particular situation researched. Action research makes no claims about its ability to transfer data or generalise from a specific situation to the whole populations (external validity). Instead, the fact that it relates to a particular situation is a purported strength, lending it a high degree of relevance for participants. And the immediacy with which a solution can be applied invariably makes it popular with practitioners who value its practical worth. This is not to say that the learning occurring in one case of action research may not interest or benefit those who did not participate. Indeed, as is the intent of this research project, by reporting these case studies and making the accounts public, action research ideas can reach, and be transferable to, other practitioners in similar settings.

The “research” demand in action research is met when a collaborative research group embarks on a systematic and evidence-enriched process with the aim of examining and improving practice. In this project, in order to ensure the integrity of the developmental action research process, the research group (practitioners and researchers) attended to all of the following. They:

- used existing knowledge to inform problem understanding;
- engaged in action learning to generate focus research questions;
- collected and authenticated evidence in a process of ongoing verification;
- intervened to change practice paying attention to both theory and best practice;
- monitored the effectiveness of changed practice and emerging new theories of practice to draw conclusions and to chart future directions; and
- reported the project (presentations and publication).

Such practitioner-researcher partnerships create a big demand for the professional partners. Participation requires a considerable commitment on the part of already busy practitioners even when the process is facilitated by a consultant or external academic researcher. Yet both the researchers and the practitioners in this project wanted to engage in rigorous action research. This is a dilemma inherent in practitioner research in general, and action research in particular. On the one hand proponents of action research wish to promote the methodology as a practical and appropriate tool for institutional-based change that is manageable and sustainable. Yet, on the other hand, academic action researchers often find themselves needing to defend the methodology as a rigorous form of qualitative research that has scholastic credibility as well as practice relevance. Furthermore, action research is generally presented as an ongoing process (Cardno, 2003; Kemmis & McTaggart, 1988), spiralling beyond an initial cycle to deeper or further cycles and thus implying that the end of one project is a platform for embarking on a new cycle of action research. This gives rise to an often untested assumption that practitioners will be able to continue to apply an action research approach in resolving problems/challenges of practice after the conclusion of the formal project. It behoves academics and consultants who provide action research opportunities in the first place to consider these challenges for practitioners and to create conditions and motivation that will assist these practitioners to make critical choices about whether or how they can sustain the momentum of action research beyond a formal “supported” or “funded” professional development programme, or research project.

The action research settings

This TLRI project involved three academic researchers from Unitec Institute of Technology and the teaching teams at three West Auckland kindergartens in 2005. The project activity began in December 2004 and concluded in mid-2006. The head teachers at all three kindergartens were known to the project director and these kindergartens were among the many partnership centres that contributed to the Unitec Institute of Technology early childhood teacher education programme by accepting students for practicum and field-based learning.

In the project, a research partnership was established between the teaching teams from the three kindergartens and the three academic researchers who guided the overall project. The academic researchers engaged in a facilitated research process with each kindergarten action research group comprising head teacher and teaching staff. Although both the academic researchers and the kindergarten teachers were researchers in the project, for the purposes of this report the academic researchers are identified as the researcher-facilitators and the kindergarten teachers as the participants.

The following kindergartens were approached in October 2004 about the possibility of participating in the project and agreed to be named in the proposal for this project:

- Avondale Kindergarten (head teacher and two teachers);
- Birdwood Kindergarten (head teacher and one teacher); and
- Don Buck Kindergarten (head teacher and one teacher).

The Auckland Kindergarten Association (AKA) approved the researcher-facilitators gaining access to the three kindergartens in the project. Ethics approval to conduct research at the three sites was granted by the Unitec Research Ethics Committee prior to the start of the project. All site-based meetings were arranged to minimise intrusion of the research into the daily life of the kindergartens. Hence all researcher-practitioner meetings were scheduled after session times. The researcher-facilitators, however, who were each allocated to one specific kindergarten, paid visits to the kindergartens during session times in order to collect and verify data.

Ethical practice in facilitated action research projects requires the researcher-facilitator to take responsibility for getting the participants to check the data they have contributed. This was done in every case. Drafts of the case studies were sent to participants and their views were incorporated in the final version. At the start of the project, the intention was to ensure anonymity for the kindergartens. However, because the three kindergarten teams participated in a public dissemination event mid-way through the project (research symposiums and conferences where they were named in the course of presenting progress reports of the research), they themselves decided to forego anonymity in the final reporting. This disclosure of sites and names was subsequently approved by the AKA.

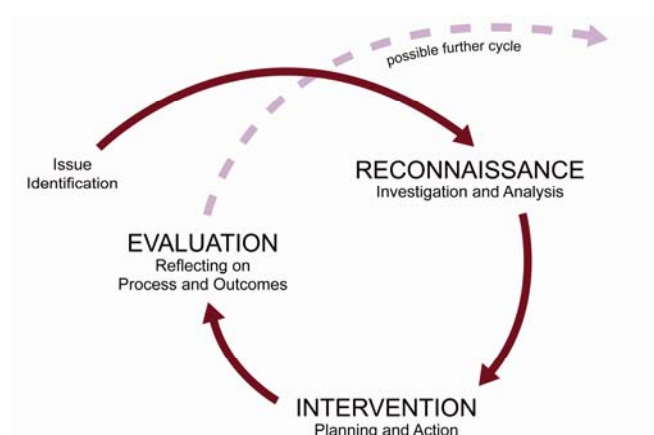
The participation of these practitioners in the project was financially supported. A grant was made to each kindergarten to defray the costs of appointing relief staff to compensate for the time spent in meetings with the researchers, data gathering, communication and other research-related activities.

Doing action research—the process

Because action research occurs as a dynamic, unfolding process of enquiry and action it is depicted as a cycle of events. In externally supported developmental action research (Cardno, 2003) of the kind that took place with these kindergartens, a facilitation schedule was agreed (four

site-based meetings between February and October 2005) to ensure that meetings with the researcher-facilitator occurred at regular points throughout the year. Each of these meetings was a half-day action learning event. The meetings were used to progress the research through the various stages of an action research cycle. In addition all participants at the three kindergarten sites came together for two full-day cluster meetings. One of these meetings was held before the start of the project to introduce participants to the methodology of action research. A final meeting in November 2005 allowed all participants to contribute to an evaluation of their specific research project outcomes and to overview the process they had experienced. This was in keeping with developmental action research which constitutes a cycle of research and action events incorporating action learning and data collection. This cycle is depicted in Figure 2.

Figure 2 **Cycle of research and action events**



Accounts of how a cycle of action research was implemented in each of the three kindergarten settings is elaborated in the case studies that form the next section of this report. In brief, in each kindergarten the participants completed a phase of reconnaissance (investigation and analysis); intervention (planning and action); and evaluation (reflecting on the process and outcomes).

Reconnaissance

In the reconnaissance phase (approximately February to May 2005) each kindergarten's action research group engaged in facilitator-led action learning with the researcher. This involved investigation and analysis of the problem that required an understanding of the theory and practice of mathematics teaching and learning. It guided the group towards a clear articulation of the research questions: the focus for collecting data. To achieve this clarity of focus for the action research, all three researcher-facilitators used a consistent systematic problem analysis exercise in a facilitated action learning meeting. Through subsequent communication and team effort, the researcher-facilitators and participants assembled the evidence needed to confirm the focus.

Intervention

A further two action learning meetings (between June and August 2005) allowed the action research groups to firm up an intervention plan that was unique to each kindergarten and begin its implementation. All three researcher-facilitators guided this phase using similar templates for planning. Participants at each site were in regular communication with their assigned researcher-facilitator throughout.

Evaluation

During October and November 2005, action learning focused on evaluation and reflection. In this final phase each of the groups participated in a site-based meeting and then in November all participants and researcher-facilitators came together for a final cluster meeting. The key purpose of this phase was to assist the participants with the monitoring of their change strategies, and further assembly of evidence, that would aid their reflection on the effectiveness of both the intervention in particular and what engagement in the total project had achieved for them.

Data-gathering methods

In the reconnaissance phase and in some cases also in the evaluation phase of each of the three research projects, participants and researcher-facilitators used documentary analysis across all three projects. In addition the participants used a range of data-gathering methods within the bounds of each project. These included small-scale surveys and the assembly of data in the form of reflective journals, note-keeping, emails to researcher-facilitators, photographs and other material that was considered to be evidence. As Waterman, Tillen, Dickson, and de Koning (2001) assert, in action research “qualitative data from multiple perspectives in the form of reflective notes, diaries, interviews and documentary evidence may be preferred” (p. 16).

Documentary analysis

Documentary analysis (Bell, 1999; Wellington, 2004) is viewed as an extremely effective approach for reviewing policy and regulation guidelines at the start of an action research project (Cardno, 2003) as part of the problem-understanding phase. Because the teachers in all three kindergartens needed to become familiar with the core documents (common to all kindergartens) that contained references to mathematics teaching and learning, and expectations held of teachers, these documents were analysed by both the researcher-facilitators and the participants in each kindergarten. In the case of Don Buck Kindergarten this analysis was extended in depth to the mathematics curriculum document (Ministry of Education, 1992) in the form of an audit of the mathematics potential in the learning environment.

Small-scale survey questionnaires

Questionnaires (Jenkins, 1999) can be a quick and relevant way of surveying opinion. Their use in action research is generally to collect descriptive qualitative data that contributes to problem reconnaissance. These instruments can also be used as end-point evaluation to assess the extent to which planned change has been effective. Carefully constructed questionnaires, similar to structured interview instruments, are most appropriate to use with small samples. The participants at all three kindergartens made use of recently collected survey data (by external agencies such as the AKA) or conducted small-scale surveys in the form of questionnaires to whānau/parents. In the case of Birdwood Kindergarten, a parent survey was used in the reconnaissance phase and again in the evaluation phase.

Reflective journals and diaries

Each kindergarten team kept a journal of their action research journey, noting events, reflection on plan achievement, and self-critique of practice. Additionally, at the closure of the project each head teacher contributed a reflective summary of what they felt they had achieved overall during the project.

Notes, emails, and photographs as evidence

Participants in the project kept notes on team meeting discussions, on reflections on their practice, and on actions undertaken and monitored in the intervention phase. Emails were also used to update the researcher-facilitators and to record actions associated with monitoring and evaluating the intervention, especially in the case of Avondale Kindergarten. Photographic evidence was used throughout to illustrate and confirm anecdotal evidence and record agreed changes.

Challenges for the researcher-facilitators

For the three researcher-facilitators in the project the following issues emerged in the application of action research methodology in kindergartens:

- ensuring nonintrusiveness of the project on the day-to-day practices of head teachers and teachers;
- balancing a systematic and structured approach to the research with the need for flexibility, in order to maintain the process as a dynamic approach that could be responsive to the immediate needs of a particular setting;
- maintaining comparability between sites in relation to the way three different researcher-facilitators applied the action research methodology;
- absorbing and responding to new learning as the application of the “developmental action research” process unfolded; and

- coping with site-based factors such as staff turnover which was experienced in two kindergartens.

Challenges for the participants

For the participants in this highly collaborative and new experience as practitioner-researchers there were also challenges. These are summed up by the participants as follows:

- frustration associated with a formal problem analysis phase (reconnaissance), when they felt they could have made suggestions for solutions, but instead experienced what they considered an unexpectedly long drawn-out phase leading to clarification of the issue;
- frustration their hopes of focusing on “mega” issues (for example, social conditions beyond their control but known and difficult to tackle) were not the immediate focus of the project, in spite of their realisation that a project of this scope could realistically address only an issue that could be dealt with; and
- “a time commitment, although anticipated, that was demanding”. This was associated mainly with the additional paperwork, data collection, and assembly of the evidence throughout the project.

Teachers becoming practitioner-researchers

If action research is to be valued by both research and practice communities then it must be committed to the development of practitioners as researchers as well as changers of practice. In the application of action research methodology across three kindergarten sites the academic researchers in this project endeavoured to make the partnership a real learning experience for all.

We have asked our practitioner partners to articulate what it has meant for them to make the transition from being practitioners concerned with improving practice to becoming practitioner-researchers who both improve practice, add to their own knowledge of their theories of practice, but above all add knowledge that can be disseminated to the community of theory and practice knowledge that constitutes the domain of early childhood research.

Our practitioner partners assert that this research has led to the following practitioner-research outcomes. They have:

- learnt a new process which can be applied in other situations;
- developed awareness of using evidence in everyday practice in order to improve this;
- been made to feel more accountable about the changes they make;
- been challenged to be more collaborative in their teaching teams;
- acknowledged that they are on a learning journey; and

- been motivated by the knowledge that their research and action can make a difference to both themselves and others if it is in the public domain.

A significant part of the learning journey for the three kindergarten head teachers in this project was their willingness to attend two research dissemination events in December 2005. All three head teachers presented the progressive findings of their action research journeys in public forums at the annual symposium for New Zealand Research in Early Childhood Education (NZRECE) and the annual conference of the New Zealand Association for Educational Research (NZARE) in Dunedin.

3. Project findings

Introduction to the case studies

Action research provides a means for achieving a research aim that is two-fold. Firstly, such research sets out to investigate the status quo. Secondly, once knowledge about the status quo is established, findings from this initial phase of the process are used to improve practice. Furthermore, because action research is iterative in nature, these projects proceed to a stage of evaluating improvements made with a view to basing further change on evidence. Consequent on these findings, the project might establish a new focus in which further research is conducted as a prelude to further action, and so on. Unlike traditional, large-scale projects that are established around answering a general research question, action research has both macro (overarching) and micro (specific to a setting) research questions.

In the case of this project the macro research question related to all three kindergartens that participated in the project. The macro research question that guided the project asked:

- What do the participant kindergarten teachers know and practice in relation to the teaching and learning of mathematics, and how can this be improved?

The key micro research questions specific to each kindergarten were:

- How can we establish a platform for making mathematics prominent? (Avondale Kindergarten);
- How can we enhance a collaborative mathematical partnership between teachers and parents? (Birdwood Kindergarten); and
- How can we grow teacher confidence in strategising for children's mathematical learning? (Don Buck Kindergarten).

The focus for the research in each kindergarten was established in the reconnaissance (investigation) phase of the action research process. The findings in relation to each kindergarten are presented as individual case studies:

- the case of Avondale Kindergarten: establishing a platform for making mathematics prominent;
- the case of Birdwood Kindergarten: enhancing collaborative mathematical partnerships between teachers and parents; and
- the case of Don Buck Kindergarten: growing teacher confidence in strategising for children's mathematical learning.

In action research, the critical concern is to use knowledge generated in the process of assembling evidence, discussion, and reflection to illuminate and understand the problems/challenges of practice. Whilst commonalities and significant differences between sites also generate important findings, it is the knowledge of site-specific practice that informs and guides change. In this section, the three case studies are documented to show how each kindergarten set out to answer their unique research question followed by a meta-analysis of findings and discussion informed by the theory base.

The case of Avondale Kindergarten: establishing a platform for making mathematics prominent

The kindergarten

At the time this research project began, Avondale Kindergarten in suburban Auckland was staffed with three full-time permanent teachers and a teacher aide. The kindergarten works with an average of 45 children in the mornings and 40 in the afternoons and experiences a high rate of turnover with almost half of each cohort in each term being “new” to the group. The children come from a diverse range of ethnic backgrounds. A snapshot of ethnic mix in March 2005 showed morning session children comprised Samoan (20), Indian (17), Māori (9), Tongan (9), European (8), Chinese (4) and six other ethnic groups. This kindergarten is located beside a primary school that has a decile 2 rating indicating a socio-economic composition that is at the low end of the scale.

Many of the children are from new immigrant families with approximately half of the children in each cohort speaking English as their second language and one-tenth of each cohort not being English speakers at all. Whānau/parents mirror this linguistic diversity and whilst many are keen to volunteer help in kindergarten activities, this help is often limited by the language barrier. A further barrier is that as new immigrants, many of the Indian mothers that offer to help are unfamiliar with the Aotearoa New Zealand early childhood curriculum and the education system in general. The head teacher comments that “they are seldom able to assist with the supervision of children and rarely able to help them to explore in a mathematical way”.

The teaching team of Avondale Kindergarten was interested in participating in this research project because, as well as having a connection with the project director in the course of their studies in early childhood education, they were motivated to improve mathematics teaching and learning in their setting. The head teacher and other team members had been concerned throughout the 2004 year that the team was not attending sufficiently to the teaching, and therefore the learning, of mathematics. All three teachers were interested in joining a project that would allow them to study this dissatisfaction with mathematics teaching in a systematic way.

Understanding the problem—the reconnaissance phase

The facilitation of this action research process began with an orientation on developing an understanding of the problem situation and one of the main challenges for the researcher-facilitator was to guide participants to explore the dimensions of the problem and rein in their instinctive need to implement a ready-made solution. For example, initially the head teacher was drawn to the idea of conducting a survey. She stated:

The solution I was thinking of at the time was carrying out a survey with the parents and trying to find ways to involve them and work on the children's dispositions.

In terms of the action research model that guides this project (Cardno, 2003), the participants engaged in guided dialogue and data gathering to reconnoitre the terrain of the problem or challenge. They did this to gain both a wide and deep understanding of the complexity of the issues and the factors that had made it difficult to resolve their specific problem in past attempts. The reconnaissance phase for Avondale Kindergarten involved two discussion sessions (3 hours each) interspersed by the collection of data by the participants to further inform their understanding.

Analysis of the problem

Guided by the researcher-facilitator, the teaching team talk was funnelled from a broad ranging exploration of the problem from the perspective of each participant to a narrowing down of key aspects which could be agreed by all three team members. The vague sense of frustration that permeated all three participants' consideration of what was problematic for them was distilled at the end of the first discussion session (February, 2005) to be expressed as follows:

The problem for us is that it is hard to be a teacher of mathematics in a setting where there are several barriers.

Several spreads of brainstormed ideas noted on whiteboard were themed and re-themed to gain a clearer picture of the dimensions of the problem—and in particular the barriers that the group felt were part of their problem. The agreed problem dimensions recorded at the end of this session were:

- social factors (the transient nature of the population, ethnic diversity, and the attendant language barriers especially for new immigrants; consequent limitations to whānau/parent involvement in assisting with teaching; some children's ethnic-related dispositions that might be counter to those associated with mathematics learning, such as taking initiative to explore);
- working conditions (high student to staff ratio; lack of time to devote to mathematics teaching because social conditions made it necessary to prioritise the learning of boundaries or rules for socialisation; all team members having been in these roles for only one or two years and still developing as a team; insufficient capable whānau/parent voluntary help);

- system expectations (plethora of demands from multiple stakeholders; balancing act needed to sift specific requirements from general directions; uncertainty about whānau/parent expectations because of diversity of values/cultures); and
- self expectations (wanting to be good teachers of mathematics yet sometimes not confident about ability; anxiety about subject knowledge—what mathematics is and how to teach it in early childhood settings).

Much discussion was focused on the issue of having little control over the conditions that prevailed at Avondale Kindergarten. As one participant said:

If we agree that we can't be effective mathematics teachers in this culture then it's a problem we can't change. That means we can't be a better maths teacher because of the barriers. I think we need to improve ourselves to get over these barriers.

And another confirmed the belief that:

If we don't see how the social factors are ever going to change then we have to look at ourselves. That could be the way to start to look at solutions.

Thus, very early in the process of exploring the dimensions of the problem, the teaching team was critical of their own description of the issue, realising that they had no power to influence prevailing socio-cultural conditions. This realisation enabled them to take a more pragmatic view where they, as the teachers, accepted that their own practice could be the focus of the project. They now recognised that an immediate constraint related to their admission that they were often overwhelmed by the variety of expectations they felt they had to cope with. These expectations were communicated by whānau/parents and by official documents.

This problem identification phase provided them with an opportunity to sift through a range of issues that had an effect on their teaching, and the children's learning, of mathematics. Expectations ranged from their own aspirations as professionals, to whānau/parent expectations and the expectations of the system under which they operated. Some data assembly and analysis was called for. The team agreed that they needed to assemble and review data that was available to them in the form of previous reviews of practice, and documents pertaining to expectations related to the effective teaching and learning of mathematics, before the next facilitated meeting (March, 2005).

Summary of previous reviews

In 2004, Avondale Kindergarten had participated in a survey of parents conducted by the AKA. The results provided a snapshot of whānau/family views ($n = 22$) at that time. Respondents represented every ethnic group involved in the kindergarten with the largest group (a quarter of respondents) being of Indian ethnicity. Of significance to this research project was the finding about the extent to which the kindergarten was meeting expectations of whānau/parents in relation to a range of aspects such as curriculum and teaching philosophy, developing social skills, and so on. The expectation that the kindergarten provide reading, writing and mathematics skills scored

the lowest ratings of all aspects of this kindergarten's provision. Seven respondents perceived provision was below their expectations.

