BUILDING ON WHAT CHILDREN KNOW AND CAN DO: SOME MESSAGES FOR THE FUTURE FROM THE EARLY NUMERACY RESEARCH PROJECT

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Background
In recent years, increasing attention has been given to the early years of schooling, in recognition of the importance of children gaining a positive start to their school experience. Much of the early emphasis was on literacy needs, but the last couple of years have seen an increasing emphasis on mathematics.

The Early Literacy Research Project (Hill & Crevola, 1998) worked with 27 disadvantaged primary schools to bring about substantial improvements in early literacy outcomes. Part of this research involved the development of models and guidelines for teaching, assessment and additional support for young children learning to read. As a result of the research, Hill and Crevola offered a general design for improving learning outcomes, which they

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believed had application in literacy, numeracy, and other curriculum areas. The nine elements of the design are leadership and coordination; standards and targets, monitoring and assessment, classroom teaching programs; professional learning teams; school and class organisation; intervention and special assistance; home, school and community partnerships; and beliefs and understandings.

The Early Numeracy Research Project (ENRP) was established in 1999 by the (then) Victorian Department of Education, with similar aims to those of the Early Literacy Research Project, but having a numeracy focus. The aims of the project include exploring effective approaches to numeracy learning, and supporting schools in implementing Hill and Crevola’s key design elements in the numeracy context.

The ENRP is a collaborative venture between Australian Catholic University, Monash University, the Victorian Department of Employment, Education and Training, the Catholic Education Office (Melbourne), and the Association of Independent Schools Victoria. The project is funded to the end of 2001, in 35 project (“trial”) schools and 35 control (“reference”) schools (Clarke, 1999, 2000; Clarke, Sullivan, Cheeseman, & Clarke, 2000). The ENRP has a major professional development component, with teachers meeting with project staff for statewide, regional cluster, and local inservice programs.

Important differences from the literacy project included the need for development of a comprehensive and appropriate learning and assessment framework for early numeracy (such frameworks were well established for reading), and the need to address the personal confidence with and understanding of mathematics of many primary teachers. This paper reports some of the insights and experiences of teachers, schools and the research team in the first eighteen months of the project.

The Learning and Assessment Framework and “Growth Points”

The impetus for the project was a desire to improve numeracy learning and so it was necessary to quantify such improvement. It would not have been adequate to describe, for example, the effectiveness of the professional development in terms of teachers’ professional growth, or the children’s engagement, or even to produce some success stories. It was decided to create
a framework of key “growth points” in numeracy learning. Students’ movement through these growth points in trial schools could then be monitored by project teachers, and also compared to that of students in the reference schools.

The project team studied available research on key “stages” or “levels” in young children’s numeracy learning, as well as some frameworks developed by other authors and groups to describe learning.

In developing the framework it was intended that the framework would:
- reflect the findings of relevant research in mathematics education from Australia and overseas.
- emphasise the “big ideas” of early numeracy in a form and language readily understood and, in time, retained by teachers.
- reflect, where possible, the structure of mathematics.
- allow the description of the mathematical knowledge and understanding of individuals and groups.
- form the basis of planning and teaching.
- provide a basis for task construction for interviews, and the recording and coding process that would follow.
- allow the identification and description of improvement where it exists;
- enable a consideration of those students who may benefit from additional assistance.
- have sufficient “ceiling” to describe the knowledge and understanding of all children in the first three years of school.

The principles informed the process of developing and refining the framework in late 1998 and throughout 1999 and 2000. In 1999, the interview covered seven mathematical domains: Counting, Place value, Addition and subtraction, Multiplication and division, Time, Length measurement, and Mass measurement. In 2000, the Space strand has been added to the interview, with two domains: Properties of shapes, and Visualisation and orientation.

Within each mathematical domain, growth points were stated with brief descriptors. There were typically five or six growth points in each domain. To illustrate the notion of a growth point, consider the child who is asked to find the total of two collections of objects (say nine objects and another four objects). Many young children will “count all” to find the total (“1, 2,
3, …, 11, 12, 13”), even once they are aware that there are nine objects in one set and four in the other. Other children will realise that by starting at 9 and counting on (“10, 11, 12, 13”), they can solve the problem in an easier way. Counting All and Counting On are therefore two important growth points in children’s developing understanding of addition.

The ENRP growth points for Addition and Subtraction Strategies are shown in Figure 1.

1. Count all (two collections)
   Counts all to find the total of two collections.
2. Count on
   Counts on from one number to find the total of two collections.
3. Count back/count down to/count up from
   Given a subtraction situation, chooses appropriately from strategies including count back, count down to and count up from.
4. Basic strategies (doubles, commutativity, adding 10, tens facts, other known facts)
   Given an addition or subtraction problem, strategies such as doubles, commutativity, adding 10, tens facts, and other known facts are evident.
5. Derived strategies (near doubles, adding 9, build to next ten, fact families, intuitive strategies)
   Given an addition or subtraction problem, strategies such as near doubles, adding 9, build to next ten, fact families and intuitive strategies are evident.
6. Extending and applying addition and subtraction using basic, derived and intuitive strategies
   Given a range of tasks (including multi-digit numbers), can solve them mentally, using the appropriate strategies and a clear understanding of key concepts.

