Number Learning in the Primary Years

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This chapter provides an overview of recent Australasian research on number learning in the primary years—that is, research pertaining to the number learning of 5- to 12-year-old children. The research has been categorised using the headings of (a) developmental frameworks in number, (b) counting, (c) place value and the number system, (d) addition and subtraction, (e) multiplication and division, (f) mental computation, (g) number sense, and (h) fractions and decimals.

**Developmental Frameworks**

Over the past 4 years a large number of research studies have been instigated by government numeracy initiatives. Much of the Australasian research into children's early number learning has its roots in the work of Steffe and von Glasersfeld in the United States (Steffe, Cobb, & von Glasersfeld, 1988) and Wright (1994). A major feature of such research has been the construction of developmental frameworks. For example, the *Count Me In Too* project in New South Wales (NSW) and the Victorian *Early Number Research Project* (ENRP) both describe and highlight the importance of developmental frameworks in number. For a discussion of projects funded through the Australian Commonwealth Government's *Numeracy Research and Development Initiative*, see Stephens and Steinle (2003).

The *New Zealand Numeracy Project* has extended the framework of these earlier projects, while adopting a different approach to teachers' follow-up practices (Hughes, 2002). According to Young-Loveridge and Wright (2002), patterns of performance of almost 10 000 Year 4 to 6 students provide substantial support for the hierarchical organisation of the framework. Furthermore, Thomas, Tagg, and Ward (2002) reported that the 64 000 children involved in the *New Zealand Numeracy Project* made impressive gains in their learning, irrespective of gender, age, ethnicity, or school region.

Reviews of the NSW *Count Me In Too* project (Wright & Gould, 2000; Wright & Gould 2002a) have examined the links between the research base of *Count Me In Too* and other research in early number. The analysis of large-scale data by Wright and Gould (2002b) supports the effective implementation of the program, with good indicators that the program has positively influenced the number learning of students. Mitchelmore and
White (2003) provide a further analysis, showing that results on the NSW Basic Skills Tests, for Year 3 students who had participated in the *Count Me In Too* project, increased steadily and significantly during the period 1996 to 2002.

An *Emergent Numeracy Profile* was constructed as part of the *Early Numeracy Research Project* (e.g., Clarke, Sullivan, Cheeseman, & Clarke, 2000; Clarke, 2000, 2001; Clarke et al., 2002). Data collected from individual interviews with over 5000 children was used to refine the framework. This was used as a basis for the design of structured, numeracy-specific, teaching and learning materials to scaffold a hierarchy of skills, strategies and dispositions concerned with mathematical thinking and problem solving. By using task-based interviews, based on developmental frameworks, teachers gain first-hand knowledge of children's mathematical understanding on which to establish their expectations, with many teachers commenting that their own mathematical knowledge had been enhanced considerably as a result of focusing on children's mathematical thinking (Clarke, 2001).

These large-scale projects have combined and extended earlier research into children's number learning to produce focused professional development programs for teachers of lower and later primary, and junior secondary years. Unquestionably, these projects and their related research have benefited many children and their teachers, but questions remain regarding the wisdom of ascribing so much importance to counting, which is just one facet of mathematics.

**Counting**

Counting has been a major focus for research in the early years of schooling for some time (Doig, McCrae, & Rowe, 2003). Such research has been given new vigour by the large-scale developmental frameworks projects.

In particular, the ENRP examined a wide range of research into the stages of young children's mathematics learning, and identified six growth points for counting (Clarke, 2000, 2001; Clarke et al., 2000). These growth points are (a) rote counting, (b) counting collections, (c) counting by 1, (d) counting from 0 by 2s, 5s and 10s, (e) counting from a number greater than 0 by 2s, 5s and 10s, and (f) extending and applying counting skills (Clarke et al., 2000; Gervasoni, 2000).

Gervasoni (2003a) explored the counting development of low-attaining children participating in the ENRP. The children were assessed with an individually administered interview, with results compared to the ENRP developmental framework of growth points. The progress of Year 1 and Year 2 children who participated in a follow up intervention program was...
compared to children who did not. Results suggest that the intervention was more effective for Year 1 children, but that the effectiveness of the intervention was dependent on the transition across a growth point children needed to make.

With respect to assisting children who could be described as being at risk in mathematics, Gervasoni (2003b) reported a study that explored the counting errors made by 40 Year 1 children, from 16 Victorian schools, prior to their commencement of a mathematics intervention program. The counting tasks in the pre-assessment interview focused on number conservation, one-to-one correspondence, counting collections of objects, and producing forward and backward number word sequences. Analysis of the results highlighted several common difficulties and issues related to learning to count, mostly related to bridging decades when counting forwards or backwards.

A smaller scale study (Baturo, 2003) examined the number understandings of Indigenous students, who are among the most educationally disadvantaged group in Australia with respect to mathematics. In this study, 18 Year 5 to 7 students in a Queensland Aboriginal community were tested to determine their baseline knowledge of whole numbers. Students' test results on number identification, place value, counting, grouping and regrouping, comparing, ordering, and estimation were analysed. Selected students were interviewed to establish whether misconceptions were language, context, or mathematics based. The interviews revealed that misconceptions were generally related to language and mathematics schema. Although there was evidence that use of real-world contexts assisted children's performance, this assistance did not necessarily appear to be of lasting value.

Willis (2000) discusses what is meant by children at risk by drawing on research into the Indigenous children's ability to count. Some lower primary Indigenous children interviewed by Willis were found to be able to subitise (i.e., distinguish the number of items in a collection without counting) but not count. This raises questions about the assumptions many researchers make about the teaching of counting. Willis suggests that this also has implications for assessment and planning of curriculum sequencing in Years 1 and 2. Willis claims that whether or not children are at risk relates to whether their long-term progress or mathematical growth is at risk, and not to the social group to which they belong.