The newly constituted teaching team at Avondale Kindergarten had discussed this finding and consequently examined both their own practice and their knowledge of the whānau/parent body that might have implications for the kinds of teaching practice valued by whānau/parents. One of the difficulties they were encountering related to whānau/parents with Indian and Chinese experiences of extremely formal pre-school education, and their difficulty to adjust to the *Te Whāriki* (Ministry of Education, 1996) way: a philosophy of play as the platform for learning. Nevertheless, this team was not prepared to ignore the message inherent in the survey results and turned an eye on their own practice in an effort to be responsive.

In June 2004, the newly appointed head teacher had led a self-review of mathematics teaching with the team. Her team had brainstormed what was currently being done, identified the gaps, discussed the reasons the gaps existed, and planned some changes. These changes led to making mathematics teaching more explicit, including the increased use of specific mathematics language and concepts, informing whānau/parents more specifically about what was being done in mathematics teaching, engaging in professional development to increase teacher confidence in mathematics teaching, and accepting the invitation to participate in this action research project to increase the effectiveness of mathematics teaching and learning.

Documentary analysis—system and kindergarten levels

A range of documented expectations guides the teaching and learning of mathematics in all kindergartens. In reviewing the documents relevant to the three site-based action research projects reported here, the researchers completed an analysis of common system level documents pertinent to all three sites and the results were shared with the practitioners. This was a useful exercise as it served the purpose of refreshing familiarity with these well known documents. However, involvement in an analysis that focused on extracting references to mathematics teaching and learning guidance revealed that the participants from Avondale Kindergarten were not familiar with this aspect of the documents. They were not making use of the documents to increase their understanding of expectations but were happy to consider doing this in the future. Presentation of the documentary analysis summary led to a dialogue that focused on the notion of “dispositions” to both learning and teaching. The team was keen to revisit the documents that explained what was important and what was expected.

These participants agreed strongly that the official documents confirmed the importance of “disposition” in children and that they wished to take greater note of this in their focus on improving mathematics teaching and learning. The isolation of learning and teaching expectations in official documents (for example, see *Auckland Kindergarten Association Service Delivery Manual*, AKA, 2003) reiterated for them that the idea of disposition is raised in the context of teachers deciding what to assess in relation to a child's learning. This reinforced the expectation held at a systemic level that teachers should both understand the notion and apply it in daily

activity. For the team this clearly identified for them the expectation held at system level that those who make management and teaching decisions should recognise that “dispositions are important ‘learning outcomes’. They are encouraged rather than taught” (Ministry of Education, 1996, p. 44).

As well as appreciating the opportunity to revisit the plethora of documents that officially guide their practice, this teaching team was self-critical of their earlier belief that the problem they sought to address was just too big to deal with. They revisited their stance on making themselves the focus of the project. It was evident to them that their management and teaching decisions could be refocused to consider not only the encouragement of mathematical disposition in children but also in themselves, as teachers. They commented that:

The teaching dispositions go hand-in-hand with the children’s dispositions.

They talked about their own dispositions to teaching mathematics:

For me personally, confidence with mathematics is an issue because I always found maths very hard when I was at school. It wasn’t my favourite subject ... it’s not my passion or something I would immediately choose to do.

We can’t ignore the teacher’s ability.

As a consequence of this analysis of documentary evidence, the teaching team at Avondale Kindergarten was better informed about where expectations came from in a system where there were many levels of stakeholders. They were also clear at this point that they were accountable for meeting these expectations at the system level, local level, and institutional level.

At the system level, the government agency for institutional review, the Education Review Office (ERO) would expect that their programme planning and implementation was of a high quality. Affirmation that they were meeting criteria set by ERO for offering a programme with variety was contained in this kindergarten’s most recent ERO report which confirmed that mathematics language and concepts were incorporated throughout the programme.

At the local level, the AKA would expect delivery of a high quality programme and local whānau/parents would have expectations of mathematics teaching and learning that were communicated to them, on behalf of the affiliated institutions, in the AKA pamphlet “What do I learn at kindergarten?”.

At the institutional level, the teaching team’s concern, once these national and local expectations were isolated, was related to the high expectations they had set for themselves to match espousals of effective teaching and learning with actions that led to demonstrable learning outcomes for children. They acknowledged that in relation to mathematics teaching they had not articulated these expectations amongst themselves, in a way that would reinforce their commitment or help them to communicate this to whānau/parents:

For parent expectations, mostly we observe what parents do and say and we haven’t written it down.

One of the particular challenges for this team was a diversity of expectations from whānau/parents. They talked about the parent who “dragged the child to the teaching table and made them sit and do writing work” and the parent who “carried the child to the teaching/learning situation and placed her next to the teacher”. Then there was the other extreme: whānau/parents who were never sighted and both parents and children with no English language capability. Some of the frustration for this teaching team lay in the very nature of the context in which they operated: a highly ethnically diverse and transient community and the high child–teacher ratio.

The research team took a critical stance related to their own practice when it came to two-way communication of expectations. Firstly, they believed they could make better use of whānau/parental comment and expressed aspirations than was currently the case. Secondly, they felt that they often missed opportunities for communicating their expectations to whānau/parents. This related to both what they expected from children and from whānau/parents, in terms of creating learning opportunities outside kindergarten time.

Emerging themes

By the end of the second facilitated meeting in this reconnaissance phase, the Avondale team was beginning to understand the nature of the complex problem they faced in enhancing mathematics teaching and learning. They had steered away from their earlier position of feeling that the barriers (largely the sociocultural factors in their community) were where they should focus. They had adopted a more pragmatic approach in their decision to focus on themselves, the teachers, as a place to begin. Because they had initially felt overwhelmed by the range of expectations they had to meet as teachers, they also decided to focus on ways in which mathematics could be given more prominence—starting with it featuring regularly and often in day-to-day activities:

We can’t change social factors but we need to work with these to the best of our ability.

You often have to try to overcome, work around the social factors to show the system. And because you have these high system expectations the danger is that you focus on the able children in the group.

An ongoing concern for the team was that they felt they were held accountable by the AKA for demonstrating the extent to which they were meeting expectations in relation to every child’s learning. Yet, for many children (those with both sociocultural and linguistic barriers that militated against self-initiation of mathematics exploration) they felt they were falling short of what was expected of them. One participant said:

So you can show we are meeting the goal but we might only be meeting it with a few children. Teaching ability comes out with able children.

Focus on the teachers

They decided to describe what competent teaching of mathematics in this kindergarten would require. The following statement was compiled.

A competent teacher of mathematics:

- has a good knowledge of mathematics concepts and language;
- is able to judge the linguistic and mathematics ability of each child;
- is able to “draw out” the mathematics in day-to-day activities and follow this up—for example at mat time;
- plans for mathematics in each kindergarten area;
- has the commitment to teach mathematics concepts and language on an ongoing basis;
- is able to adapt the teaching of mathematics to a range of ability;
- is able to supervise and teach rules and routines on an ongoing basis, including teaching how to use and look after equipment;
- is able to reflect, record and document children’s mathematical learning;
- is able to relate children’s mathematical learning to whānau/parents face-to-face on a daily basis; and
- is able to involve whānau/parents by being specific about how they can help their children’s mathematical learning by being communicative and encouraging.

The participants in this team were highly committed to improving their practice and two of the three had participated in AKA professional development activities focused on mathematics teaching. One participant was completing an undergraduate paper on the teaching of mathematics for credit towards a Bachelor of Education degree, this having been the case a few years previously for the other teacher. They were critically self-reflective of their current practice. As one said:

I don’t tend to focus on maths because I’m not very confident in that. I don’t really like maths. When I looked at my learning stories I tended to focus on other areas although I have now done learning stories focused on maths now that I am starting to bring maths into everyday activities.

And another says:

The children weren’t doing it because we weren’t doing it.

In short, the decision to make changes by “starting small” and by turning the spotlight on themselves led to changed action that was both immediate and incremental.

Making mathematics prominent

The team discussed their wish to “draw out” the mathematics in their daily activities, to “talk mathematics”, to “plan for mathematics”. They shared with one another their attempts to act on the decision to make mathematics prominent in their planning and action:

I wasn’t doing it every day but since we talked about it the other day I’ve tried it every day.

It also turns into action when you are using maths language with the children—like today—when the children started jumping and we talked about how long it was, making it wider. I was asking them to make it wider, jump further, because I was thinking of maths. That’s where we are slipping it into activities.

I was finding it a bit hard at first. I was doing something with dollies and I thought I didn't really do much maths because it wasn't a maths activity. Then M said, take a step back the next time it happened. And I thought about it and I got them started on counting the finger and toes, thinking which dolly is bigger. It went somewhere else. It's ticking in a bit more for me in everyday activities.

So I think maths first and then do the activity and then that's a maths activity.

This team engaged in a high degree of critical reflection. They examined and rejected a theory of practice that had been adopted to excuse their neglect of mathematics in everyday activities. It was a theory of practice adopted in what they felt were insurmountable contextual constraints created by language and cultural barriers. In adopting a new theory of practice which allowed them to work with the sociocultural constraints, they recognised that they had, in part at least, contributed to the *status quo* that they uncovered for themselves. In essence, they had learnt that if they focused on their practice consistently, this could lead to change and better mathematical learning experiences for children.

Intervention phase—planning and monitoring new practices

A facilitated meeting (May, 2005) was held specifically for the purpose of planning an intervention: a range of strategies for changed practice that could be monitored. The team devised a formal plan (Table 1) and also made a commitment to continue the practice changes to which they were now committed. These new practices had already begun during the reconnaissance phase and focused on the participants “drawing out the mathematics” in everyday activities.

Table 1 **Intervention plan: Avondale Kindergarten**

GOAL All teachers to make mathematics teaching a prominent priority.				
OBJECTIVES	OUTCOMES	ACTIONS	RESOURCES & BUDGET	DATE
To develop an induction process for the kindergarten to sustain commitment to mathematics being prominent	1. Continuation of emphasis on mathematics	1. Consultation with system managers to communicate prominence of mathematics (for inclusion in advertisement)		May/June
	2. Awareness of commitment to prominence accorded to mathematics	2. Head teacher involvement in appointment process		April
	3. Effective contribution to kindergarten curriculum	3. Add "maths is important" statement to kindergarten information documents (for appointment)		May
		4. Provide early professional development to strengthen confidence in mathematics teaching	Up to \$1000	August/September
		5. Continue to plan sustainability and emphasis on mathematics		

Teachers

The team brainstormed several strategies that they intended to implement straight away. These included giving the planning of mathematics (weekly and long term) more significance, the creation of a “mathematics book” that would be on display for whānau/parents, teachers and children; and a continuation of the whole team making an effort to put mathematics foremost as a learning outcome for children.

The following comments give voice to the direction of the teacher talk:

Planning for maths teaching is first, drawing out maths should happen as a result.

Team meetings must be time to plan for maths teaching. I will write in “build on strategies”.

It would be good if we write how we got to that success. Put the strategies in the team meeting records.

Because the children in this kindergarten do not often initiate mathematical thinking, teachers are required to plan for maths teaching.

Right, so for example, to be able to teach the children the language—mathematical language and concepts, you have to know what the basic concepts are in the first place and we have to know which language to use. And for that we have to look at each area and brainstorm about—like—what kind of match we could bring to certain games and activities.

Planning for maths has helped me also. Driving to kindergarten I think what maths could be in the activity I am doing today. For example, “directions”. With that thought in my mind I start the activity. Then it depends on which child comes to me and their level of English.

In the course of discussing the various strategies that this team wanted to initiate, the head teacher expressed her concern about sustaining the commitment that everyone had made to the new emphasis on mathematics in their day-to-day work. It was now known that two of the team of three would be moving to new positions by the end of June. None of the team members wanted to lose the momentum that was now evident. One suggested:

Perhaps have a chat with P who is going to interview people for the positions here to see if she is aware of the different things that we are doing so she can choose the best applicants in terms of this.

The team agreed that whilst the AKA had a general induction programme for new appointees to kindergarten positions, there was no specific process at the institutional level that could be used to communicate and clarify an expectation as particular as the one that now pertained to mathematics teaching and learning being accorded prominence.

Induction of new teachers

Closely related to the focus on teachers was the concern that kindergarten level structures and systems would need to be robust to sustain the commitment to mathematics being given prominence. This was a particular challenge in an environment that not only had transient families

but also high staff changeover. The team devised a formal plan to use as a basis for the development of an induction process that would support their curriculum goal.

Monitoring the Intervention

From June to August 2005, the kindergarten team continued to build on their early efforts to “draw out the mathematics” in their everyday activity. The researcher-facilitator was in regular telephone contact and visited the kindergarten in late July to observe mathematical activity and record progress towards the goal of making mathematics prominent.

The team provided the researcher-facilitator with opportunities to observe changes they were making in their daily practice as relevant to the teaching and learning of mathematics. They continued to keep records of their management and teaching decisions related to mathematics, and their production of new documents developed to meet the objectives of the intervention plan. These items were evidence that could be validated by the researcher-facilitator as the intervention and associated monitoring proceeded in tandem. One aspect of evidence related to efforts to keep up the momentum in making mathematics happen and making it visible. Another aspect of evidence related to the changes made to sustain this commitment regardless of staff changes, by developing a sound foundation for induction that brought mathematics teaching and learning into prominence.

Focus on teachers

The researcher-facilitator was able to observe innovations that had been introduced and continued to be refined. These included participants’ endeavours to integrate mathematics language and concepts into everyday activities far more than had hitherto been their practice. Some photographs capture this greater emphasis. For example, to increase mathematics thinking in everyday experiences, when children made a long dragon and then others joined in to make it longer (see Image 1), the participants engaged in relevant mathematical dialogue throughout the progress of the learning experience.

Mathematics was to be made a prominent feature of the kindergarten scene. The teachers established what they called the “mathematics wall” with resources that could be pointed out to the children to facilitate learning of a variety of concepts. The participants compiled the “mathematics book” primarily for a whānau/parent audience with pages dedicated to explaining aspects of mathematics learning in the curriculum and how this learning could occur at home. The book was prominently on display and within easy access. Pages were regularly added and material updated (see Images 2, and 3). As one of the team stated:

We are in the process of making it visual for parents as well. Notice board, carpentry, technology, laminating, photos.



Image 1: The long and the longer dragon

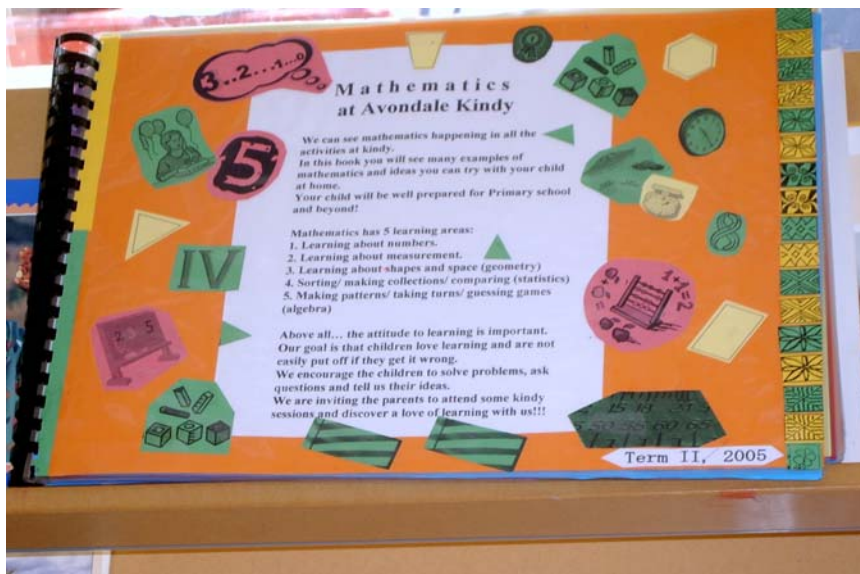


Image 2: The cover of the mathematics book on display

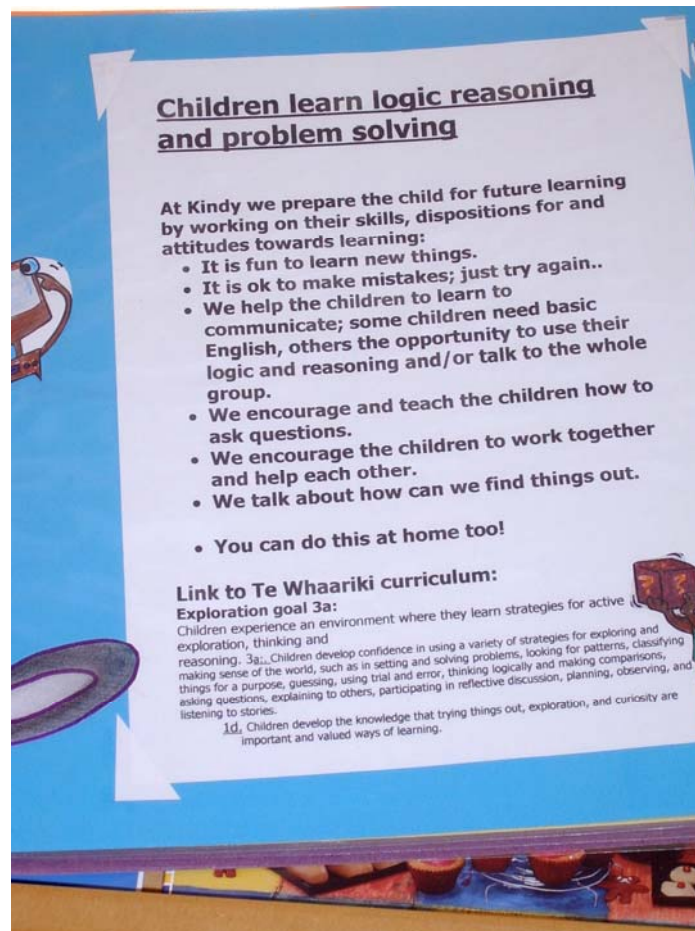


Image 3: A page from the mathematics book

Focus on the induction of new teachers

The head teacher acted on the formal action plan for establishing an induction process that would strengthen the goal of according prominence to mathematics. She prepared a “Kindergarten Profile” for the AKA Professional Services Manager to use in advertising vacancies at Avondale Kindergarten. In this profile, as well as describing the nature of the kindergarten and its community, there was specific mention of the *Commitment to Mathematics* and *Involvement in Mathematics Research*, drawing attention to the following as important competency criteria:

- planning and reflections on planning with a focus on mathematics;
- ability to judge linguistic / mathematical ability of the children;
- knowledge of and teaching of mathematics concepts and language;
- adapting teaching to a range of ability;
- skill to supervise and be consistent; and
- willingness to be involved in professional development.

The following statements were also made about the emphasis on mathematics within the appointment documentation:

Teaching mathematics concepts and language is our first teaching goal for many of the children. Because the children do often not initiate mathematical thinking, teachers are required to plan for mathematical thinking. This means that the teacher needs to be aware of the mathematics curriculum and “draw out” the mathematics and use mathematical language whenever a possibility occurs. The following are also important:

- planning learning experiences with an eye on mathematical potential helps developing mathematics concepts and language;
- teachers looking through mathematical lenses helps involve the children in thinking mathematically and doing investigations; and
- teachers using mat time to recapitulate for all children the mathematical learning that has been going on, teaching and highlighting specific mathematics concepts.

(Centre Document, 2005)

Evaluating the intervention and identifying the next steps

A final site-based meeting for the purpose of formally evaluating the intervention strategies was held in early August 2005. The participants and the researcher-facilitator had been monitoring change throughout the intervention and the team was adamant that they would continue to do this as part of their normal planning and reflection on teaching. In relation to the induction aspect of the intervention, this end-point meeting had two objectives: firstly, to set some criteria by which the team could judge the effectiveness of their plan to introduce an induction process to sustain the focus on mathematics; and secondly, to prompt the team to collect evidence about the impact of changed practice.

In the case of Avondale Kindergarten, by the time this meeting was held, there were two new staff members in the team—both relievers. The first part of the meeting was used to familiarise these new participants with the research project’s progress to date and bring them on board. The head teacher anticipated that by the beginning of October there would be two permanent new members in her team. One of the relieving teachers at this meeting shared her views about the newly developed induction process as she had experienced it over the two weeks she had been employed.

Yes it was good. I got the information and I was able to take the information home. But I think the book [Displaying Mathematics] was helpful. Definitely helpful as an on-the-spot resource to use. I can use it by myself, with the children—a multi-purpose book.