Figure 1. ENRP Growth Points for Addition and Subtraction Strategies.

In discussions with teachers, we have come to describe growth points as key “stepping stones” along paths to mathematical understanding. However, we do not claim that all growth points are passed by every student along the way. For example, one of our growth points in Addition and Subtraction involves “counting back”, “counting down to” and “counting up from” in subtraction situations, as appropriate. However, there appears to be a number of children who view a subtraction situation (say, 12–9) as “what do I need to add to 9 to give 12?” and appear to make little use one of those three strategies.

Also, the growth points should not be regarded as necessarily discrete. As with Wright’s (1998) framework, the extent of the overlap is likely to vary widely across young children, and “it is insufficient to think that all children’s early arithmetical knowledge develops along a common developmental path” (p. 702).
The Development of the Interview

Once the early drafts of the framework were developed, assessment tasks were created to relate to the framework. A major feature of the project is a one-to-one interview with every child in trial schools and a random sample of around 40 children in each reference school at the beginning and end of the school year (February/March and November respectively), over a 30- to 40-minute period.

Although the full text of the interview involves around 50 tasks (with several sub-tasks in many cases), no child moves through all of these. The interview is of the form “choose your own adventure”, in that the interviewer makes one of three decisions after each task. Given success with the task, the interviewer continues with the next task in the given mathematical domain as far as the child can go with success. Given difficulty with the task, the interviewer either abandons that section of the interview and moves on to the next domain, or moves into a detour, designed to elaborate more clearly the difficulty a child might be having with a particular content area.

To elaborate this process, consider a task within the domain of Addition and Subtraction Strategies. This task focuses on the child’s understanding and use of “counting on”. The child is asked to count out four green, little plastic teddy bears, while the interviewer counts out nine green teddies. Having established that there are “nine green teddies here, four green teddies here”, the interviewer covers the nine teddies with an ice cream lid, and asks the child to say “how many altogether?” There are several possibilities here:

- the child doesn’t know where to start or is making little progress (in which case the interviewer removes the lid, and determines whether the child is able to “count all”).
- the child counts all by perceiving the nine teddies (even though she/he can’t see them), counting from 1 (1, 2, 3, 4, …, 13).
- the child counts on from either 9 (9, 10, 11, 12, 13) or 4 (4, 5, 6, 7, 8, 9, 10, 11, 12, 13).
- the child just knows that 9 and 4 total 13.

This task enables the teacher (and the team who code the interview record sheet) to determine whether the child is able to count on, count all, or not either of these at this time.

All tasks were piloted with children of ages five to eight in non-project schools, in order to gain a sense of their clarity and their capacity to reveal a wide range
of levels of understanding in children. This was followed by a process of refining tasks, further piloting and refinement, and where necessary, adjusting the framework.

The form and wording of the tasks are influenced by the growth points for which they are intended to provide evidence, while at the same time the consideration of the data provided by a given task can lead to a refining of the wording of a given growth point.

The interview provides information about those growth points achieved by a child in each of the domains. Our aim in the interview is to gather information on the most sophisticated strategies that a child accesses in a particular domain. However, depending upon the context and the complexity of the numbers in a given task, a child (or an adult) may use a less sophisticated strategy than they actually possess, as the simpler strategy may do the job quite nicely in that situation.

It is important to stress that the growth points are “big mathematical ideas or concepts”, with many possible forms of progress between them. As a result, a child may have learned several important ideas or skills necessary for moving to the next growth point, but perhaps not of themselves sufficient to move there. Also, to achieve many of the growth points requires success on several tasks, not just one or some.

Of course, decisions on assigning particular growth points to children are based on a single interview on a single day, and a teacher’s knowledge of a child’s learning is informed by a wider range of information, including observations during everyday interactions in classrooms. However, teachers agree that the data from the interviews are revealing of student mathematical understanding and development, in a way that would not be possible without that special opportunity for one-to-one interaction. It appeared that the children also enjoy that special time having the teacher “all to themselves”. Teachers report that children appreciated the opportunity to show what they knew and could do.

Teachers meet regularly with each other and the research team (after school in regional centres and in Melbourne for full-day professional development) to share experiences and insights, and to discuss appropriate teaching plans for children, using what has been learned during the interview and classroom discussions and observations. The interview in November gives a measure of how much children have developed in their knowledge, skills and understanding over the course of the year.
Parent information evenings have been conducted in all 35 project schools. Many schools have also run “family maths type” evenings.

Unifix cubes are used to represent the frequencies of various totals of three dice.

Teachers “fishing” for particular shapes at an ENRP PD day.