And another point she raised related to the whole team demonstrating the commitment to making mathematics teaching prominent:

The teaching team needs to be doing the same thing. If one teacher is doing all the work with maths, consistently focused, and the other teacher is not comfortable with maths so that could be a concern. As long as all teachers are on board with it then there is no problem.

The head teacher confirmed that the AKA had used the documentation she had provided which explained the emphasis on mathematics in the appointment process. She had made a point of discussing this very early on with the relieving teachers.

First thing I focused on is putting the kindergarten profile together and making sure that for new people coming on board that they know that maths is important in this kindergarten. I have given X and Y material to read—the list we made about teaching maths. We sort of discussed what is important—children’s language problems, often don’t know the concepts and mathematical words. And we talked about how when we see maths happening, to bring it back at mat time and talk about it to consolidate using mathematical concepts in the work and making it clear for the other children as well.

She had started to include a focus on “reflecting about mathematics” in every planning and reflection meeting with the team. In fact, a new column was created to record mathematics aspects in the “Daily Sheets” that recorded mathematical experiences and offered a basis for reflection and forward planning. This was working well according to the head teacher because:

Then we write down what each teacher has observed in daily activities, then it is each teacher’s responsibility to follow up on that. So each teacher individually plans/thinks how we can go further with that activity. How can you expand what children are already doing.

And in relation to induction, she said:

The induction plan really consists of telling the teachers that this is important, we are involved in research. I have also given them material to read—on maths in this kindergarten and what a competent teacher is in this kindergarten from a maths perspective.

So—what I also believe is, it’s good not to leave it to just one meeting but to have continuity—for the longer period because it doesn’t stay with just one meeting. Maths focus has to be born. I have notified the teachers that this is the focus. You have also to give them the opportunity to think about and to see how they can live with it. If I bring it back daily / weekly in planning we can see what we are thinking about beforehand. I think it’s in that that we can improve the maths as a team. New teachers come in with new ideas and we think about these new ideas too.

A critical concern arose at this point in the project. This was that the head teacher was now the sole practitioner in the action research, and she was concerned about maintaining the momentum of the project. A further concern, shared by the researcher-facilitator, was the sustainability of change in a situation where staff turnover was a constant challenge. Hence, the head teacher was concerned not only about maintaining momentum in the short term, but also about the recurring issue of the induction of each new staff member into this kindergarten’s values, and its moral and theoretical commitment to make mathematics prominent. The tenacity and commitment of this head teacher to continue with the project in the face of daunting and recurring barriers is to be commended. Many others would have given up at this point but the belief of this leader in the “rightness” of the new theory of practice was unshakeable.

The current action research group acknowledged that, in addition to further monitoring of change, it needed to do a more formal evaluation of the head teacher’s efforts to highlight mathematics in

the induction process. The relievers suggested that it would be useful to review efforts at two specific points: three weeks after appointment and once the new teacher was six weeks into the job. A set of questions was developed by the team for the head teacher to use in order to get feedback from the new teachers:

The questions for evaluating induction effectiveness (3 weeks after starting) were:

- What was your initial reaction to the appointment documentation (focus on mathematics)?
- What has helped you to meet this expectation (during your induction)?
- What has challenged you (during your induction)?
- What can we do together to improve this?

The questions for evaluating induction effectiveness (6 weeks after starting) were:

- Are we including mathematics in our planning?
- What has been the mathematics that has been focused on in the last few weeks?
- What has been missed out/could have been done in more depth?
- Have mathematical concepts/language been followed up on at mat time?
- Have mathematical learning stories been written up and displayed?
- What else can we do to focus on mathematics—which strand, learning experience, game?

Ongoing evaluation

The head teacher's standardised sets of questions to use in reviewing the induction process were trialled with Y (one of the relievers) at the end of August 2005. She emailed the researcher-facilitator a record of this discussion which is reproduced below:

E-mail message:

I have evaluated the induction with my other reliever today.

First we talked about the routines.

We are finding that we are recording the daily activities most of the time, although I am finding that if I don't put it on the table in our lunch break, it gets forgotten.

It is not feasible to reschedule this till after the afternoon session, because of other meetings and tasks.

Weekly planning discussion:

We decided to write any "links to maths" under the heading "links to *Te Whāriki*".

Y (the reliever) told me she was happy about the maths focus when she first heard about it, because "in each activity we can introduce maths", and "maths gives a lot of possibilities" (with its 5 strands it gives a variety of areas you can work with).

It was quite clear to Y what was expected, especially after having read the handout "Maths in our kindergarten", which she found quite clear. (So this has helped the induction.)

The amount of information given was just right.

I hadn't given Y the information of maths in each kindergarten area. She thought it a good idea to put this into an induction folder, for the teacher to read when ready or needed.

Y is planning beforehand for maths possibilities in her activities.

This is working well for her.

What is not working?

Y finds that the children are not taking a lot of initiative to write numbers.

Between August and November 2005, this kindergarten was challenged by further staffing changes. By the middle of October, two permanent appointments had been made but by the time the researcher-facilitator met the team again in mid-November, one of these teachers had resigned. The head teacher nevertheless carried out her commitment to implement a review of the induction process with the two new permanent teachers, A and B, and incorporated this into a series of meetings. She reported the following:

Discussion on 11/10/05

A and B have read the information on "Maths in our kindergarten".

We have discussed the following:

- draw the maths out in children's play
- maths games (perhaps mosaic tiles / hopscotch game / spider game)
- record/display maths learning (A3 paper)
- show at mat time what they have made. Compare/discuss the maths aspect of the project
- keep up daily records on maths in special column on daily sheets.

Discussion on 18/10/05

Mentioned the Mathematics Book and forward planning for maths in each area.

Discussion on 25/10/05

- maths needs more focus
- collect learning stories
- improve documentation related to maths
- include maths game/activity on writing table
- filing tray in office for maths learning stories.

End-point evaluation

In mid-November 2005, the current Avondale Kindergarten teaching team met with the researcher-facilitator once again to look at what had been achieved in terms of change strategies since the meeting in August. The head teacher was accompanied to this meeting by the one remaining new permanent staff member and was still relying on a reliever to complete the teaching complement.

The two teachers from Avondale Kindergarten summarised the evidence that showed what had changed in their practice as they pursued the action research goal. This is presented under the headings of documentation, planning and display:

- *documentation:*
 - mention of mathematics in staffing advertisement
 - statement of competent mathematics teaching (kindergarten-specific)
 - evaluation questions to frame ongoing review of induction process
- *planning:*
 - daily and weekly planning to “draw out the mathematics”
 - term evaluation of teaching plans
 - creation of special mathematics section in planning outlines
- *display:*
 - mathematics display book
 - mathematics display wall
 - mathematical learning stories on display
 - attractive displays of mathematics equipment

Overall, the teachers at Avondale Kindergarten believe they have gone some way to “developing a system for keeping mathematics alive, keeping it in the centre of the picture”. The importance of a “system” is borne out by the continuing difficulty this kindergarten has in retaining staff. The practitioners who were involved in this research (past and present team members) were very concerned to put something enduring in place. Their hope is that future teachers will succour and sustain this endeavour to enhance mathematics learning and teaching despite socio-cultural barriers. This will only happen if the teachers themselves make a concerted effort to keep the prominence of mathematics alive and well.

The case of Birdwood Kindergarten: enhancing collaborative mathematical partnerships between teachers and parents

The kindergarten

The Birdwood Kindergarten is located in West Auckland and, at the time of this research project, was staffed by two full-time permanent teachers. The teachers operate a roll that caters for up to 30 children in morning sessions and up to 30 in afternoon sessions. However, the actual number of children on the roll frequently falls below this capacity and also, there is a consistent pattern of irregular attendance of children who are on the roll. The 2005 Education Review Report revealed that the ethnic make up of the kindergarten community included Māori (12), Samoan (12), New Zealand European (8), Tuvalu (4), South East Asia (4), Tongan (1), Fijian (1), Cook Island (1), Niuean (1), and Zimbabwean (1). Many of the families have lived in the area for some time creating a relatively stable community environment—it is not uncommon to have a family’s first, second and third child in attendance at the kindergarten. In some instances the second generation of children from a family are enrolled. The kindergarten is located beside a primary school that has a decile 1 rating indicating a socioeconomic composition that is at the lowest end of the scale—a 2004 AKA Parent Survey revealed that the biggest majority (44%) of families earn under \$25,000 with a small number (4%) earning over \$69,000.

At the time of this research project, the two teachers at Birdwood Kindergarten had had a long-term working relationship: They had been working together as a team for nearly five years. The teacher holding the position of head teacher had been there for more than 12 years. Although an administrator is employed for four hours each week, the teachers undertake added administrative and management tasks that would normally have been done by a whānau/parent committee. The Birdwood Kindergarten community has, for several years, experienced difficulty in forming a whānau/parent committee.

The participants were interested in participating in this research project because, as well as having had working relationships with members of the research team in the course of their own studies (upgrading to a teaching degree in early childhood education) and professional development, they were motivated to develop their understandings and their practices to improve the mathematics teaching and learning in their kindergarten. The participants were concerned that the community was unaware of the extent and potential for mathematics learning and teaching that happens in the early years and, in particular, that happens in the kindergarten. In order for mathematics teaching and learning to be effective for children it was crucial, they felt, that the kindergarten community—the whānau/parents and the school’s new entrant teacher—be both informed and involved. The participants shared a desire to “involve them on our journey”; they were convinced that collaboration was the key to creating a “culture of mathematics teaching and learning” for young children—in the kindergarten and in the home setting. Further, it was this collaborative approach that, they believed, would “support the (child’s) transition to school” and their ongoing learning in mathematics.

Understanding the problem—the reconnaissance phase

This action research project began with a facilitated orientation towards developing a deeper understanding of the challenge ahead. It was essential, at this stage of the project, that the participants engage in a dialogue and data gathering process to gain both a wider and deeper understanding of the complexity, and of the issues, involved in their identified problem and to increase their understanding of why, in the past, any attempts to resolve these issues or change their practices may have met with difficulty. This reconnaissance phase for Birdwood Kindergarten involved two discussion sessions (3 hours each) interspersed with a data collection by the participants to further inform their understandings.

Analysis of the problem

After considerable dialogue that involved a wide-ranging exploration of the issues that enabled both participants to share their perspectives, a process of funneling took place. This guided process involved a narrowing of the key aspects that both participants agreed were at the heart of their action research problem. It was quickly evident they both believed that in order to improve the learning and teaching of mathematics in the kindergarten, it would need to be done in collaboration with whānau/parents and be consistent and responsive to children's ongoing mathematical learning when they go to school. This led to their rationale for deciding that both the whānau/parents and the school's new entrant teacher be involved in some way. With these ideas in mind, they formulated their first action research statement:

How are we going to educate ourselves, the children and the kindergarten community to develop a collaborative knowledge and capability of learning and teaching mathematics in early childhood?

Ideas from brainstorming were noted on a whiteboard and then themed and re-themed to gain a clearer picture of the dimensions of the problem—and in particular of the issues that the participants felt contributed to their problem. The focus of this discussion and data gathering involved considerable soul searching. The participants identified their own attitudes towards, and experiences with, mathematics as being influential in their approaches to mathematics teaching and learning. Hence the decision, though they felt it somewhat ironic, to make mathematics the focus of the current teaching journey. One participant wrote:

Some years ago I was confronted with my mathematical disposition when I came across an early school report ... alongside number ... all I remember, is the word "poor".

The other participant described similar experiences:

I need to look at my maths demons from years gone by and fight them head on, I hope to change my opinion of myself. I need to believe that I have the capability to create fun and rich mathematical experiences across the curriculum for our young students.

Hence, at this early stage in the process of exploring the dimensions of the problem, the participants were critically aware of the impact that environmental experiences might have on

mathematics learning, and consequently on their teaching of mathematics. With their own experiences in mind, they questioned the kind of environments that might be prevalent in their diverse kindergarten community and, as a result, the mathematical experiences children might receive. They wondered:

... whether (the children) actually come from an environment that encourages and supports their mathematical learning?

They questioned whether many of the whānau/parents or the school's new entrant teacher had an understanding, and therefore an appreciation, of the possible mathematics teaching and learning that took place in the kindergarten. This was particularly true, they proposed, of those for whom the Aotearoa New Zealand early childhood education "structure" was new or unfamiliar:

Many families do not understand the concept of children learning through play ... see the more formal school setting as the way to learn.

Therefore, by the end of the session, the agreed dimensions of the problem were:

- community mathematical knowledge and capability: that whānau/parents and the school's new entrant teacher are aware of, understand, and appreciate the mathematics learning and teaching of mathematics in the kindergarten; and that there was uncertainty about whānau/parent expectations about mathematics teaching and learning in the early years because of diversity of values and cultures;
- teachers' mathematical knowledge, capability and manageability: being confident and able to recognise the mathematics component, and therefore the potential, in everyday experiences and to use the resources available; being able to document and make visible (i.e. display) the learning and teaching of mathematics in the kindergarten, in ways that are useful for informing whānau/parents and the school's new entrant teacher of the mathematics learning and teaching that does happen in the early years; and
- children's mathematical knowledge and capability: that both teachers and whānau/parents are aware of children's competencies, knowledge, skills, and attitudes in mathematics, and can support and extend them.

In the next step of the problem identification phase, the participants assembled and reviewed available and relevant data. This specific site-based data analysis included previous reviews of practice and documents pertaining to expectations related to the effective teaching and learning of mathematics in a kindergarten. At this point they decided they needed to include whānau/parents in the data gathering process. They felt that in order to establish a collaborative approach, it was essential to both inform whānau/parents of the research project and open up some discussion to invite whānau/parents to share their ideas and be involved. Therefore, they decided to devise a whānau/parents survey, with an introduction and an explanation, to begin this process.

Summary of previous reviews

Earlier, in 2004, Birdwood Kindergarten had participated in an AKA survey that had explored how the whānau/parent community viewed the kindergarten's provision of care and education for their children. The results provided an indication of whānau/parents' views (47% responded) and these respondents represented every ethnic group involved in the kindergarten community. Of significance to this research project was the extent to which the kindergarten was meeting whānau/parent expectations in relation to particular aspects, such as curriculum and teaching philosophy. These data revealed that whānau/parents' expectations in reading, writing and mathematics skills scored a varied response—a considerable number of respondents felt that their expectations were exceedingly “well met”; for half the respondents their expectations were “met”; but for others (about one-fifth of respondents), provision was “below expectations”.

The participants at Birdwood Kindergarten had discussed this finding. It had, at the time, provoked them to examine their own practices and their knowledge and understandings of the whānau/parent kindergarten community in order to understand what may have influenced the “below their expectations” responses expressed in the survey. They queried whether these responses suggested that the kinds of teaching and learning practices more highly valued, by many of the kindergarten community whānau/parents, might be similar, or the same, as those that are reinforced by the home intervention programme (HIPPIY New Zealand, 1992) that was well-known in the community. HIPPIY, as the teacher-participants understood it, provided a more structured and formal method of early childhood education with a greater emphasis on a skills-based approach. In contrast, the participants advocated a curriculum with a play-based philosophy and an integrated and holistic approach to learning and teaching.

Nevertheless, the teachers were prepared to accept the challenges inherent in the AKA's survey results and in their understanding of the importance of early mathematics learning and teaching for all children in the community. It was with this in mind, when the opportunity arose, that they started on this mathematics project. Yet it was, as one teacher said, “a journey I thought I would never see myself make”.

At the system level, an Education Review Office (ERO) review was carried out at the time of the reconnaissance phase of this research project. The results of this review provided the participants with generic feedback on their performance in the area of teaching and learning mathematics. The ERO report (2005a) affirmed that, according to the high quality criteria set by the ERO office, “early literacy and numeracy ... strongly underpin the teaching programme” (p. 2) in the kindergarten. This report stated that:

The teachers support children to understand the fundamentals of numeracy. They provide for children to count, to classify and sort items and display numbers in prominent places in the centre. Children appear to have a good grasp of number and are beginning to use numeracy in their play. (p. 5)

These comments were extracted from Education Review Office report, highlighted and displayed for the whānau/parents to read within the kindergarten environment (see Image 4).



Image 4: Display of extracts from the Education Review Office report

However, the participants remained self-critical and were interested in increasing their competencies in their own teaching practices that would enable them to enhance children's mathematical learning and foster children's dispositions towards mathematics—they were keen to:

Take advantage of situations that might arise [for children mathematically] to create a sense of enthusiasm for the children.

[Take] action to continue with new resources or resources to address different mathematics concepts.

Documentary analysis—system and kindergarten levels

Although an emphasis on learning and teaching of mathematics in a kindergarten relies on teachers' knowledge and understanding, a range of documented expectations also guide it. The researchers completed an analysis of the common system documents pertinent to all three sites (further detail is included in the case study of Avondale Kindergarten).

In the case of Birdwood Kindergarten, presentation of a summary of the analysis of the system level documentary led to a dialogue about the kinds of teaching and learning documentation they were expected to produce in support of the teaching practices in the kindergarten. The participants were keen to explore the expectation that they use a variety of methods to document their teaching and learning processes. They were interested in increasing the variety of documentation that they

produced and in making it, and the mathematics teaching and learning, more visible. They were keen to explore how this documentation could be used to develop and support a collaborative approach to enhancing young children's learning of mathematics in both the kindergarten and the home environment (and later, in the school environment). Hence their aim to increase the involvement of the whānau/parents (and the school's new entrant teacher) in the documentation processes.

At the system level, the AKA has expectations that high quality curriculum be delivered. These are communicated to teachers and the community through the guidelines and other documentation it produces. The *Auckland Kindergarten Association Service Delivery Manual* (AKA, 2003) reinforced the ideas the participants had in mind and challenged them to consider the notion of "pedagogical documentation". The manual suggested that "pedagogical documentation" should reveal, "to the teacher, other adults and the child what processes of learning are occurring" (p. 8-7). The participants agreed with this idea as it was consistent with their developing understandings and the expectations they had of their own documentation. It strengthened their commitment to the idea that this kind of documentation could be extremely valuable in developing a collaborative approach to the teaching and learning of mathematics at the kindergarten. Pedagogical documentation, it stated, was the kind of documentation that speaks to its audience in such a way that it has the potential to "clarify for all what concepts the child is currently exploring" (p. 8-7). In this instance, it was the concepts of mathematics and the learning and teaching experiences in mathematics that the participants had in mind.

Other local community expectations, pertaining specifically to the learning of mathematics in this particular setting, are those that are espoused by the new entrant teacher in the primary school adjacent to the kindergarten. It is expected that, on entry into school, a child would have acquired particular competencies in mathematics:

- counting forwards and backwards to 10;
- recognising colours and shapes; and
- singing a repertoire of songs based on numbers and colours.

These expectations had been articulated to the participants and it was their understanding that these expectations are articulated to members of the whānau/parents community in response to any queries about how best to support children, mathematically speaking, in their transition into the school environment.

For the participants, the official documents at both the institutional and system levels highlighted expectations that working in partnership with whānau/parents involved developing a shared understanding of teaching and learning in early childhood. It was this shared understanding of the complexity of young children's mathematical learning, and teachers teaching mathematics, that they saw as being a valuable focus for their kindergarten. Pedagogical documentation would enable them to work collaboratively with whānau/parents. It would enable the participants to share their knowledge and understanding with whānau/parents of how mathematics learning and teaching happen in the opportunities that arise everyday:

It's interacting, adults with children. At the basis, the idea is interaction, doing maths everyday.

Making these processes visible would also inform the school's new entrant teacher of the mathematics teaching and learning happening in early childhood and consequently, enhance children's mathematical learning on entry into school and beyond:

Make her think too, that when she gets these children going (to school) we encourage them to take their portfolios because it tells a lot about the skill and knowledge they start off with. They've actually got a lot of the foundation.

The participants foresaw that their intentions "to make mathematics learning and teaching really obvious" would contribute to their desire to "create a culture of mathematics." They believed this would enable whānau/parents to see "all the other maths that they don't see like the sorting, seriation, the comparisons". It offered them the possibility of "raising parent expectations"; they were adamant that "we've got to move on from counting" in order to create a rich mathematical environment that acknowledges and enhances many aspects of children's mathematical learning. This culture of mathematics would be noted and appreciated by the kindergarten community:

Make her think too, that when she gets these children going (to school) we encourage them to take their portfolios because it tells a lot about the skill and knowledge they start off with. They've actually got a lot of the foundation.

So that when they talk about our kindergarten they'll be saying you know that maths kindergarten, I don't know the name of it but it's the maths kindergarten.

Emerging themes

Two themes emerged during facilitation in the reconnaissance phase. They related to the teachers' documentation of teaching and learning in mathematics and collaboration with whānau/parents and the new entrant teacher at the local school.

Focus on teachers documenting the teaching and learning of young children's mathematics in the kindergarten

As part of the process of clarifying the expectations they had of their own teaching practices, the participants devised statements of competencies that would guide their process, inform their practices, and consequently be reflected in their documentation. A competent teacher of mathematics would have:

- a knowledge of what children are capable of, mathematically;
- a knowledge of children's interests including the meaning of, and the significance of, the possible mathematics learning;
- a knowledge of the mathematics curriculum and the ability to link the mathematics in early childhood (*Te Whāriki*) with school mathematics;
- skill in documenting and displaying mathematics in the kindergarten in ways that are clear, simple, informative and instructive, and at the community level;

- the ability to reference (*Te Whāriki* and mathematics curriculum) and use both documents effectively; and
- a use of teacher knowledge to motivate and create opportunities for mathematics teaching and learning.

Focus on collaboration

In order to test their assumptions about whānau/parent attitudes, as well as their knowledge and understanding of the teaching and learning of mathematics that might happen in the kindergarten, the participants had devised a “5-minute survey” for whānau/parents to complete in their own time. They devised a number of questions that would offer them a glimpse of the understandings in the community about the mathematics provided for children, whānau/parents aspirations about their child’s mathematical experiences in the early years, and whānau/parent attitudes towards mathematics brought about by their own school and/or other experiences.

The participants were hopeful that this survey would offer them an opportunity to open up some discussion with the whānau/parents community about mathematics teaching and learning.

The results of the 5-minute survey were:

- of the 30 whānau/parents who had been provided with the survey, 11 responded;
- 10 responses indicated that whānau/parents understood children were taught “counting” in the kindergarten; 4 indicated “addition and subtraction” and another “water, volume”; and
- 6 responses indicated that “addition and subtraction” should be taught; 1 indicated children should be taught “algebra” and another “working with rods”; 1 parent was adamant that what the children were doing in regards to mathematics in the kindergarten “was fine” given their age and understandings.

What was most surprising to the participants was that a greater number of responses indicated that the whānau/parents had had positive experiences themselves with mathematics when they were at school—7 indicated a positive experience, and 4 a negative one.

Intervention—planning and monitoring new practices

A second facilitated meeting (May 2005) was held specifically for the purpose of planning a range of intervention strategies for changed practices that could be monitored. These new practices had already begun during the reconnaissance phase and focused on participants “documenting the learning and teaching of mathematics in the kindergarten and links with children’s experiences in the home”. The participants devised a formal plan and made a commitment to continue the changes in their practice that they were now committed to. These changes had two particular emphases, one on documenting the teaching and learning of mathematics and the other on collaborating with whānau/parents.

Teachers documenting the teaching and learning of mathematics

The participants identified a number of strategies that they intended to initiate immediately, including:

- setting up a wall display “making mathematics visible”—this would involve a variety of different types of pedagogical documentation e.g. learning stories, photographs, parents’ voices, teachers’ voices, teaching plans and evaluations (see Image 5);
- documenting learning stories of individual children’s experiences that highlight the mathematics learning and teaching and placing these in the children’s portfolios;
- devising a description of “that mathematics kindergarten” that explained the “what, why and how” of mathematical experiences; and
- continuing to explore and develop the use of available resources.



Image 5: The wall display “making mathematics visible”

Collaborating with the whānau/parents and the school’s new entrant teacher

As noted earlier, the 5-minute survey showed the majority of the parents who completed the survey had had a positive experience with, and remained positive towards, mathematics. The teacher-participants hoped this would contribute to the willingness of whānau/parents to be involved. However, the teachers were concerned about how difficult it was to “reach out” to whānau/parents whose presence, for whatever reason, was not so evident in the survey results or in the kindergarten.

Although the participants felt it essential to keep all whānau/parents informed, they were mindful of the difficulties of getting everyone involved, and they were keen to explore ways of inviting them into the kindergarten. They perceived it as one thing to create a “display” of the mathematics teaching and learning but the next challenge was to ensure that it was “dynamic” rather than “static”; that is, it was owned and used, read, and added to by the whānau/parent community as well as by themselves. As well as reflecting the mathematics teaching and learning that was happening in the kindergarten, it would also reflect what was happening in the home environments. This documentation would be shared with the school’s new entrant teacher to inform her of mathematics experiences in the kindergarten/community settings. The participants decided to:

- devise a newsletter system, specific to mathematics, with suggestions on how whānau/parents could support and extend their child’s mathematical learning in the home environment; and
- provide the school’s new entrant teacher with a copy of the mathematics newsletter inviting her to give feedback, and have an input, that would increase the whānau/parents knowledge and understanding of experiences that children encounter in the school environment.

Monitoring the intervention

From June to August 2005 the participants continued with their efforts to enhance the teaching and learning of mathematics in the everyday kindergarten experiences. The researcher-facilitator was readily available via telephone or email to respond to requests.

Focus on the teachers

Throughout this phase of the project the participants were able to observe their innovations and refine them as necessary. They tried to document significant incidents of mathematics teaching and learning through their photographs and in their teaching and learning stories. These were then either placed on the “mathematics teaching and learning” display wall or in the child’s (assessment) portfolio.

“Doing mathematics” in everyday curriculum experiences

Photographs were used to capture children’s mathematical engagement with the learning environment. The participants used these photographs to communicate to the whānau/parents the mathematics that children might encounter in their everyday experiences in the kindergarten. A photograph of a child’s engagement with puzzles was interpreted using a mathematics lens. The participants documented their ideas of what the children might be doing when they are “doing mathematics” embedded in the experience of completing a puzzle: matching, exploring shape, developing spatial understanding. This documentation was sometimes displayed in the kindergarten before being placed in the child’s portfolio—a space was provided for a whānau/parent signature in acknowledgement that they had read it.

Children engaging in mathematical thinking, using mathematical language

The participants documented significant instances that captured children's interest in, and their use of, mathematics language. One participant wrote "... was able to tell me the names of the triangle and circle ... when he had finished counting all of the different shapes he said "1,2,3,4,5,6,7,8,9,10!" They used the documentation to demonstrate how they worked alongside children to enhance the mathematics in the learning situation. The participant explained: "He needed help with the name of the trapezium and square".

Teachers initiating mathematical "thinking and doing" experiences

The participants planned to focus on particular mathematics concepts: for example, "counting, sorting and classifying", and devised ways of accentuating these concepts. The documentation displayed on the wall, and in the newsletters, revealed the "what, why and how" these experiences unfolded: "We decided a treasure hunt would be a great idea ... a fun way of introducing and consolidating the children's counting skills and number value". Although these experiences were teacher-initiated, the documentation reveals how the children contributed their own ideas. It explains: "The children came up with some great ideas" of what they should hunt for".

Teachers highlight how mathematics is integrated into the early childhood curriculum

The participants used other displays in the kindergarten environment to highlight the nature of the integrated curriculum valued in the kindergarten; they accentuated the links between the mathematics and science—for example, the mathematics that arose from the teacher's interest in promoting children's fascination with spiders within their outdoor environment and within specific curriculum areas; or the mathematics that arose from the teacher-initiated planned focus on health that had taken place over the winter months.

Teachers ensure that resources support mathematics teaching and learning

When an opportunity to buy new resources for the kindergarten arose, the participants had bought gym equipment with enhancing mathematics in mind "to make ... healthy bodies but by using this gym equipment we were going to be using mathematical language; and then we got the (mathematics) curriculum book and discovered geometry, spatial awareness".

Focus on collaborating with whānau/parents

The mathematics teaching and learning documentation was clearly visible in the kindergarten and indicated to the community that they would be regularly informed of significant mathematics learning and teaching occurrences in the everyday curriculum. This documentation was used to formulate the "maths newsletter" that was sent home with the children to inform the whānau/parents of these learning experiences and offer suggestions of how they could enhance their child's learning within the home environment (see Image 6).

Making visible the mathematics teaching and learning in the kindergarten

The participants reflected on how they constructed their documentation and made changes to make it an "attractive newsletter" with greater use of digital photographs and computerised colour

enhancers. They believed this would make it more inviting and more readable for whānau/parents. As part of the teacher-initiated planned learning experiences, the participants identified strategies to involve whānau/parents and made these expectations visible to them—they wrote “recipes will be given to families to take home to enable children to continue cooking during the holidays”.

Whānau/parents enhancing the mathematics in the home environment

As well as informing whānau/parents of the mathematics teaching and learning experiences, the newsletter provided specific suggestions of what whānau/parents could do with their child/ren to enhance the mathematics learning in the home environment. The participants encouraged whānau/parents to communicate how they had implemented the suggested experiences in the home environment—they created a “Parent’s Voice for Mathematics” form which was given to families to invite follow up (see Image 7).

Parents contributing to the mathematics teaching and learning documentation

A number of parents used the “Parent’s Voice for Mathematics” form and wrote stories about what had happened at home. One parent wrote: “We counted together how many items were in the Treasure Hunt. (child) said 8. There were 10. After we finished we both enjoyed the hunt and (child) helped putting the items away. (child) loves doing Treasure Hunt and talks about it”. In response, where opportunities arose, the participants acknowledged and documented how children had talked about their home experiences in the kindergarten. One participant wrote a “child’s voice” story that included “(child) ... talked about his treasure hunt he had done the night before at home with his mother”. This was placed in the child’s assessment portfolio.



Image 6: The mathematics newsletter

- made two visits to the school’s new entrant teacher to open up dialogue and discussion about mathematics in the kindergarten and mathematics in the school.

Further discussion was used to encourage the participants to consider evidence that demonstrated a qualitative component. The questions “had making the teaching and learning of mathematics visible made it more accessible to the kindergarten community?” and “had they achieved an effective collaborative approach?” were used as the framework for further discussion.

It was evident in the documentation and in the “teacher talk” that the project had enabled the participants to become more aware of “the mathematics that is within different curriculum areas.” It was also evident in the environment that they had been able to make the mathematics more visible. However they queried what evidence they had that demonstrated how effective they had been in developing a collaborative approach. They were able to provide some documented anecdotal evidence of feedback from whānau/parents who had used the specifically devised “Parent’s Voice for Mathematics” form. This also provided documented evidence that some parents were reading the newsletter and following through with the suggestions provided, offering children further opportunities to explore in the home environment the mathematics that was happening in the kindergarten. Other parents had approached the participants to give verbal feedback and another three parents had come into the kindergarten to cook with the children, accentuating the mathematics involved.

The participants believed that their “relationship has been strengthened” by their visits to the new entrant teacher in the neighbouring primary school. The responsiveness of the school’s new entrant teacher showed in the way she “deliberately made sure we were there so we could see the mathematics learning that was happening at school”. The participants were encouraged by this and in the knowledge that she was aware of their interest in mathematics; their visits to the school had inspired them to take “some of *their* ideas” about mathematics back into the kindergarten. The school’s principal and the new entrant teacher had also visited the kindergarten to observe children engaged in learning experiences. The participants were able to demonstrate the kind of teacher-initiated learning experiences that happen for children at large group times, in particular experiences that are intended to enhance children’s mathematical thinking and learning in some way.

In summary, the participants identified the significant benefits they believed had arisen from the intervention. These included:

- an increased teacher focus and knowledge of mathematics;
- the potential of mathematics in different curriculum areas;
- an increased use of mathematics language within the curriculum and in their interactions with children;
- a greater awareness amongst whānau/parents that mathematics is more than counting;
- greater involvement of whānau/parents in the programme;
- the use of “user-friendly” newsletters insuring that mathematics was not “scary”;
- overall stronger teacher/whānau/parent relationships;

- teachers' ability to self-promote—their knowledge, philosophy and curriculum; and
- the reward of hearing children's new knowledge—as one participant exclaimed: "Hearing the children come out with what we are trying to teach them. How beautiful is that!"

The participants were able to rejoice in these benefits—as one exclaimed:

We look at (the display boards) and give ourselves a pat on the back. We can see the progress. If (the documentation) was all tucked away in a portfolio or book it wouldn't be so inspirational.

The participants were interested at this point in the views of the whānau/parents who had participated and been involved in the change strategies. They approached whānau/parents of the morning group for some insight from their perspective on the impact of the strategies, by asking them to complete a brief "evaluation questionnaire". The number of responses they received encouraged them: 20 of the 30 whānau/parents provided with the evaluation questionnaire had taken the time to complete it. All of the whānau/parents who responded to the evaluation questionnaire acknowledged their awareness of the mathematics focus that had been happening in the kindergarten throughout the year:

- all 20 whānau/parents indicated that they had noted specific happenings in the kindergarten. Nine noted the newsletters; 8 noted curriculum activities; 5 mentioned the wall display; 4 mentioned the mathematics that occurred during mat times; and 3 indicated that they had read about the mathematics in the learning stories the teachers had written; and
- all 20 whānau/parents had participated in a shared experience with their child, that involved mathematics, as a result of the newsletter or curriculum experiences. Sixteen had counted with their children; 8 had sung songs that involved mathematics; 7 had included shapes; 6 had cooked; 5 sorted; and 3 acknowledged that they had added with their children.

However, although the participants were heartened by the strategies mentioned in the evaluation questionnaire, the absence of other strategies (for example, parent voice forms, children's individual plans) indicated that these needed to be strengthened before the participants could describe them as "effective strategies". Furthermore, both the participants continued to be concerned about the ongoing challenges of establishing a collaborative approach with the "harder to reach" whānau/parent group: there was still the challenge of "getting some whānau/parents on board, more involved". There existed, amongst this group of whānau/parents "a lack of verbal and written feedback" that made them invisible in the documentation. The participants proposed several reasons for this:

- language barriers—whānau/parents for whom English is another language had difficulty/didn't feel comfortable approaching or communicating with teachers;
- busy hard working whānau/parents—many of the whānau/parents in the community are necessarily double income families and shift work is common; and
- a different understanding of expectations between teachers and whānau/parents; the participants felt that many whānau/parents were unaware of the importance of "preschool education" let alone the possible mathematics learning that happens in the early years.

The participants were interested in continuing to use the mathematics newsletter to encourage all whānau/parents to be involved. They saw it as an opportunity “to share with the whānau/families what we are doing” in order that whānau/parents can “do it at home”. They expressed their ideas and understandings about how the concept of “the partnership” might be interpreted. They had ideas about how this partnership worked and of their expectations of whānau/parent involvement in children’s learning—as one participant stated:

Our expectation is that you do more than just drop your child at the door and sign them in and run away.

The other participant expanded this idea and reiterated how they saw the newsletter as being instrumental in communicating these expectations to whānau/parents:

The fact that you are actually responsible for your child’s learning, you are the child’s first teacher. It’s your responsibility to provide your child with every opportunity and here’s some of the exciting ways to do it.

Although there was evidence that a number of the whānau/parent were engaging with the newsletter, the participants discussed how they would gather verification from the whānau/parents that these strategies were effective and worthy of ongoing improvements. Consequently, they devised a list of possible questions they would use to formulate a questionnaire that would be handed out to whānau/parents to complete in their own time. They decided they would also seek answers to these questions through one-on-one conversations with whānau/parents as this would enable them to target, where possible, those invisible voices: the group of whānau/parents for whom there was no documented evidence of any engagement with the mathematics teaching and learning strategies implemented. As the head teacher commented:

Collaboration with parents proved to be a real challenge, particularly finding strategies to involve Pasifika families. Although we actioned several strategies to include as many families as we could, we came to accept that there were families that were involved and responsive to the project and those that chose, for whatever reason, not to be involved.

The case of Don Buck Kindergarten: growing teacher confidence in strategising for children’s mathematical learning

The kindergarten

Don Buck Kindergarten is situated in Massey, Auckland and is staffed by two full-time permanent teachers. The head teacher had been employed at the kindergarten for eight years but the second teacher had only been part of the teaching team for a few months when the project began. The staff team includes a teacher aide (administration) who attends twice a week and an education support worker who attends regularly to support a child with special needs. The kindergarten

caters for 30 children in the mornings and a different 30 children in the afternoons. It has a stable roll, with most children attending on average for a period of 18 months, when they leave for entry to school.

Ethnic data collected in May 2005 showed that over half the whānau/families classed themselves as New Zealand European. The responses indicated 58 percent New Zealand European, 13 percent Māori, 5 percent Chinese, 5 percent Indian, 5 percent Tongan while 14 percent responded as “other”. The other category included families who named themselves Samoan, Fijian, Tuvaluan, Cook Island, Niuean, Filipino and Canadian. The local primary school is adjacent to the kindergarten and has a decile rating of 5, illustrating the broad socioeconomic community attending the kindergarten. Economic data collected in May 2005 indicated that the income levels of the respondents ranged from over \$69,000 to under \$25,000. Although many of the families have working parents, the kindergarten enjoys strong parental support from its community. The whānau/parents are most supportive as committee members, and in particular for special events such as fundraising.

About a year before the research project began, the head teacher at Don Buck Kindergarten had initiated the possibility of working in partnership with a researcher to enrich the mathematical experiences for the children at the kindergarten. A previous Education Review Office (ERO) review (2001) had reported that:

Children use mathematics for real purposes during cooking, and practise numeracy skills during mat activities, teachers should now consider ways to extend the authentic use of ... mathematics skills within the context of play. (p. 5)

When the possibility of participating in a research project focusing on mathematics teaching and learning arose, the head teacher was approached and expressed interest. Later her motivation was shared with a teacher, new to the team, and together they agreed to join the project. Their rationale was to give mathematics a higher profile at the kindergarten and to provide increased opportunities for children to learn mathematics.

Understanding the problem—the reconnaissance phase

To identify a research problem, related to the teaching and learning of mathematics, the participants at Don Buck Kindergarten explored a variety of sources through which they gathered substantive data to inform this reconnaissance phase of the research. During this phase the participants met with their researcher-facilitator for two sessions (3 hours each) to report on their findings.

The first meeting between the participants and their researcher-facilitator set the scene for an in-depth discussion exploring the broad parameters of mathematics teaching and learning. The participants engaged in frank and open dialogue confirming their shared desire to provide a rounded programme which would increase meaningful mathematical experiences for the children. The initial ideas raised indicated an interesting variation in the views of the two participants on

what aspects of an early childhood programme best provided for children to experience rich mathematical learning opportunities. One participant hoped the research project would provide time to focus on the resources of the kindergarten:

We've got resources so let's use them. It's about utilising our maths area and our planning.

The other participant emphasised the importance of developing stronger relationships in the teaching/learning process:

For me it is about learning alongside others. We are all going to be learning about maths together. Involving all of us working together, parents-teachers-children, to achieve and improve mathematical outcomes for the children.

However both participants agreed that the key issue affecting children's opportunities to maximise their mathematical experiences centred on the teachers' own personal and professional inhibitions about mathematics teaching.

Analysis of the problem

As the participants' exploration of the problem increased, in-depth dialogue resulted in a clearer picture of possible directions for the research at Don Buck Kindergarten and in the opening session the first research statement agreed on by the teachers was:

We want to find out what children need to maximise their mathematical learning.

The researcher-facilitator encouraged the participants to unpack this statement and themes within the problem were articulated. It was soon evident that teacher knowledge and confidence was given a high priority in the teachers' reflections on their ability to maximise children's mathematical learning experiences. The question "What is it that stops me from picking up on children's mathematical learning?" elicited some very personal reflections such as:

Maths has always been a great passion of mine even from the time I was at school. I have great memories of being quite competent in this area at school and always being praised by the teacher for my abilities. Now however I feel quite incompetent in my ability to teach maths concepts to small children despite my deep passion for doing so. Why do I feel this way? What can I do to change this? I think I need to get back to basics. I believe I am making maths more difficult, more complex, than it needs to be.

Maths is not my favourite curriculum area. I don't have enough knowledge on that subject so I have a negative attitude. I don't feel I am capable of it myself so how can I give out information to a child if I don't have it myself? ... and because I experience boredom with the maths games and maths equipment we have I don't always look for the possibilities with the other materials we have ... I don't use them for maths learning.

Further discussion moved to the programme itself and drew out the participants' philosophical beliefs that underpinned the day-to-day running of the Don Buck Kindergarten programme. The participants believed in authentic learning experiences embedded within an emergent curriculum. This forced a return to the issue of mathematics-specific resources versus generic resources that

provided for rich, and sometimes spontaneous, mathematical thinking in the children. This discussion raised statements such as:

We've got to take a long hard look at ourselves, what we do and what we provide, before we move forward.