**Linking Assessment and Teaching**

One of the most exciting parts of the project is the way in which teachers have taken what they have learned from the interviews and other ongoing assessment to inform their practice. They have been able to identify appropriate activities to target the needs of their children. Some examples of this now follow.
One teacher noticed from the interviews that many of her Year 1/2 children could read, write and interpret two and three digit numbers, but they had considerable difficulty when it came to ordering them. She asked children to cut out numbers from a variety of catalogues, and to order them, thus focusing on this important idea.

Another teacher used a simple card game to provide practice in recognising the smaller and larger of two one-digit numbers. Having removed the picture cards, and shared the pack between the two players, the students take it in turns to place a card down. The student whose card is larger takes both cards. The game continues until all cards are with one player. (This can take a long time!)

In developing strategies for solving addition and subtraction problems, one key growth point includes a confident understanding of combinations that add to 10. Many ENRP teachers are using “tens frames” to help children develop this understanding.

One teacher used a card game (from Swan, 1997) to help children to recognise combinations of cards which add to ten. All non-picture cards are spread out in an array, face up in roughly equal piles, and children in turns take a selection of cards (two or more) which add to ten, where possible. The game continues until no such combinations remain.

On the same mathematical point, another teacher posed the following problem: “The principal has told me that ten new Preps are coming soon,
but I forgot to ask how many girls and how many boys. How many of each could there be?” The children took this question, and developed a range of different strategies for determining and representing the possibilities. It was a nice example of a task which links different content areas – in this case, Number and Chance and Data.

What Do the Results Show?

Student assessment in trial and reference schools enables the research team to decide whether the improvement over the year in student understanding would have happened anyway, or whether it has been enhanced by the involvement of trial schools in the project.

In 1999, there was clear and positive growth in both trial and reference schools. However, looking at the data overall, children in trial schools outperformed those in the reference schools at every grade level and in all of the mathematical domains studied.

Teachers’ Stated Professional Growth

Given the clearly successful efforts of trial school teachers in developing children’s mathematical skills and understandings in 1999, it becomes increasingly important for the research project to start to look at successful teachers’ practice to try to discern those aspects of “what the teacher does” that make a difference. After slightly more than one year’s involvement in the project, teachers were asked to identify changes in their teaching practice (if any). There were several common themes:
• More focused teaching (in relation to growth points).
• Greater use of open-ended questions.
• Giving children more time to explore concepts.
• Providing more chance for children to share strategies used in solving problems.
• Offering greater challenges to children, as a consequence of higher expectations.
• Greater emphasis on “pulling it together” at the end of a lesson.
• More emphasis on links and connections between mathematical ideas and between classroom mathematics and “real life mathematics”.
• Less emphasis on formal recording and algorithms; allowing a variety of recording styles.

Several of these themes are evident in the following quote from a teacher:

The assessment interview has given focus to my teaching. Constantly at the back of my mind I have the growth points there and I have a clear idea of where I’m heading and can match activities to the needs of the children. But I also try to make it challenging enough to make them stretch.

Teachers’ Observations of Children’s Growth

Teachers were also asked to comment on aspects of children’s growth that they had observed which were not necessarily reflected in movement through the growth points. Common themes were the following:

• Children are better at explaining their reasoning and strategies.
• Children enjoy maths more, look forward to maths time, and expect to be challenged.
• The development of a “give it a go” mentality is very evident, with greater overall persistence.
• Children are thinking more about what they have learned and are learning.
• All children are experiencing a level of success.

One teacher commented on her children’s positive attitudes to mathematics:

Children seem to be more enthusiastic, take more risks and have more confidence in their abilities. They can’t wait to participate. They’re excited about maths. For example, we brainstormed the combination of green or red lollies to make 10 and when the children opened their bag, they
exploded with excitement! “I’ve got 3 and 7!” “I’ve got 2 and 8!” All this over adding to 10!!

**Some of the Things We Have Learned From the Project So Far**

There are many things we have learned from the first eighteen months of the project. Here are just a few:

1. The insights gained from one-to-one interviews in mathematics provide powerful and important information on what children know and can do, and are an excellent basis for teachers’ planning.

2. We have many extremely capable children in Years Prep to 2, but also some who need additional support in their mathematical “journey”. Much of our discussion at inservice days has involved how best to meet the needs of all the children in our classes. A very useful strategy is the use of open questions in mathematics, which enable children to respond at a level that is appropriate for them. In 2000, we are also researching a range of approaches to additional assistance inside and outside the classroom, with individuals and small groups.

3. Having high expectations of all children, and encouraging a feeling that we can all “do mathematics” is very important, and appears to have very positive effects.

4. Encouraging children to share their thinking in mathematics, particularly their methods for solving problems, is valuable.

There is much more to be done and to be learned before the project concludes at the end of 2001. It continues to be a privilege for all of us in the research team to be co-researchers with dedicated and capable teachers who are developing confident and competent young learners and users of mathematics.

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**References**


KEYNOTE: Building on what children know and can do