The children need a focus area, a place they can go knowing maths is going to be there. But isn't the potential for maths everywhere? I don't want to 'play at school' and push children into maths learning they are not interested in e.g. rote learning with counting.

In general terms the participants at Don Buck Kindergarten prided themselves on their partnership with whānau/parents, and their ability to use this partnership to benefit children's learning. A recent review by the ERO (2005b) had substantiated this belief in the following words:

Teachers request written information from whānau/parents about their child and include them in the evaluation of their child's learning. Additionally they exchange information with whānau/parents on an ongoing basis and individual learning goals are developed collaboratively. (p. 4)

However, when engaging in dialogue focusing purely on the mathematics education aspect of Don Buck Kindergarten, the participants reflected that there was more that could be undertaken to strengthen whānau/parental participation in this area:

Our ultimate goal is to get them (the parents) really involved and working alongside us. I like partnership (with parents). Sharing information because they may be skilled in the (mathematics) area and come up with a lot of information.

It's probably going to need a lot of research on what happens in the home.

Throughout the lengthy discussion, notes were recorded on large paper and the robust discussion enabled further brainstorming to be straightforward as, even at this very early stage of the project, these ideas quickly became the dimensions of the research problem: teacher knowledge and disposition; the programme; and whānau/parents.

However, during the second session, the problem dimensions expanded to include not a focus not only on the adults in the children's lives (that is, the teachers and the whānau/parents), but also the children. The participants' decision to focus on the children grew as they came to an agreement that the most important ingredient of the teaching-learning triad of parent, teacher and child was the child. They discussed children's prior knowledge, children's ability to "take in" mathematical information, children's hidden mathematical understandings, and children's dispositions to "things mathematical":

This has made me think... Do they (children) have the ability to take on mathematical information? Thinking about a 3 year old child that's just learning to become comfortable and feel safe at kindergarten. Are they able to take on maths knowledge at this point?

In a group situation where there is maths happening is there maths learning taking place at the same time or are they just learning to fit in with a group?

It's an attitude as well. It's a disposition to have a go, willingness to fail, taking risks.

About the children's dispositions to learn—we need that in. I think that is the basis point. Without this we can't do anything else.

Finally, a fourth dimension, children's knowledge and dispositions, was added to the description of the problem. The focus on the children developed from the participants questioning their own ability to "teach mathematically". In order to provide for children, they recognised the child's knowledge base as crucial to the problem, together with a disposition to learn. Brainstorming, followed up with observation, revealed that the participants believed that children's mathematical learning could be affected by their natural abilities and attitudes to certain types of play. Hence in the particular context of this project, they considered that appropriate dispositions for strengthening mathematical ability at Don Buck Kindergarten would need to be explored. By the end of the second session, the initial problem had been amended to focus clearly on teacher competency, in supporting the children's mathematical learning, and was defined as follows:

How do we provide a programme which enables children's mathematical learning to be maximised?

The problem identification phase provided the participants with the opportunity to reflect on their perceptions of the status quo at Don Buck Kindergarten in terms of mathematics teaching and learning. However, the participants recognised that much of their knowledge of the mathematics education received by the children at the kindergarten was based on informal observation and intuition that "they could do more for children". They hoped that data gathering would provide evidence to not only substantiate their perceptions but also to influence their planning for the next direction of the project. They agreed the next step was to explore relevant documentation and theory and to investigate and record mathematical aspects of the programme. A further decision, initiated by the participants with enthusiasm, was to update their theoretical knowledge base before proceeding further.

Documentary analysis—system and kindergarten levels

A range of documents, both national and regional, guide teaching and learning in kindergartens. These documents were analysed by the teacher-participants and the researcher-facilitators for recommendations pertaining specifically to the teaching and learning of mathematics (further details of the researcher-facilitators' analysis of these documents for all three sites is included in the case study of Avondale Kindergarten).

The participants at Don Buck Kindergarten believed strongly that they did meet the expectations and requirements of all these documents, which they regarded as underpinning quality early childhood education. They highlighted, in particular, that in their programme planning and implementation they:

- addressed the principles of the national early childhood curriculum, *Te Whāriki* (Ministry of Education, 1996);
- followed the Desirable Objectives and Practices (DOPs) as defined in *Quality in Action* (Ministry of Education, 1998);

- aimed to achieve the professional standards for kindergarten teachers (Ministry of Education, 2004a);
- operated according to the Auckland Kindergarten Association Service Delivery Manual (AKA, 2003); and
- were guided by the strategic plan (Ministry of Education, 2002).

Their search for supportive mathematical references is summarised in the reflective statement of one participant:

Throughout the initial stages of this research project we were looking for mathematics-specific content within these documents—something that would provide us with a reference point from which to begin. However what we found was quite the opposite: all of these documents indirectly referenced maximising children’s learning opportunities through the provision of the “curriculum”. So does the “curriculum” in early childhood education include mathematics as a core subject?

The participants agreed that they did not expect to find mathematics or numeracy advocated as a core subject, nor did they wish it to be so. However, they did locate some mathematics-specific findings, and these are summarised in Table 2 below:

Table 2 **Document analysis Don Buck Kindergarten**

Te Whāriki

Section D has links between the essential skills and learning areas of the *New Zealand Curriculum Framework* (Ministry of Education, 1993) and each strand of *Te Whāriki*, mentioning in particular numeracy, problem-solving and desirable dispositions for mathematical learning.

Quality in Action (DOPs)

While the DOPs themselves refer only to ‘curriculum’, in all five sections of *Learning and Development* (DOPs 1 Š 5), within the document there are six references to mathematics, two to problem solving, however none to numeracy.

Auckland Kindergarten Association Service Delivery Manual

Mathematics is listed as a curriculum area requiring systematic review.

The participants concluded their findings with a question:

These documents meet their intended purpose of forming the foundation and extending the learning and development of children through quality education. It is clearly not their intention to provide subject-specific information so where do we go when we want, or need, more specific subject knowledge to provide that quality education?

This analysis led to an increased focus on the programme, the environment, and the resources. More specifically, the question was about how the teacher and child could work together, within this programme, to maximise the child’s mathematical learning and how the contribution from whānau/parents could be strengthened to add rich family-based values and experiences to the kindergarten programme.

Investigating the mathematical richness of the existing programme

Following up on their intuitive sense that they “could do more” for the children, the participants made a range of plans to develop a rounded investigation of how they, and the whānau/parents, were currently supporting children’s mathematical development. These included observations of children engaging in mathematical activity in a variety of contexts, auditing the curriculum areas/areas of play for mathematical potential, time sampling the area specifically designated as a “maths area”, and using the “parent voice” to gain feedback on the observations of their children.

The participants reported that these investigations had heightened their awareness of the potential for “maths learning” across the environment; a sample of their reporting is:

When we started to brainstorm what we could currently use in view of resources, and we broke it down into curriculum areas, we actually had to think about what maths really meant. We went to the dictionary for definition but it only quotes four things: shape, base, number and size. We first took that and then started saying “volume, pattern, sequencing ... these are all maths concepts. Then we emailed you (the researcher-facilitator) and after that we brainstormed again and it (the mathematical potential) was endless.

When I started to go through the maths games I thought “well I could do this” and if I made my own maths games they would have more relevance for the children. For example we are focusing on bugs and spiders at the moment and the children are bringing in their own books. We could start photocopying these to make maths resources that are really relevant to what we are doing.

As part of their normal practice at Don Buck Kindergarten, the participants were in the habit of observing children’s experiences through learning stories, an observation tool designed by Carr (1998a; 1998b). The participants valued how the credit model of this format provided them with opportunities to record children’s strengths and dispositions, thus assessing the learning of the “whole child”. During the reconnaissance phase of this project, the participants decided to make “mathematical happenings” the focus of their observations. However it was soon apparent to them that it was rare to document a learning situation which did not contain any evidence of mathematical thinking, or doing. In constructing learning stories, the format for observation allows the observer to make links to the national early childhood curriculum, *Te Whāriki* (Ministry of Education, 1996), and ensures that even when observing through a specific lens, in this case mathematics, the assessment of the child’s learning experience remains grounded in the holistic nature of early childhood education. This affirmed the participants’ beliefs that focusing on mathematics would not detract from their normal programme.

As the participants progressed through the reconnaissance phase, they became increasingly aware of the high level of mathematics knowledge and skills abundant in many of the children. Frustration at their own level of mathematics knowledge continually reminded them of their original intuition: that if they had a deeper level of mathematics knowledge, they could provide richer opportunities for children to think and act mathematically. They returned with consistency to their original problem: how to provide a programme which would maximise children’s mathematical learning. One participant summarised their frustration:

One of the things that came through for me when I was doing the time-sampling was that I realised I could go a lot deeper, we could talk about maths concepts so much more, we could extend their (the children's) knowledge base so much more—if we had more knowledge ourselves—so therefore the next step?

Teacher knowledge

Reflecting on the outcome of their documentary analysis, the participants returned to the issue of where to go for more specific mathematical support. They arranged for a day in the library at their researcher-facilitator's tertiary institution to explore theory, in order to increase their confidence in researching their role in enhancing children's mathematical learning. The participants spent the day accessing journals and the websites of online journals, and sourcing other respected published articles they deemed relevant to increasing their personal mathematics knowledge.

Reflecting on the usefulness of the day, and its follow-up, the participants listed key benefits as:

- providing time and resources to research relevant material they would not otherwise have had;
- consolidating the relationship between them and the researcher-facilitator;
- gaining skills in researching for data; and
- providing the data they needed for further reflection.

The participants subsequently skim read the articles, sorted for meaning, read the most relevant, and discussed implications for their kindergarten programme. One participant reflected:

We are already using this knowledge as we proceed through the project.

As a further follow-up to this day of exploration the participants accessed the national mathematics curriculum, *Mathematics in the New Zealand curriculum* (Ministry of Education, 1992) to further advance their mathematical knowledge. An outcome of their analysis of this document was that they came to value it as a framework for the mathematical potential within their programme, despite the document being written specifically for the compulsory education sector. They returned to their initial audit of the mathematical potential in the curriculum areas, and designed a framework for recording the mathematical potential of their total kindergarten environment. The effectiveness of this is described later in the report, as it became an integral component of the intervention phase of the project.

The findings from the reconnaissance phase of the project, together with their recent ERO review (ERO, 2005b), encouraged the participants to further improve the teaching and learning of mathematics in their programme. In the report of the review, ERO stated:

Numeracy is a current area of interest at Don Buck Kindergarten. The centre is part of an NZCER research programme and this is highly evident throughout the centre. A wide range of maths equipment across the centre supports children's maths concept development. They access this freely as they use it in the context of play. Teachers use every opportunity to seize mathematical moments. Teachers acknowledge the importance of number knowledge and children benefit from frequent exposure to counting. Children engage in maths activities

that are challenging and meaningful to them. Their ideas are valued as they contribute to collecting data about current topics. At the time of the review, children were asked to choose what vegetable they wanted to grow in the centre's vegetable garden. They needed to illustrate and graph this information. Children were involved in collaborative decision making as to how they would redevelop the vegetable garden. As a result, teachers are reflective about their practice and are providing very good mathematical foundations for children. (p. 4)

Despite remaining convinced that the key person in the teaching and learning triad was the child, and the child's knowledge and disposition to learn mathematics, the participants' reflection on their findings thus far convinced them that the complexity of their current problem centred on the adults in the teaching and learning relationship. Hence the participants agreed to define the problem through the three original dimensions, focusing on the contribution of teachers, whānau/parents, and the environment to children's mathematical learning. With these dimensions in mind, the participants remained mindful that solutions would, of course, be for the enhancement of the child's mathematical learning and development.

Emerging themes

The key themes for Don Buck Kindergarten then were: teacher knowledge and disposition; the provision of a mathematically-rich programme within an appropriate learning environment; and whānau/parent involvement in their children's mathematical learning.

Teacher knowledge and disposition

Despite being confident in their role as kindergarten teachers, personal reflective statements on their ability to provide stimulating mathematical experiences for children had already enabled the participants to document not only their strengths, but also their fears and the barriers they needed to overcome to improve their teaching of mathematics. Comments from the participants included:

I still need to read more literature to increase my knowledge about teaching mathematics.

I would like to learn from other teachers.

It then seemed appropriate for the participants to explore the concept of mathematics itself, documenting their thoughts and beliefs about "what *is* mathematics", and recording the potential for children to think and act mathematically within the kindergarten environment. As the discussion became more focused, a question arose: How much mathematics knowledge does a kindergarten teacher need to confidently and competently support children's mathematical development? The participants agreed that there could never be "too much" and summed up the discussion in this way:

Enough to react to children's findings and to be able to not only answer their questions but to respond positively, to challenge them further.

Sometimes I find myself out of my depth even though I have a reasonable level of mathematics knowledge from school—I still need more because I guess I still feel insecure.

However, their reflection on the current ERO review (2005b) indicated a strengthening of the participants' own dispositions towards mathematics and a pride in their personal development thus far:

We have just had our ERO review and the comments made about the teachers' ability to use every opportunity to expose children to maths is very positive. Made us feel we are improving our practice through research.

The challenges for the participants included having the mathematical knowledge to support children's mathematical learning confidently, having the knowledge to use meaningful strategies to recognise and extend children's mathematical thinking, and having the confidence to share that knowledge with whānau/parents.

The provision of a mathematically-rich programme

The participants considered the learning/teaching environment crucial in maximising children's mathematical learning, in terms of both the structure of the setting and the planning for play/learning. They believed that the current setting at Don Buck Kindergarten did not do enough for children's mathematical learning: There were mathematics-specific resources that were not used; they acknowledged there were generic resources that could be used more effectively to support children to think mathematically; and they were mindful that there were curriculum areas/areas of play which did not always provide enough potential for spontaneous mathematical events to arise. During the discussion the participants found themselves reflecting on situations which they felt had been positive examples of supporting children's mathematical thinking and their dialogue contained reflective ad hoc statements such as:

There was this musical game, with singing, starting from the number 7 and slowly subtracting people away. I realised that I wasn't just playing a game. I asked the children before starting how you would depict the number 7, and made a story to see how many fingers they held up.

I realise I use much more mathematical language than I thought I did—positional relationships, matching, shape recognition, sorting...

You know the project books we make—well I realised that they are full of mathematical situations—we just need to make it more obvious.

As well as becoming more alert themselves in making mathematics more visible in the programme, the participants began to notice an increase in the children's awareness of "things mathematical". Reflections from the participants included:

We have noticed recently that the children are using more maths concepts in more curriculum areas. It appears they have developed a more resourceful approach and are picking up on our excitement and passion for maths. It could be that they are becoming more confident and competent in these concepts.

We have noticed that the children are scaffolding other children's learning through more probing questioning, instead of doing it for others. They are using language and encouragement as a teacher does. For example: one child was doing a puzzle and was

finding it difficult to complete. Another child suggested she look at the shape, size, colour etc of the space and the surrounding pieces.

However, despite these positive recollections, these participants kept returning to the belief that they “could do more” to support children’s mathematical development.

Whānau/parent involvement in their children’s mathematical learning

There was strong agreement that no learning in early childhood should be investigated without considering the input from whānau/parents. The participants described how they valued the involvement and participation of the whānau/parent community at Don Buck Kindergarten, and they made plans to better value the contributions that whānau/parents can make to children’s mathematical learning. The following dialogue describes the participants’ relationship with the children’s whānau/parents:

Partnership is very important to us. We work very hard at our partnership that is an en-dash and if we are looking at what the children need (mathematically), we need to look further than the kindergarten environment, we need to look holistically.

Holistically I would say that parents need to be involved anyway but to maximise it (children’s mathematical learning) we need to get parents’ support. If they become enthusiastic they can enhance it so much. I wonder if we could do some parent education in maths?

But how to get parents involved? One solution would be to put a notice at the door saying we are putting out a questionnaire. How could we look a parents’ knowledge base? Because that’s what affects the child’s disposition, what the parent currently knows [about mathematics] and how it appears in the home.

Yes, I think the parents and the home background very much influences the disposition the children have towards mathematics.

In considering this aspect of maximising children’s mathematical learning, the participants decided that they would seek to better understand the mathematical knowledge and experiences that whānau/parents shared with their children, and to improve the mathematical partnership between themselves and their community of whānau/families.

Intervention—planning and monitoring new practices

The focus of the third facilitated session (May 2005) was for the participants to design an intervention plan. However, one of the participants (half the teaching team) had recently resigned, and the head teacher was running the programme at Don Buck Kindergarten with a reliever. A permanent appointment had not been made, but the interview process was well under way. Therefore, although the head teacher was alone in deciding on the intervention plan, she was aware of the mathematics calibre of the possible successful applicant and was certain that Don Buck Kindergarten could continue its commitment to the research project. After reporting on

progress related to the dimensions of the problem, she was convinced that these dimensions were still most appropriate for the focus of the research:

- teacher knowledge and disposition;
- the programme; and
- whānau/parents.

Discussion centred on teacher competency and confidence, as this had been a high priority for the participants from the beginning of the project. The head teacher reflected on the increase in mathematical knowledge that she had acquired through the reconnaissance phase of the project. The following examples illustrate the confidence with which she declared her current disposition towards mathematics teaching and learning:

When we last met we were talking about the opportunities (for mathematics learning) that were missed because we lacked the confidence to maximise them. I think my competency in the last few weeks has grown so much because I am prepared to take a risk now. I can now understand the (mathematics) concepts and use mathematical language. I have to understand it before I can be competent, and I have to know I am competent and therefore feel confident.

Discussion now centred on the appointment of a permanent teacher because, even if an early appointment was made, the head teacher was concerned that there might be quite a time gap before the successful applicant would be able to take up the position. She pondered the situation thus:

We'll need some plan for involving relievers in some way. It might be a long time before we can fill the position so we'll have to think of strategies. Anyway we'll still have to think of ways we can initiate a new permanent teacher into the project at this stage of the year.

The intervention phase would begin with improving the methods by which whānau/parents were informed about the prominence of mathematics at Don Buck Kindergarten, and culminate in a parent–teacher mathematics workshop to be held later in the year. The rationale for implementing a mathematics workshop grew from two perspectives: the enthusiasm of the head teacher to share the children's mathematical thinking and learning with the whānau/parents; and her prior knowledge that the whānau/parent community rated mathematics, along with literacy, a current priority for their children. The head teacher anticipated:

I know they'll come because of the focus on numeracy and literacy that's everywhere these days. They recognise the significance of maths for their children.

The head teacher devised a formal plan for the intervention (Table 3), taking into consideration that during the intervention phase a new permanent teacher appointment would be made.

An exciting brainstorming session established that during the design and preparation of the workshop, the teaching team would necessarily address all the other dimensions of the original research problem. A multitude of details were covered as the planning of the workshop developed. An evening during term 3 was tentatively decided upon, avoiding the term breaks,

coinciding with the start of daylight saving and warmer weather, and acknowledging that the majority of the parents were at work during the day. At its next meeting (late May 2005), the Don Buck Kindergarten committee would be informed as a matter of course, and the planning of the workshop would be shared with committee members. This was an example of the collaboration between the participants and the whānau/parent community at this kindergarten: the first action in their intervention plan was to collaborate over the date and content of any combined event.

Table 3 **Intervention plan: Don Buck Kindergarten**

GOAL Parents to be involved in the mathematics project				
OBJECTIVES	OUTCOMES	ACTIONS	RESOURCES & BUDGET	DATE
To plan and implement a mathematics workshop for parents/whanau	Parents to become more informed about children's mathematical learning	Fix a date for workshop	K and committee	27/05/05 (probably late September not in term break)
	Strengthening of partnerships at our kindergarten between teachers and parents/whanau	Order AKA pamphlets	K	
		Use committee meeting on 27 May to start planning with parents	K and committee	27/05/05
	Parents to develop skills in recognising potential for mathematical thinking	Organise a keynote speaker	K and M	
		Start gathering evidence of the work children have been doing related to project	K and team	ongoing
		Gather readings relevant for parents	K and team	ongoing
		Develop a handbook for parents on mathematical language	K and team	ongoing
		Develop a handout for the workshop	K and team	
		Arrange a series of hands-on table experiences to follow presentation to allow for parent interaction	K, team and guest	
		Plan the workshop content and organisation (inc. supper)	K, team and committee	

Monitoring the intervention

Through June and July 2005, the teaching team at Don Buck Kindergarten continued to focus on improving their ability to provide richer mathematics learning experiences for the children. As

well as addressing the intentions of their intervention plan, they implemented ideas that had developed as a result of the data collected during the reconnaissance phase. By now a new permanent appointment had been made. The new teacher displayed a keen interest in mathematics teaching and learning and was soon influenced by the head teacher's enthusiasm, and determination to continue with their successful piece of mathematics research. An early reflection on her role at Don Buck Kindergarten illustrated the mathematical richness of the programme, and the mathematical confidence of the children. She identifies the effectiveness of positive mathematics experiences in the early years, as she concludes her reflection:

I believe there is a real maths focus at Don Buck Kindergarten and I really enjoy that attitude of having fun with maths and how it is so meaningful to the children in their everyday life. Maths is fun to learn and if children gain that attitude during their early years they will benefit for the rest of their life.

The researcher-facilitator was available through email or telephone contact as requested by the teaching team. Additionally, two informal meetings were held, one to introduce the researcher-facilitator to the new participant and the other to respond to the participants' request for guidance in the preparation of the parent-teacher workshop.

The head teacher capitalised on having the new teacher participate in the project, and used the new partnership as a means of summarising the research so far. As well as engaging in long-term preparation for the workshop, discussion at the two informal meetings allowed the head teacher to monitor the actions related to the original dimensions of the research problem at Don Buck Kindergarten: teacher knowledge and disposition; the provision of a mathematically rich programme; and whānau/parent involvement in their children's mathematical learning.

The participants further developed their partially prepared audit data into a list that linked mathematics concepts and curriculum areas/areas of play (for a partially completed working copy see Image 8).

	Volume (Measurement)	Pattern (Algebra)	Shape (Geometry)	Quantity (Number)	Size (Measurement)	Sequencing (Algebra)	Matching (Number)	Pos Relationships (Geometry)	Number (Number)	Sets (Number)	Problem solving (Maths)	Working theories (logic & reasoning)	Predicting
✓ Music		✓	✓					✓	✓				✓
✓ Drama		✓	✓	✓	✓	✓	✓	✓	✓	✓			
✓ Family		✓	✓	✓	✓	✓	✓	✓	✓				
✓ Books		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
✓ Puzzles		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
✓ Art		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
✓ Blocks	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
✓ Water	✓			✓	✓	✓	✓		✓	✓	✓	✓	✓
✓ Gross motor		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
✓ Natural Environment	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
✓ Maths games		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
✓ Manipulatives		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
✓ Gardens		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
✓ Sand	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
✓ Swings					✓	✓	✓	✓	✓	✓			
✓ Writing		✓	✓	✓	✓	✓	✓	✓	✓	✓			
✓ Playdough	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
✓ Science	✓		✓		✓	✓	✓	✓	✓	✓			

Image 8: Audit list of the mathematical potential around the kindergarten

Participant-initiated communication with the researcher-facilitator to check for mathematical accuracy convinced the participants that they were “on the right track”. Two developments from this audit list emerged: the preparation of “mathematics posters” for display in the curriculum areas at the kindergarten; and a brochure, listing opportunities for mathematical experiences in the home and community. Planning of the brochure led one participant to suggest:

What about we have a focus strand per fortnight or week. The focus could go into a newsletter informing families. Children could get excited about this focus, talking about it at home, thus involving parents as we make it.

While the brochure was produced with the mathematics workshop in mind, the very attractive laminated posters were gradually displayed prominently at appropriate locations around the kindergarten, with the intention of interesting whānau/parents in the mathematical potential in each area. The mathematics posters proved very useful for the whānau/parents, informing them of the vast amount of mathematical possibilities available for children to engage in mathematical thinking across the total kindergarten programme.

The new teacher-participant already had a high personal level of knowledge of mathematics content *per se*, but being relatively new to early childhood teaching, she was keen to further her knowledge and experience in the teaching of mathematics in a kindergarten. She contributed a comment frequently shared by beginning teachers:

In order to teach you need to know it, in order to pass it on.

The head teacher gave her support by recommending that the new participant use the work already undertaken together:

We've done the checklist of all the curriculum area. It's now redesigned as a chart. So all you need to do now is go back to it. Explore the new maths games. Help me finish the project book, it's nearly ready to read through. Take a look at the documentation of the gardening and the voting system.

This advice, together with the head teacher's increased positive disposition towards mathematics and her improved personal mathematics knowledge, was to further advise the new participant:

It is all here, we have been doing this all year. We didn't know it all either, but now I know that if you have a certain amount of knowledge, with a positive disposition you can use the knowledge that you have got.

The head teacher suggested methods for the new participant to move swiftly into the research project while still working within the normal pattern of a kindergarten programme:

... gathering learning stories, looking for all the mathematics that is appearing through those; taking photos of anything you see that is mathematical; and documenting incidental conversations/statements that indicate mathematical thinking (for example the mandarin segments)

One pathway into the research project for the new participant was to assist in the organisation of previously collected data. The head teacher encouraged her participation with:

I couldn't do much of this because I was on my own; now that we have you it's great taking time together during the week to organise all the stuff we will be using. There is a lot of evidence on the computer that needs to be sorted too.

Together the participants continued to strengthen the partnership between themselves and the whānau/parents. They developed the ideas they had proposed for working together with whānau/parents to maximise a variety of mathematical learning experiences for the children at Don Buck Kindergarten. They checked the ongoing addition of the mathematically-specific resources that were being introduced gradually into the environment and ensured that these were displayed prominently around the kindergarten. As well as the display of the mathematics posters (see Image 9) listing the mathematics potential of all the curriculum areas, they monitored the:

- new mathematics games and resources;
- project books displaying the kindergarten's mathematical journey during the research, throughout a variety of projects;
- photographic displays, documenting snapshots of children thinking mathematically; and
- parent voice, as it appeared in the feedback to the learning story observations.

These resources were designed to be multi-functional: first and foremost the participants hoped that the attractive presentation of the resources would engage the interest of the whānau/parents;

secondly that the resources gave the whānau/parents visual evidence of the children being mathematically active. The head teacher commented:

I want parents to see that while their children are at play they are actually learning, about maths, about problem solving, about social interaction.

They also wanted the resources to inform the whānau/parents of mathematical experiences they could share with their children away from the centre, in the community or at home.

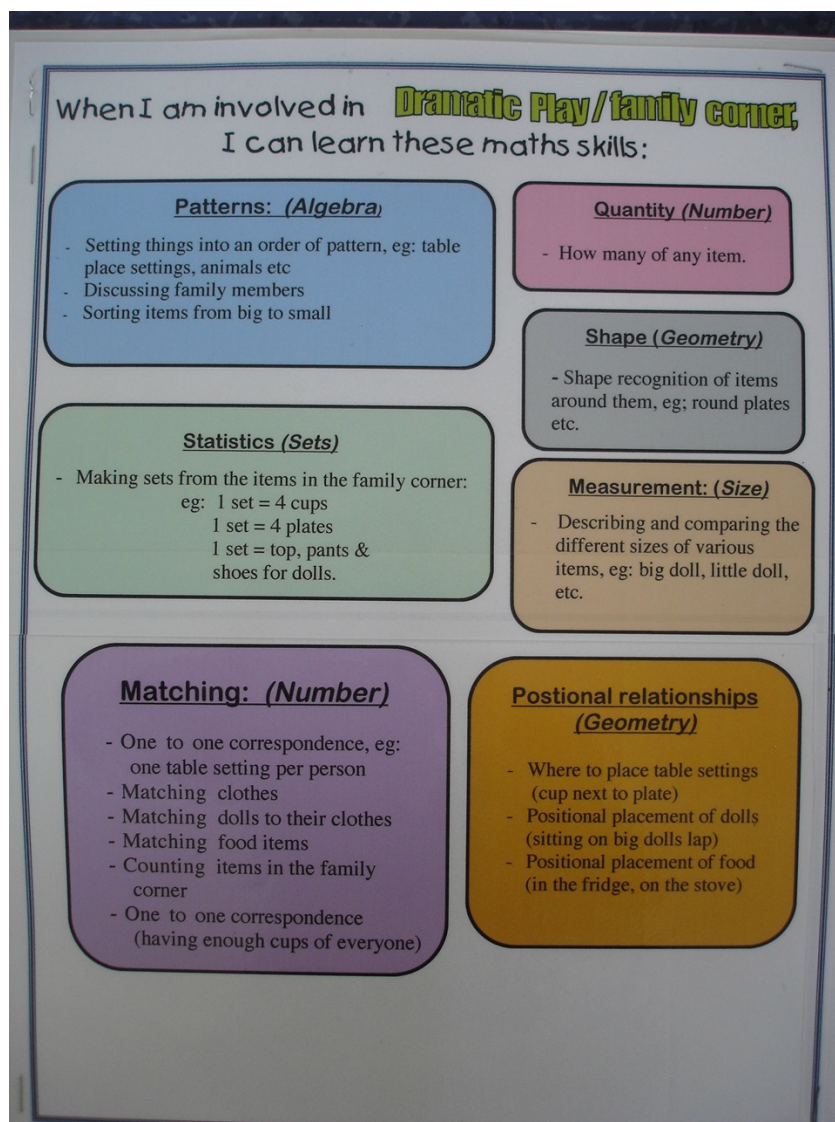


Image 9: Example of a mathematics poster in a curriculum area

Monitoring the resources took place through reflection and collection of evidence; the following reflection from one of the participants illustrated the effectiveness of the new mathematics games:

As educators we want to provide quality education for the children and therefore we need quality resources, which help the children to learn new concepts and to challenge their thinking. The new games are giving the children opportunities to learn turn-taking, but they are also developing their memorising skills, increasing their mathematical language and lots of mathematics concepts.

The value of a project book was described by the other participant, as she reflected on the production of the particular book that documented the children's participation in the re-planting of a vegetable garden:

At Don Buck Kindergarten we base our programme on the emerging interests of the children. We work to a project approach whereby collaborative investigation takes place, based on these emerging interests. These investigations are published in a "project book" that tells the story of the learning that took place. At the time of the research we were replanting our vegetable garden ... and this provided many opportunities to include mathematical learning. ... It became very obvious to us as educators how easy it is to weave mathematical learning opportunities within the programme. ... The project book provides a living record of this process. Children have constant access to this book providing them with opportunities to revisit their learning ... and to increase the complexity in their understanding of mathematical concept.

The project book was also constantly available to whānau/families. This kept them fully informed of the mathematical learning taking place for their children and allowed them an opportunity to be involved, working collaboratively with the child and the teachers. Through this collaborative approach, whānau/parent knowledge increased and they were more willing to become involved. The participants were thrilled to notice how one child had revisited the vegetable project when reading through the project book for herself, and demonstrated her learning. One participant commented:

Today a child came to me with a camellia bud in her hand. She told me she was going to see how many days it took for the bud to develop into a flower. To document this she drew her own graph.

While the resources for use in the kindergarten were being completed, the participants continued to plan and prepare for the mathematics workshop. They arranged a second informal meeting with the researcher-facilitator to affirm their planning. They presented their plans for the content of the workshop and brainstormed the resources required: for their own use; for the whānau/parents' interactive experiences; and as handouts for the whānau/parents. The workshop took place at the kindergarten on Thursday 27 October 2005 and aimed to:

- empower whānau/parents by helping them to recognise that mathematics is an easy thing to be involved in on a daily basis; and
- showcase for whānau/parents what the kindergarten teachers had achieved in the action research project, including some new resources.

Evaluation

According to the research schedule, the purpose of the final site-based meeting in early August 2005 was to formally evaluate the intervention strategies. However, as the intervention phase at Don Buck Kindergarten would be continuing until the delivery of the mathematics workshop in October, only a partial evaluation occurred at this meeting. Therefore, for Don Buck Kindergarten, the evaluation continued at the final cluster meeting of the project held in November. The evaluation phase had two key objectives to:

- set some criteria by which the teaching team could measure the effectiveness of their mathematics workshop and the lead into it; and
- explore how to use the evidence collected to ensure sustainability of the increased mathematical activity at the kindergarten.

Interim reflection; moving towards the evaluation phase

So, bearing in mind that the parent-teacher workshop had not yet taken place, this section describes the final preparation and build-up to the major event of the intervention phase, focusing on the preparation of the resources.

Further monitoring showed that the resources for display in the kindergarten were nearly completed. As the participants focused their attention on further planning and preparation for the mathematics workshop, discussion revealed that the overall outcome for the workshop was that it would generate informed interest and support from the whānau/parents towards their children's mathematical learning. The participants intended to present the whānau/parents with a package of readings to supplement the content of the workshop. Already two reader-friendly articles were planned, together with the brochure that had developed from the original mathematics audit of the curriculum areas/areas of play. As they finalised the production of the brochure entitled *Doing it together: Mathematics* one participant described their intentions as:

Where we are headed with the brochure is to give the whānau/parents suggestions for how they can support their children at maths. We've divided it under the five strands of the school maths curriculum and we've listed first the maths understandings under each strand and then listed suggestions about "doing maths" in everyday situations with your child. It's mathematical awareness really, and how you can put it into practice, so easily.

The process of designing and compiling the brochure became a real mathematical learning experience for the participants themselves.

The participants at Don Buck Kindergarten had been identifying change throughout the intervention phase. The evaluation phase began with the teaching team revisiting their original problem, and its dimensions, to reflect on these changes. As one participant opened the discussion, dialogue continued:

At the very beginning we started off with teacher knowledge, and the environment.

And the parents?

Well the parents were on the outer really at that time. It's funny how they became the key.

And then we went a long way on the children, but we sort of lost them along the way.

Well they're not lost because all the change has been for their benefit.

And we didn't do all the things we thought we would—it just happened that not all our ideas came to fruition.

Although the intervention plan had not been completed, already at the August meeting the participants were able to evaluate the benefits of the research project. These included:

- being involved in discussions about mathematics;
- having opportunities for self-reflection on mathematics teaching;
- experiencing the growth in children's knowledge and dispositions towards mathematics;
- learning the action research process, and useful for future replication; and
- being funded to implement long-term plans for improved mathematical experiences.

The participants then brainstormed further data they should collect:

- parent questionnaires/feedback about the mathematics workshop;
- reflection about the effectiveness of the new resources;
- mathematics readings relevant for whānau/parents; and
- reflective data from themselves on the pathway of the mathematics research project book and its usefulness for whānau/parents.

End-point evaluation

In November 2005, with the intervention phase completed, the participants from Don Buck Kindergarten met again with their researcher-facilitator. They summarised their perceptions of effective changes to their practice related to mathematics teaching and learning. They presented their summary under the headings: teacher knowledge; the programme; and whānau/parent involvement.

Teacher knowledge—what we achieved

- sourcing relevant readings for personal improvement;
- making a library of mathematics education literature, containing both theory and ideas for practice;
- developing an extensive audit list of potential for mathematical learning across the curriculum areas;
- compiling a mathematics brochure for whānau/parents; and
- designing and manufacturing mathematics posters for the curriculum areas.

Overall the participants reflected that the integration of the readings they collected during the research, together with the resources they had made as a result of their increased knowledge, had certainly proved that increased subject knowledge was a bonus in enhancing children's mathematical learning.

The programme for teaching mathematics—what we achieved

- constantly reviewing the mathematics happenings within the programme;
- writing learning stories with a more defined mathematical focus;
- strengthening the “maths area” so that it is no longer an area where most of the mathematics happens but just a place where the specific “maths resources” live;
- displaying anecdotal photos which had more meaning mathematically; and
- producing project books which documented a stronger focus on children thinking mathematically.

The participants were far more confident in their engagement in both planned and spontaneous mathematical episodes and had acquired an increased awareness of the mathematical potential when planning for holistic learning experiences within the programme.

Whānau/parent involvement—what we achieved

- developing an increased confidence in discussing aspects of mathematical learning with the whānau/parents;
- explaining more clearly the children's mathematical thinking that was evident in the project books;
- selecting mathematical readings appropriate for distribution to whānau/parents;
- facilitating a successful mathematics workshop; and
- having the mathematical knowledge to analyse the whānau/parent feedback sheets on the workshop.

The participants agreed that their involvement in the project had increased their confidence in working with whānau/parents in the area of mathematics. They were able to respond to questions on the night of the workshop and they knew where to access information for further information sharing. Whānau/parent response to this workshop was most positive and encouraging for the participants. On the questionnaire/feedback sheet provided, one parent stated:

Very relevant and meaningful—thank you

The head teacher said, in retrospect:

Workshop facilitation was a new area for us, and challenged us substantially, however it proved to be a successful medium for further consideration when sharing information with families. It has always been something that we had moved away from due to our belief that it would not be successful.

Something we did learn too is that parents like an informal approach to sharing information, like books and readings, shared with them on a casual basis as they request it.

Overall, in keeping with the principles of the Aotearoa New Zealand early childhood curriculum, *Te Whāriki* (Ministry of Education, 1996), while the mathematics area at Don Buck Kindergarten has been strengthened, it is now complemented by the spread of mathematical opportunities across all curriculum areas/areas of play. As teachers, the participants are confident about the sustainability of both the level of mathematics education at the kindergarten, and of their continuation to adopt an action research model *per se*, for improvements in other aspects of their work.

Meta-analysis of the findings

The key findings of the project relate to the macro research question: What do the participant kindergarten teachers know and practice in relation to the teaching and learning of mathematics, and how can this be improved? These findings illustrate the extent to which:

- mathematics subject knowledge contributes to the development of a positive disposition towards mathematics for early childhood (kindergarten) teachers;
- mathematically focused teaching strategies enable early childhood (kindergarten) teachers to maximise opportunities for children's mathematical learning;
- pedagogical documentation enhances the teaching and learning of mathematics in early childhood;
- the distribution of children's work through documentation is an integral method for sharing children's mathematical thinking with whānau/parents; and
- an action research model allows early childhood teachers (kindergarten) to build on their existing knowledge base to research their mathematical practices.

The findings are organised according to their contribution to the strategic and practice values of the TLRI.

Discussion of the findings related to the strategic value of the TLRI

In keeping with the TLRI principle that research projects will address themes of strategic importance to education in Aotearoa New Zealand, this project sought in particular “to build teacher understanding of the strengths and weaknesses of current pedagogical practice related to mathematics”. During the reconnaissance phase, in all three settings the participants quickly came to the realisation that *they* needed to be the focus of learning and change, and were prepared to make a high commitment to learning. Their reflections included:

We've got to take a long hard look at ourselves, what we do and what we provide, before we move forward.

If we agree that we can't be effective mathematics teachers in this culture then it's a problem we can't change. That means we can't be a better maths teacher because of the barriers. I think we need to improve ourselves to get over these barriers.

If we don't see how the social factors are ever going to change then we have to look at ourselves. That could be the way to start to look at solutions.

Teachers' mathematical knowledge and disposition

By far the outstanding finding of the project was the realisation of the importance of teachers' own mathematical knowledge and their personal disposition towards mathematics, leading to the improved strategies for providing mathematically stimulating learning opportunities for children. Therefore the key findings discussed in this section are that:

mathematical knowledge contributes to the development of a positive disposition towards mathematics for early childhood (kindergarten) teachers; and

mathematically-focused teaching strategies enable early childhood (kindergarten) teachers to maximise opportunities for children's mathematical learning.

Fundamental to the effective teaching and learning of mathematics is the issue of teacher confidence, which in turn is related to teacher knowledge, and the notion of dispositions in pedagogy. In relation to this project, every participant defined teacher knowledge as subject knowledge related to mathematics, which could enable an early childhood teacher to confidently recognise and enrich children's mathematical experiences.

Teachers' knowledge of mathematics

Advantages of personal subject knowledge for early childhood teachers, and in particular in mathematics, is well-documented internationally (Anning & Edwards, 1999; Aubrey, 1994, cited in Pound, 1999; Baroody, 2004; Copple, 2004; Perry & Dockett, 2002). Perry and Dockett advise that to help children develop their mathematical ideas, it is a benefit if an early childhood teacher has a sound understanding of their own mathematics. Similarly, Copple states that for early childhood teachers, "unquestionably, teachers' knowledge and skill [in mathematics] are vital to educational effectiveness" (p. 86). In agreement with both, Baroody suggests early childhood teachers need a "deep understanding" of content knowledge of mathematics. Aubrey, cited in Pound claims that adults' subject knowledge plays a crucial role in their ability to provide explanations in helping children make connections. This was recognised by one participant who noted:

We can't ignore the teacher's ability.

Within Aotearoa New Zealand, a study by Hedges and Cullen (2005) found that "little attention has been paid to teachers' and children's subject knowledge" (p. 60). Then, possibly anticipating reactions to this statement from within the early childhood field, they report that the study revealed that an "increased focus on subject content learning is not incompatible with early childhood pedagogy and philosophy" (p. 77). In the study, although teachers held the belief that

subject knowledge was important, it appeared that teachers frequently missed opportunities to pick up on children's subject-specific cues, nor were they documenting subject-specific points of learning. This led Hedges and Cullen to assume that perhaps "Subject knowledge requires more explicit acknowledgement in early childhood education" (p. 72). The teachers participating in this TLRI project all undertook strategies early on to increase their personal knowledge of mathematics through the reading of relevant literature. In particular, the participants at Don Buck Kindergarten increased their "library" of mathematics education literature by researching beyond their usual sources of information.

Early childhood links to the New Zealand Curriculum Framework

All the participants in this project agreed that one source of information for increasing their mathematical knowledge was the national mathematics curriculum document, *Mathematics in the New Zealand curriculum* (Ministry of Education, 1992). One participant summed up the value she gained from the mathematics curriculum document with:

Although "doing" mathematics with children is enjoyable, a lack of content knowledge limits our ability to document the children's mathematical learning effectively e.g. our ability in communicating our understandings of e.g. geometry and algebra in ways that increase parent's knowledge of the mathematics that is happening in the kindergarten. We have become more familiar with the mathematics described in the Mathematics in the New Zealand Curriculum and are able to effectively use this document to enhance the mathematics teaching and learning in the kindergarten.

Although written for schools, for some years many early childhood teacher education programmes have been advocating the content sections of the document as a resource that provides a framework for recognising the mathematical potential across a variety of learning experiences within early childhood settings. Many of the participants in this project were familiar with the document but had not accessed it since their preservice/in-service teacher education studies. Those with experience of the document agreed that it had enabled them to improve both their subject knowledge and their confidence in supporting the learning of mathematics in early childhood.

Soon after the publication of the mathematics curriculum (Ministry of Education, 1992), Hill, in 1995, recognised that the document provided "an empowering framework [for early childhood mathematics] that was developmentally appropriate, child sensitive, interactive and flexible" (p. 3). It would, she claimed, "form an excellent, broad, but focused, basis for making the links between the experiences and beliefs of early childhood teachers and the meaningful mathematising of children's learning experiences" (p. 3). As there were ongoing concerns at the time in the early childhood community about a "push down curriculum", Hill advised that if the mathematics document was used in ways that were conducive to and supportive of early childhood philosophies and practices, it would provide a flexible but valid framework for early childhood mathematics. She was adamant that the use of the document in early childhood pre-service teacher education would enhance the teaching and learning of mathematics in early childhood. She believed it would counteract:

the incidence in early childhood centres of both ad hoc structured maths teaching, and the loose “maths is everywhere” approach will cease and early childhood mathematics will gain purpose and meaning, will be acknowledged by parents who need to see the long term perspective and will form a solid foundation for at least the next ten years of mathematics using the same framework! (p. 5)

Both Hill (1995) and Haynes (2000) emphasised how “empowering” it was for early childhood teachers to be able to make parallel connections between the two documents: the early childhood curriculum, *Te Whāriki* (Ministry of Education, 1996) and the national mathematics curriculum, *Mathematics in the New Zealand curriculum* (Ministry of Education, 1992), while Pound (1999) also reminds us that Menmuir and Adams (1997) claim “it is vital that early childhood specialism is equally valued alongside subject expertise” (p. 84). The participants at all three settings in this project found that it was possible to use their increased knowledge of mathematics without jeopardising their philosophical beliefs in providing for the holistic nature of children’s learning. As one participant stated:

I haven’t changed my basic way of working, it’s just that I’m more conscious of maths

Teachers’ positive disposition toward mathematics

Fundamental to the successful teaching and learning of mathematics is the need for teachers to have confidence in themselves when entering a mathematical domain; confidence that can be both domain-specific and dispositional. Pound (1999) suggests that an early years teacher’s lack of confidence in their own mathematical ability can be problematic for young children’s learning, and emphasises that a positive disposition towards “things mathematical” equips an early childhood teacher to enrich mathematical opportunities for children. In all three kindergartens, initially, some of the participants in this TLRI project claimed they held a negative, and sometimes fearful, disposition towards mathematics. Their anxiety about mathematics related clearly to their own past experiences in mathematics education. They showed courage in making comment such as:

For me personally, confidence with mathematics is an issue because I always found maths very hard when I was at school. It wasn’t my favourite subject ... it’s not my passion or something I would immediately choose to do.

Some years ago I was confronted with my mathematical disposition when I came across an early school report ... alongside number ... all I remember, is the word “poor”.

Participants agreed that through their participation in the project, they had experienced a change in their attitude and therefore in their ability to engage in mathematical experiences with children. They no longer felt inhibited in efforts to give mathematics a priority in their daily practice. At this stage in the project comments included:

Through this project I developed strategies to support my continuous growth in mathematical knowledge and teaching practices.

Later we began to identify children’s mathematical learning within different curriculum areas.

With the emphasis on numeracy in recent years, both the teaching community, through curriculum documents, and government agencies, through publicity in the media, have emphasised that the learning of mathematics should be enjoyable and even fun; for example, *Te Whāriki* (Ministry of Education, 1996) and *Feed the Mind* (Ministry of Education, 1999)). *Te Whāriki* goes as far as to say that children should develop “the expectation that numbers can amuse, delight, illuminate, inform, and excite” (p. 78). Maxwell (2001) discusses the relationship between enjoyment and emotions in terms of mathematics education. She describes how a model for the learning and teaching of mathematics designed by Nathan and McMurchy-Pilkington (1997) suggests “that the learners, the tasks and the teachers are held together by ‘constructive tensions’ where a change in one component shifts the equilibrium causing the other components to change” (p. 36). Maxwell points out, therefore, that teachers need to remain alert to changes in any one of these components in order to maintain the learners’ interest and curiosity, particularly focusing on themselves.

Carr (1997) claims that although dispositions are different from knowledge and skills, they can in fact be a product of knowledge and skills. Disposition can include for example: inclination; natural tendency; and temperament; that is, words which support the concept that disposition is a way of responding. Further to this Pound (1999) states that “Children’s dispositions to mathematics is also inextricably linked to (both) emotions and experiences” (p. 33). Although in these instances both Carr and Pound are speaking of dispositions in terms of young children, Pound states that it is the teacher’s responsibility then to ensure that they are confident enough in their own mathematical ability, pedagogically sound in their beliefs and hold positive dispositions towards mathematics themselves. In this way they can monitor children’s learning experiences successfully, aware of the balance between knowledge, skills, and dispositions, so that children are motivated to bring positive dispositions of their own towards their mathematical experiences. The participants in this project experienced an increase in their provision of mathematical learning experiences as their own positive dispositions towards mathematics strengthened. While initial comments included:

I need to look at my maths demons from years gone by and fight them head on, I hope to change my opinion of myself. I need to believe that I have the capability to create fun and rich mathematical experiences across the curriculum for our young students.

I need to believe that I have the capability to create fun and rich mathematical experiences across the curriculum for our young students.

Later in the project one participant realised:

Yes—the teaching dispositions go hand-in-hand with the children’s dispositions.

Planning the learning environment

The participants at all three kindergartens focused on the learning environment, albeit in different ways. After improving their personal mathematics knowledge and disposition, they began their interventions by engaging in “first order change”. This is change that attends to the conditions, structures, systems, and environment as a prelude to moving on to second order change. Engaging in second order change addresses more specifically the effectiveness of changed teaching

strategies by evaluating the effect of these on children's learning outcomes. In this research project, environmental change occurred after just the one cycle of action research.

The intervention plan for each kindergarten was unique to each setting, flowing from the heightened awareness of the status quo and relating to evidence-informed discussion. However, a feature shared by participants at all three kindergartens was their focus on planning for children's mathematical thinking and learning. Rinaldi (2006) writes of "two forms of thinking: convergent thinking, which tends towards repetition, and divergent thinking, which tends towards the reorganisation of the elements" (p. 117); that is, in the latter case, a process which includes much problem-solving and decision-making, incorporating that important element of learning the "right to change one's mind". This could be likened to Carr (2001) when she writes about "planning for difficulty" (p. 167). The participants all acknowledged that with their increased mathematical knowledge and positive disposition towards mathematics, they became more skilful in planning the environment to provide richer opportunities for children to engage in more open-ended mathematical experiences.

While retaining their beliefs in planning for holistic learning and development, some participants found that unless they deliberately and specifically included mathematics in their weekly and daily planning discussions, it could be overshadowed. For example, at one kindergarten this planning took the form of a thorough audit of the mathematical potential in the kindergarten, linking mathematics concepts and curriculum areas/areas of play to ensure the planning of a holistic coverage of learning experiences. The participants provided evidence of changed practice since they had given mathematics a priority in their planning, and this is reported on in the individual case studies. One participant commented:

The project provided a specific subject focus framework that we will be able to use, in our everyday planning and evaluation strategies, to explore other subjects or challenges.

Searching the official documents for teaching and learning strategies

This project found that the participants were only marginally aware of the way in which official documents provided a foundation in relation to the teaching and learning of mathematics. All the participants found it useful to both assemble and then analyse relevant documents. These included *Te Whāriki* (Ministry of Education, 1996), *Quality in Action* (Ministry of Education, 1998) and *Auckland Kindergarten Association Service Delivery Manual* (AKA, 2003). Across the kindergartens, this raised awareness of specific references to mathematics in key documents, and also highlighted what was not there. At one kindergarten this search for supportive mathematical references is summarised in the reflective statement of one participant:

Throughout the initial stages of this research project we were looking for mathematics-specific content within these documents—something that would provide us with a reference point from which to begin. However what we found was quite the opposite: all of these documents indirectly referenced maximising children's learning opportunities through the provision of the "curriculum". So does the "curriculum" in early childhood education include mathematics as a core subject?

Although initially disappointed to find little specifically related to the teaching and learning of mathematics, all the participants after analysis, understood the collective intent of these documents. Further reflection and familiarity with the documents confirmed their usefulness to participants. As one head teacher noted:

These documents meet their intended purpose of forming the foundation and extending the learning and development of children through quality education. It is clearly not their intention to provide subject-specific information.

Discussion of the findings related to the practice value of the TLRI

In keeping with the TLRI principle that research projects recognise “the central role of the teacher in learning”, this project sought in particular to demonstrate how teachers share children’s learning with a range of stakeholders, of particular benefit to learners, other teachers and whānau/parents. It was clear early on in the project that the participants in all three kindergartens wished to improve their sharing of the children’s mathematical thinking with the whānau/parents and the wider community. One participant summed up this goal:

We want to use this opportunity to work more closely with our whānau/parents and to share with them what maths their children are doing while at kindergarten.

Making mathematics visible through documentation

The participants focused, in particular, on making the teaching and learning of mathematics more visible in whatever documentation they produced as part of their every day practices. Therefore the key findings discussed in this section are that:

- pedagogical documentation enhances the teaching and learning of mathematics in early childhood; and
- the distribution of children’s work through documentation is an integral method for sharing children’s mathematical thinking with whānau/parents.

In all three kindergartens a number of strategies were employed to draw whānau/parent, and children’s, attention to mathematics in a highly visible way. Ways of reaching out and informing whānau/parents included a variety of forms of documentation. Examples of increased visibility of mathematics included:

- a mathematics display wall;
- a mathematics newsletter;
- a “Mathematics Parent Voice” sheet;
- mathematics inclusion in the weekly planning sheet;
- mathematical input into learning stories;
- a brochure outlining the scope of mathematical experiences in the kindergarten;
- inclusion of mathematical detail in daily reflections;

- highlighting of children’s mathematical thinking and action in the project books; and
- a parent–teacher mathematics workshop.

While evidence-based detail is reported in the individual case studies, an example of improvement is summed up by the head teacher from one kindergarten, commenting on the success of the addition of a new column for mathematics reflection in the *Daily Sheets*:

Then we write down what maths each teacher has observed in daily activities, then it is each teacher’s responsibility to follow up on that. So each teacher individually plans/thinks how we can go further with that activity? How can you expand what children are already doing?

Documentation in early childhood settings

Katz and Chard (1996, cited in MacNaughton & Williams, 1998) remind us that “documentation has been a practice used in many early childhood programmes for some time”. MacNaughton and Williams define documentation as:

... a process or event ... to gather and organise information about (something). Documenting something provides a written or pictorial record of what has occurred. As a teaching technique, documentation refers to gathering and organising information to provide a written or pictorial record of children’s learning. (p. 201)

In more recent years, it has been recognised by many early years writers (for example, Fler & Richardson, 2004; Gould & Pohio, 2006; Rinaldi, 2006) that teachers increase their competencies and their abilities to notice, recognise, and respond to children’s learning (Ministry of Education, 2004b) when they document the children’s work. Rinaldi explains how a teacher’s familiarity with “critical facts” (p. 72) enables them to focus on what is important in a child’s engagement in a particular situation, while Fler and Richardson write of teachers “mapping children’s cognitive competence” (p. 132), which again demands of teachers a certain level of specific subject knowledge. The participants in this project used documentation as part of a knowledge-building process of mathematics teaching and learning, and in turn, in keeping with Rinaldi, the documentation had the potential to impregnate and enhance the knowledge itself. The participants at one kindergarten emphasised:

We really want to use this[(documentation)] to raise awareness of the importance of mathematics activity in both the kindergarten and home environments

Gould and Pohio (2006) state how undertaking documentation can increase teachers’ ability to examine their own practices. For all the participants in this project, their documentation was driven by their intent to explore, and reflect on, the teaching and learning of mathematics in their particular setting. As reported on in the individual case studies, the participants all achieved their aim of using the documentation to contribute towards creating a culture of mathematics specific to their setting. Participants were excited to find that the simple act of making mathematics more visible through increased documentation had a positive effect across their programmes in general.

Pedagogical documentation

As a result of their focus on documentation *per se*, in all three kindergartens there was a marked increase in the use of what is increasingly understood as pedagogical documentation. The *Auckland Kindergarten Association Service Delivery Manual* (AKA, 2003) defined pedagogical documentation for the teachers as documentation that reveals to teachers, other adults, and children the processes of learning and teaching that are occurring. Similar definitions of pedagogical documentation are to be found in the writing of others (Carr, 2001; Gould & Pohio, 2006; Rinaldi, 2006).

As the project progressed, there was a marked increase in the use of pedagogical documentation in all kindergartens. The participants used various types of pedagogical documentation to emphasise the mathematical teaching and learning experiences, to accentuate children's mathematical competencies, and to assess "where to now". In the course of the interventions that took place, a key activity for participants in all three kindergartens was the pedagogical documentation that they produced for both children's individual and group mathematical experiences. Central to this documentation was the use of learning stories that emphasised the mathematics, displays that showcased children's mathematics experiences, and learning in the form of posters, wall displays, project books created by the teachers, children's learning portfolios, and planning/diary records.

In focusing on learning stories in particular, the participants were mindful of the relevance of Carr's design of the "learning story" in relation to mathematical engagement. Carr (2001) writes that, as learning stories developed from the traditional narrative type of observation, it became clear to those trialling them that they were "observations in everyday settings, designed to provide a cumulative series of qualitative 'snapshots' or written vignettes of individual children displaying one or more of the five target domains of learning disposition" (p. 96). The five domains of disposition are:

- taking an interest;
- being involved;
- persisting with difficulty or uncertainty;
- expressing an idea or a feeling; and
- taking responsibility.

Recalling that initially they, themselves, had expressed low dispositional feelings towards mathematics, the participants believed that an increase in their learning stories would not only highlight the engagement of a child in mathematical thinking and activity, but also the dispositions displayed during that engagement.

Despite the increased focus on mathematics teaching and learning during the project, the participants' beliefs in a holistic learning environment remained firmly grounded in the principles of *Te Whāriki* (Ministry of Education, 1996). Accordingly, their determination to improve their learning story documentation was in keeping with Gould and Pohio (2006), who describe the

value of learning stories as “one way that early childhood teachers in New Zealand address the principles in *Te Whāriki*” (p. 85) in their practice.

The participants at all three kindergartens provided evidence of a heightened use of such documentation and their plans to sustain this focus and details are to be found in the individual case studies.

Documentation as a means of collaboration between whānau/parents and teachers

One of the first aims of the project for all the participants was to develop a shared understanding of mathematics teaching and learning in their kindergarten, in the hope that this would enable parents to participate in the learning and teaching of mathematics in ways that were meaningful to the particular setting. Collaboration with whānau/parents, often referred to as “partnership with parents”, is a recognised strength of early childhood education (Billman, Geddes & Hedges, 2005; Grey & Horgan, 2003; Keesing-Styles, 2000). However, as Grey and Horgan point out, “[Although] partnership with parents is a phrase that has become part of the professional dialogue of early childhood education ... the concept of partnerships is rarely discussed and debated amongst early childhood practitioners” (p. 259). Furthermore Fleet, Patterson and Robertson (2006) describe how the transformation to a collaborative relationship can be challenging for both teachers and whānau/parents. In citing Arthur, Beecher, Death, Dockett, and Farmer (2005, p. 42), they emphasise the importance of recognising that “not all families have positive attitudes towards or trust educational settings” (p. 356).

Nevertheless, Fleet, Patterson and Robertson (2006) claim that “the use of pedagogical documentation in early childhood services can promote stronger relationships between educators and families” (p. 355), and strengthen their claim by quoting Katz (1998):

... documentation makes it possible for parents to become acutely aware of their children’s experiences in the school. ...The enthusiasm of the children and the interest of parents in children’s work helps to strengthen the involvement of parents in the children’s learning, provides a basis for parent-child discussion, and deepens parents’ understanding of the nature of learning in the early years. (p. 39)

As stated earlier, the participants at all three kindergartens used a variety of ways of reaching out to the whānau/parents to involve them in their child’s mathematical learning, and on the whole all were pleased with the outcomes. However, participants in all three kindergartens expressed varying levels of concern at what they perceived to be barriers to collaboration by their whānau/parent communities. They indicated that although they made mathematics visible in their own planning and documentation practices, there was only a small increase in whānau/parent contribution to their children’s mathematical learning. For example, the participants at one kindergarten were aware of the busy nature of their whānau/families’ lives and acknowledged that in order to aim for a more robust two-way collaboration between themselves and their community they would need to “seek negotiated solutions as a positive start to their concern” (Keesing-Styles, 2000, p. 6).

The participants at the other two kindergartens found that socioeconomic and socioethnic conditions in kindergartens often created barriers to the achievement of their aspirations to improve aspects of teaching and learning and these are reported on in their case studies. In the case of one kindergarten the socioethnic mix of whānau/families precluded their direct involvement in assisting with teaching. At this kindergarten, participants summarised this condition as:

Its social factors, the transient nature of the population, our ethnic diversity and the language barriers especially for new immigrants. So there are limitations to whānau/parent involvement in assisting with teaching. And we have to remember that some children's ethnic-related dispositions that might not fit our beliefs about mathematics learning—for example taking initiative to explore.

At the start of the project the participants at another kindergarten, expressing their current disappointment in involving their whānau/parents, stated:

There seems to be a different understanding of expectations between us and our whānau/parents. Many of them seem unaware of the importance of kindergarten (or any early childhood centre) as a base for learning—let alone the possible mathematics learning that happens in these early years.

Fleet, Patterson and Robertson (2006) remind teachers that “It takes time, sensitivity and an appreciation of the diversity of families, to create spaces where parents and staff reach a level of engagement that is comfortable for all” (p. 356). Similarly, Kinney (2005), describing a project which focused on teachers consulting with children to include the “small voices” (p. 111) in their programme planning, report that the effect on parents was initially one of caution. However, as the project progressed, the families “became more involved with the work of the centres” (p. 120). Of particular relevance for the migrant population of one kindergarten in the project are the words of a teacher, quoted in Connerton and Patterson (2006), reflecting on her efforts to develop sound collaborative relationships with the parents at her early childhood centre:

The issue I faced was that I was documenting for many parents who didn't speak English as a first language. That was very tricky for me, and I've tended to use shorter pieces and make effective use of photographs (p. 110).

Throughout the project all the participants were adamant in their belief that they and their whānau/parents had “complementary skills, knowledge and experiences to contribute to the child/ren's learning” (Martin, 2006, p. 19), and this remained at the forefront of their journey. Therefore, in keeping with Fleet, Patterson and Robertson (2006) who again remind teachers that they should accept that not all families will engage with documentation in the same way, the participants in all three kindergartens varied their styles of documentation to fit the communicative processes best suited to their communities. They found that making mathematics a central facet of learning, and making this visible in their documentation, not only increased their ability to keep it to the forefront of their own thinking and planning, but consequently did raise both child and whānau/parent awareness and involvement.

Summarising the findings: action research as a model for improving the teaching and learning of mathematics

In summary, this research project developed a research environment where researchers and kindergarten teachers could work together to explore the means by which mathematical outcomes for children could be maximised and relates to the final key finding of the project:

An action research model allows early childhood teachers (kindergarten) to build on their existing knowledge base to research their mathematical practices.

Using a collaborative action research approach enabled researchers and teachers to engage in a meaningful research project that ensured the teacher's perspectives were visible, and that their abilities to make a valuable contribution to the research understandings of early childhood mathematics in Aotearoa New Zealand was recognised. There is sufficient evidence to suggest the research project strengthened the teachers' interest and involvement in the learning and teaching of mathematics in early childhood, and consequently, had an effect on their practices and, and in two of the kindergartens in particular, on the involvement of the community.

The research project provided a framework whereby the teachers could investigate their capabilities, current knowledge and practice in the area of mathematics and ways of increasing this knowledge. It enabled them to undertake research and encouraged them to examine a significant issue that they identified as compromising the effectiveness of the teaching and learning of mathematics in their specific setting. The research project enabled them to use their findings to effect action designed to enhance the mathematical learning experiences for the children. Such improved mathematical outcomes would have the potential to benefit the wider community. The research project provided opportunities for teachers to involve the whānau/families in their children's mathematical thinking. It identified ways that whānau/parents could be involved in exciting mathematical experiences in the home environment. The benefits of shared mathematical experiences within whānau/family settings were evident in the recent literacy and numeracy campaign (Ministry of Education, 1999).

In seeking ways to investigate the enhancement of children's mathematical learning and development, the research was underpinned by the principles of *Te Whāriki* (Ministry of Education, 1996). Haynes (2000) had identified that it was important to the early childhood sector that the teaching and learning of mathematics in early childhood settings remain firmly within the expected philosophical domain of Aotearoa New Zealand early childhood education. The teachers were adamant that their participation in the project be consistent with the philosophical and pedagogical practices of their setting. Thus this project enabled the teachers to increase their understanding of their own processes of teaching and learning and to view them from a mathematical perspective. This enabled them to identify for themselves mathematical gaps in their own knowledge and to create forward-looking strategies for future possibilities in their teaching and learning of mathematics.

In all three kindergartens, the action research model, of reconnaissance, intervention, and evaluation gave the teachers a suitable framework for focusing on firstly, their own knowledge of,

and disposition towards, mathematics and secondly, managing and enhancing the mathematical learning environment. There is evidence to suggest that teachers increased their competencies and their abilities to recognise and respond to children's engagement in experiences in ways that could be identified as being mathematical. The model allowed them time to make the teaching and learning of mathematics more visible in whatever documentation they produced as part of their everyday practices. They used documentation as part of a knowledge-building process of mathematics teaching and learning and developed strategies to document their practices in ways that would inform whānau/families and the community, and would enable whānau/families to participate in the learning and teaching of mathematics in ways that were meaningful to the particular kindergarten setting.

Overall, they achieved their key objectives of making mathematics more visible in their kindergartens and, borrowing words from Gould and Pohio (2005), they:

made public the mathematical work of the children and their teachers. This enabled them to reify the importance of the mathematical work that occurred there as well as the practices and values of the kindergarten. By making this work public it invited reflection on the purpose, values and direction of the mathematical work of both children and teachers. (p. 83)

Final words from the teachers

At the conclusion of the project, from the teachers whose research this was, their overall impressions of participating in the action research process were summed up in the following statements.

The head teacher of Avondale Kindergarten said:

I think the main thing is that the teachers have agreed to a main focus on mathematics and the planning and evaluation of mathematics is now embedded in our system, so everyone is getting a regular reminder to focus on mathematics. It's great to have been involved in this research because it has taught me so much and I hope that one day the understandings we have gained will be part of the early childhood diploma course [i.e., having a daily focus and putting in systems to keep that focus going]. And yes, I would certainly want to be involved in practitioner research again because it has been better than any other professional development.

The teachers at Birdwood Kindergarten had this to say:

The unique opportunity of being part of an action research project gave added value to our roles as early childhood teachers. We have appreciated the opportunity to work alongside others who work within the broader field of early childhood education. Our goal to make mathematics obvious and highly visible to our community was certainly achieved. In the early and middle stages of the project we set out to display our core curriculum—the planned mathematical experiences—to share with parents the mathematical learning and teaching in the kindergarten. Later we began to identify children's mathematical learning within different curriculum areas. On reflection a stronger focus on this emergent

curriculum was needed as this is a very much part of kindergarten philosophy. We will keep this in mind in the future. The steps we took such as identifying a challenge, gathering data, identifying and implementing change strategies will be useful in reviewing the curriculum, the environment and teaching practices—we have already had an opportunity to use these steps to review another curriculum area. Being involved in this action research project has taught us to take time to identify a problem and not expect to rush this part of the process. Working with the researcher was extremely helpful. It ensured that we were guided through the project and that we stayed on task without anxiety, confusion or unmanageable pressure. Taking part in this important and worthwhile action research project has been part of our educational journey, a journey that has helped us grow both personally and professionally and will definitely continue beyond the end of the project.

And the head teacher at Don Buck Kindergarten contributed the following comment.

For quite some time I have aspired to being involved in a research project that supported the journey towards best practice. My involvement in this project not only challenged me to achieve this goal but had further benefits far beyond anything I had conceived. Mathematics is an area that I am particularly passionate about however was not feeling very confident in. Through this project I developed strategies to support my continuous growth in mathematical knowledge and teaching practices. This involved substantial in-depth reflection, using multimedia to research documentation that provoked thought for further reflection or supported current thinking. Our current review procedures now represent this more in depth reflective approach and are now supported by evidence (something we learnt is essential through the research process). The most unexpected reward from my involvement in this project is the deeper, more supportive relationships I have developed with my colleagues. The other two head teachers involved were known to me but we had never had the opportunity to really get to know one another. This has changed now as we share knowledge and information, supporting one another wherever we can. This is often the last thing that we work on, as our teaching lives have become so hectic, but is essential as we all work towards best practice. Finally, would I do it again? I haven't finished. The journey is just beginning and will never really end.

4. Limitations of the project and possible directions for future research

The limitations faced during the project were two-fold: for the teachers, the constraints of full participation in research without interference in “teachers’ work”; for the researchers, the need for consistency whilst retaining the autonomy of each site. However these were not barriers that impeded the research, but merely hurdles that needed thought, discussion and collaboration in order to be overcome.

The kindergarten teacher as researcher

Common to all three kindergartens was the issue of work conditions while participating in the project. All participants are to be praised for their total commitment to the project; this commitment meant they did not allow issues of time allocation and staff changes to interfere with their goals and aspirations to change their practice so they could improve mathematical outcomes for children.

The limitations are detailed below, followed by recommendations for future research, including some considerations for the TLRI.

Time commitment for practitioners

Time for research must be considered a growing issue in education; in particular, the proliferation of partnered research within early childhood education settings and the day-to-day practicalities of finding time for research is one of the challenges identified by Goodfellow and Hedges (2007). The teachers in this project used a variety of strategies for making “time for research”. Much of their “research” was in alignment with their regular work: planning and preparation of the learning environment; working alongside children; and observing, assessing, and documenting children’s learning. Additionally, they needed to be diligent in organising release-time and in using that time profitably towards the project. All the teachers are to be commended for their application to management of their time.

Focus on mathematics within early childhood settings

A possible limitation of this project might have been its concentrated focus on mathematics, with the potential to distract the teachers from their creation of a holistic learning environment,

contrary to the principles of *Te Whāriki* (Ministry of Education, 1996) and the Desirable Objectives and Practices (Ministry of Education, 1998). However, the teachers maintained their normal strategies and procedures throughout the project.

Changes in personnel in collaborative early childhood teaching

While one kindergarten in the project had staff stability, the other two were challenged by staff changes. Although there were no changes to the head teacher position, both these kindergartens ended the project with new but permanent teaching teams, after having relief teachers involved along the way—one kindergarten more than the other. The challenge for the head teacher in each case was to sustain the impetus of the project during times of staffing changes, and this was accomplished successfully in both cases. The staffing changes during the project highlighted the need to consider this aspect when planning partnered research that involves teachers. This is particularly important in early childhood centres where there is collaborative teaching across one learning environment.

Early childhood teachers' own perceptions of limitations

Teachers listed the issues that they perceived had, at time, limited their ability to participate in the project. These included some of the issues discussed above, but also included general workload issues; personal expectations of themselves to be successful as both a teacher and a researcher; the high turnover rate of whānau/families in one kindergarten in particular; the management of research funding; and the ongoing commitment to the expectations of the AKA.

Researchers maintaining consistency

For the researchers, it was important to ensure that they provided consistent facilitation. The strategies used by the three researchers (one researcher for each site) included the use of a clear framework for facilitation and a set of documents for both themselves and teachers to record thoughts and actions; all three researchers visiting the same site meeting and then two researchers moving to their own sites within a few days; and frequent meetings to share progress and findings.

Recommendations for future work and for the TLRI

Although the research project was limited to three teaching teams, and was contained within the parameters of one action research cycle (reconnaissance, intervention, and evaluation), it produced a considerable body of documentation that throws light on the experiences and challenges that confront early childhood teachers in their efforts to work towards a dynamic culture of early childhood mathematics, specific to their community context. Although this one

cycle provided an evaluative snapshot of the changes that took place in these three unique settings, further research would establish ongoing effectiveness.

Children's mathematical outcomes

There is a growing appreciation in the early childhood sector of how whānau/families' cultural values and aspirations can contribute to the teaching and learning of mathematics and how developing a collaborative "community of learners" approach could result in improved mathematical learning outcomes for children. The research opened up this type of discussion, but further research is needed to establish evidence of changed outcomes for children. This research needs to involve all parties in this type of collaborative relationship (the whānau/families, the teachers, and the new entrant teachers) in order to establish an effective approach to enhancing the teaching and learning of mathematics in early childhood.

Moving beyond first order change

Although each kindergarten focused successfully on changing its teaching and learning environment, with each developing its own culture of mathematics, they were unable to proceed beyond this superficial change within the limited scope of one cycle of action research. Mathematics has been identified as a key competency in *Kei Tua o te Pae*, the early childhood exemplars (Ministry of Education, 2004b), yet this research project highlights the complexities that confront early childhood teachers and that often hinder their ability to integrate a robust curriculum of mathematics into their teaching and learning environment. This is particularly pertinent in settings where there are high levels of changes to the teaching team or in communities with a high transient population. Further research over a longer period of time than this research project is needed to ascertain the long-term effect and outcomes on the mathematics teaching and learning if early childhood teachers are to get beyond what is referred to as first order change.

Pedagogical documentation and children's voices

While much is written about pedagogical documentation, further research is needed to explore how teachers understand and practise pedagogical documentation and its processes, and how it can be strengthened to provide valuable assessments of the teaching and learning of mathematics in ways that enhance or increase children's mathematical competencies. An integral aspect of the research could be the inclusion of those important stakeholders in the teaching and learning environment: the children. Further research is needed to investigate how consultation with, and inclusion of the voices of, children can contribute to our knowledge of mathematical teaching and learning in early childhood. Further research is also needed to ascertain the dominant theories and ideas that influence the mathematical practices of early childhood teachers, how these theories are articulated, and how they change over time.

Broadening the knowledge domain of early childhood mathematics

This research project is very much at the forefront of research that contributes to our understandings of teachers' engagement in early childhood mathematics teaching and learning in Aotearoa New Zealand. Given the power of teacher-driven research to inform and challenge other teachers to develop their practices, further research is needed to establish how the knowledge, understandings, and practices of teaching and learning of mathematics in early childhood in these three kindergartens are "typical" of other settings, both like and diverse. Although the importance of contextual or situational learning and teaching has been established, further research that focuses on cross-contextual studies would highlight alternative practices and offer useful examples of how teachers could enhance the learning and teaching of mathematics in a variety of early childhood settings. This would contribute greatly to the development of a dynamic and sustainable culture of mathematics in the early childhood sector across Aotearoa New Zealand.

5.

How the project contributed to building capability and capacity

Research collaborators

Unitec Institute of Technology

Maggie Haynes	project director and researcher
Professor Carol Cardno	researcher
Janita Craw	researcher

Avondale Kindergarten

Marjo Whyte-van Diessen	head teacher
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Birdwood Kindergarten

Kathryn Palmer	head teacher
Melanie Chaplin	teacher

Don Buck Kindergarten

Katrina Bone	head teacher
Petra Wyrsh	teacher

Capacity and capability building

From the proposal stage of this research project, it was always intended that the key researchers would be the kindergarten teachers, supported by the researchers from the School of Education, Unitec Institute of Technology. The tertiary researchers worked in partnership with the kindergarten teachers, introducing the teachers to the process of action research and facilitating their journey according to the protocols of action research methodology. It is pleasing to report that the combination of the partnerships and the action research methodology allowed the kindergarten teachers to successfully investigate their knowledge and practices in the area of mathematics.

In keeping with the aim of this research project, both the process and the findings of the research build capacity amongst the early childhood teaching community by adding to the body of:

- teachers as researchers;
- teachers' engagement in action research; and
- knowledge on the teaching and learning of mathematics in early childhood settings.

In analysing patterns of performance of primary students in the *Numeracy Development Project*, Young-Loveridge (2005) reports on improvements in achievement over the period 2002 to 2005. It is to be hoped that the findings from this research project will increase the competence and confidence of early childhood teachers in supporting their children's broad mathematical learning in the years before they engage in school testing of numeracy. Conference presentations have already begun to broaden this practice value of the project. Further intended conference presentations, together with paper publications, will continue to be of value to both practitioners and researchers.

The research project has met the key aims of Principle Six of the TLRI by building the capability of:

- early childhood teachers to gain expertise as teacher-researchers;
- early childhood teachers to improve their teaching practice through engaging with the findings of research;
- researchers to undertake quality research; and
- researchers to better understand teaching and learning in early childhood by engaging with early childhood teachers.

The early childhood teacher as researcher

It is evident that the research process challenged the teachers. While the concept of action research was familiar to many of them, their experiences with it had been as a result of their engagement in more open professional development models. This research project demanded that they take a more active research role than had previously been expected of them: a challenge that they responded to within the constraints of time and resources available to them. At the end of the project the participants were asked to consider how they would continue to engage in research when the project concluded. The participants addressed the question of "Where to now?", and their collective comment is summarised in the form of an analysis of strengths, weaknesses, opportunities, and threats (SWOT) that was undertaken as a group exercise at the final cluster meeting. Their input appears in Table 4:

Table 4 **TLRI cluster evaluation exercise—SWOT analysis**

Issues for future action research in our kindergarten	
<p style="text-align: center;">Strengths (internal)</p> <p>Things that we do well and that will allow us to continue to be effective action researchers:</p> <ul style="list-style-type: none"> • Reflective practice • Use of review cycles • Open to professional critique and change • Motivation and commitment to continual improvement • Collaborative relationship with our community • Physical environment (space) • Excellent administrative support • Documentation (e.g., good computer records) • Consistency in following our planning • “Recognising” mathematics • Fine-tuning our mathematical strategies • Application of knowledge to enhance other curriculum areas (e.g. science and technology) • Newsletters—continue with photographs • Communicate mathematics emphasis with new families • Collaboration with neighbouring schools • Networking/sharing this research as professional development 	<p style="text-align: center;">Opportunities (external)</p> <p>Things (outside our control) that are planned, or surprises, that may require our response. These things will contribute to continuous improvement:</p> <ul style="list-style-type: none"> • Ministerial initiatives • Funding • Parental expectations • Changes to staffing (new input) • Responding to policies and procedures (AKA)
<p style="text-align: center;">Weaknesses (internal)</p> <p>Those things that we know (or need to know about ourselves) that could act as barriers to further research and improvement:</p> <ul style="list-style-type: none"> • Time (and its management) • Current workload • Expectations of ourselves (low/high?) • Staff and children turnover rate • Documentation 	<p style="text-align: center;">Threats (external)</p> <p>Those things in the external environment that we know about or anticipate. These are often factors beyond our control that may create barriers to future plans:</p> <ul style="list-style-type: none"> • Whānau/parent involvement • Low socioeconomic families • Lack of funding • Departure of head teacher (if driver of change—prominence of mathematics will reduce or change) • Staff changes—experience might be lost • AKA obligations and expectations

This analysis shows the capability of teachers to recognise their strengths and weaknesses in relation to not only their specific research focus on mathematics, but also their ability to look beyond this focus to the broader and generic aspects of their kindergarten learning environments.

The researcher as learner

The team of three tertiary researchers comprised one experienced action researcher and two colleagues who were newer to the process. Throughout the research project, these two researchers shadowed the experienced action researcher in each of the half-day action learning events at her

kindergarten site before meeting their own research team at their specific sites. Their presence as observers had been approved by that teaching team at the start of the project. An advantage of this process was that as well as scaffolding the newer action researchers into the methodology, it sustained consistency of process across the three sites. Also, because the experienced action researcher was new to both early childhood education and to mathematics, and the other two researchers were experienced in both, the learning was reciprocated.

Additionally, the capability of the researchers was increased through the researchers meeting subsequently to reflect on their own practice as facilitators. In terms of building capacity, there is now a strong team of action researchers at this institution who can extend their knowledge to others by mentoring them in similar ways in future projects.

The researcher as facilitator

The researcher-facilitators found that there was a need to sustain momentum throughout the project, and suggest that without external facilitation it is likely that participant interest could wane at the final stage of an action research process. The involvement of the researcher as facilitator, guide, and mentor provides support but, as Fullan (1996) asserts, effective change requires both support and pressure. It is the external factor in the form of the researcher-facilitator that provides the pressure or accountability factor to ensure that the research proceeds as planned. In this project, whilst participants were diligent in tracking the consequences of changes, they needed to be motivated to continue to assemble and record evidence of change as the intervention proceeded, in order for them to provide real evidence of change for the rigour of action research rather than only action learning (Zuber-Skerritt, 2002). The challenges of facilitating research added to the researchers' capabilities as researchers.

Evaluating the process

The TLRI in Aotearoa New Zealand has three fundamental aims which are to:

- build a cumulative body of knowledge linking teaching and learning;
- enhance the links between educational research and teaching practices, and researchers and teachers, across early childhood, school and tertiary sectors; and
- grow research capacity and capability in the areas of teaching and learning.

It is evident that research project has helped to develop a greater capacity and capability within the education research community to undertake quality research. There is very little specific research within Aotearoa New Zealand about mathematics teaching in early childhood settings. The project has contributed new knowledge to the field through the application of a research methodology that is eminently suitable for creating partnerships between teachers and researchers. It has contributed new knowledge about enhancing mathematics teaching and about conducting action research: a highly applicable form of practitioner research.

The early childhood strategic plan (Ministry of Education, 2002) supports wholeheartedly the conducting of research in early childhood education, stating the “research has taught us much ... but we need to know more” (p. 19). In keeping with the recommendations of the strategic plan, this research project has allowed the teachers at the Avondale, Birdwood and Don Buck kindergartens to contribute to quality early childhood education by “establish(ing) and reflect(ing) on quality practices in teaching and learning” (p. 3) through their “conducting of research to inform future ECE policy development and monitor progress” (p. 3).

Action research projects are inherently relevant to practitioners because they focus on problems/challenges determined by the practitioners themselves. Teachers *are* the researchers. Practitioners who have engaged in an action research project experience immediacy of application of research findings within the project. This is because investigation leads to implementation of change that is evidence-based. When teachers participate in an action research project, they experience both research and professional growth. From the findings of this research we can be assured that the project highlighted the critical role of research in teaching and had direct impact on teaching and learning, thus contributing to practice.

6. References

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Dissemination

Presentations generated so far by this research

Conference presentations

- Bone, K., Cardno, C., Palmer, K., & Whyte-van Diessen, M. (2005, December). *Making mathematics central to teaching and learning in early childhood*. Presentation at the 9th annual symposium of the New Zealand Research in Early Childhood Education, Dunedin College of Education.
- Bone, K., Palmer, K., Whyte-van Diessen, M., & Youngs, H. (2005, December). *Enhancing mathematics teaching and learning in early childhood settings: Moving towards change*. Presentation at the annual conference of the New Zealand Association for Research in Education (NZARE), Otago University, Dunedin.
- Craw, J., & Haynes, M. (2006, September). *Knowing mathematics and making the learning visible*. Presentation at the Early Childhood Forum, AUT University, Auckland.
- Haynes, M., Bone, K., & Guo, K. (2006, December). *Facilitating action research: Insider or outsider?* Discussion group facilitated at the 10th annual symposium of the New Zealand Research in Early Childhood Education, Whitireia Polytechnic, Porirua.