As has been noted, research into children's counting has been enhanced and overtaken by large-scale developmental frameworks projects. Whether this situation is of lasting benefit to the mathematics research community, and thus to students, is yet to be decided. There is a danger that government
funding of these projects and thus government policy, rather than reasoned inquiry, will drive the direction of research.

**Place Value and the Number System**

Place value is a critical key to understanding our number system. There have been several studies that moved beyond counting and traditional analyses of children’s understanding of place value.

Berman (2001) developed an alternative dynamic assessment procedure for place value and numeration, particularly suitable for school psychologists. She found that conventional assessment instruments had lower content validity than the dynamic instrument, due to the restricted nature of conventional item format in the conventional instruments. Later, Berman (2002) reported on a study in which cognitive research tasks administered to children in Years 3 and 4 provided sufficient information about the children’s conceptual development in place value to describe a developmental pathway.

Price (2001), in a study of 16 Year 3 children, investigated the development of place value understandings using two different treatments over a period of 10 sessions. The children were placed in four groups, with two groups categorised as high achieving and two as low achieving. Two groups used physical base ten blocks and two used place value software with base ten representations. Although there was little difference in the learning that took place, the feedback from the children using software was found to be more positive and consistent. The software also reduced the need for assistance from the teacher, although it was not as responsive as the teacher was to an individual’s specific needs. These studies give support to other assessment frameworks such as the *Learning Framework in Number* (Wright & Gould, 2002b), that are based on the integration of assessment, teaching and learning.

Baturo (2000) identified three key place-value understandings and categorised them into three levels. Level 1 is associated with position, base and order. This is considered baseline knowledge because all decimal number knowledge is derived from this level. Level 2 is associated with unitising and equivalence, which are seen as linking knowledge because it is necessary for progression. Level 3 is associated with re-unitising, additive and multiplicative structure. The skills and understandings developed in these three levels form a foundation or superstructure for further knowledge. According to Baturo, the extensive use of base ten blocks to represent numbers results in additive structures dominating multiplicative views of place value.

Thomas, Mulligan, and Goldin (2002) conducted research investigating the structure of the number system through counting. This was based on two
cross-sectional exploratory studies of 172 NSW students in Years K to 6, with an additional 92 high ability children from Years 3 to 6. Thomas and his colleagues provided a descriptive analysis of how internal representational systems for numbers 1 to 100 may change through a period of structural development, to become powerful autonomous systems. The research describes children's visual images of number, supporting previous findings on the importance of multiplicative structures in developing the base-ten system. While the analysis is only a partial description of each child's internal representational capabilities, and the findings contrast with those of Baturo (2000), the approach complements other studies focused on analyses of children's representations across other conceptual domains (Diezmann & English, 2001; Outhred & Mitchelmore, 2000).

A study of the understanding of the number system by 221 Year 3 children, one third of whom were Māori, was conducted by Young-Loveridge (2000). The focus of this study was possible links between variations in understanding and socio-economic status. A task-based interview was used to collect the data and children's performance was used to assign them to a level of a developmental numeracy framework. The analysis showed that children's understanding of the number system varied as a function of ethnicity and socio-economic status.

Although research during the last 4 years has provided insights into children's development and abilities in place value, findings have been inconsistent, suggesting that further research is required.

Addition and Subtraction

In addition to the growth points for counting, the ENRP identified six growth points for addition and subtraction strategies. These growth points are (a) count-all (two collections); (b) count-on; (c) count-back, count-down-to, count-up-from; (d) basic strategies (doubles, commutativity, adding 10, ten facts, other known facts); (e) derived strategies (near doubles, adding 9, build to next ten, fact families, intuitive strategies); and (f) extending and applying addition and subtraction using basic derived and intuitive strategies (Clarke, 2001). This last growth point (extending and applying addition and subtraction using basic derived and intuitive strategies) derives from the finding that a small, but significant, number of children were able to compute effectively and efficiently before instruction.

Continuing research associated with the Count Me In Too project in NSW schools has focused on the Schedule for Early Number Assessment 2 (SENA 2)—a one-on-one interview that includes items dealing with more advanced addition and subtraction strategies than those in the original Schedule for Early Number Development, early multiplication, and knowledge of tens and
A study using Siegler's overlapping wave theory to explain patterns of strategy use and progression by age was applied also to large scale data derived from the *Count Me In Too* project (Wright & Gould, 2002a). This study revealed the range of strategies students use to solve addition and subtraction tasks. Wright (2001) describes case studies involving addition and subtraction with single- and two-digit numbers and early multiplication and division tasks. The reliance on counting by ones—using fingers for example—is highlighted as an inefficient strategy compared with more sophisticated strategies.

Using data gathered as part of the ENRP, Horne (2003) focused on children's addition and subtraction strategies. A task-based interview had been used with approximately 1200 children in Prep to Year 2. Initially, students were assigned growth points for each interview based on the interview data, with an analysis of covariance performed to investigate any growing difference between boys' and girls' results. The results appear to confirm that a difference exists in the strategies used by boys and girls in Years 2 and 3 to answer addition and subtraction problems, although differences appear to be in the use of mental strategies, rather than in correctness of responses. Horne highlighted that the percentage of boys moving on to more complex problems, and using addition and subtraction strategies, was higher than the percentage of girls.

Much of the research into aspects of addition and subtraction has been based, understandably, on the data collected by large-scale projects, such as *Count Me in Too*. While this is laudable, it could overshadow the contributions of other projects to the field or dissuade other researchers from contributing to the field.

**Multiplication and Division**

Much of the recent research on multiplication and division has extended earlier studies with young children by including the more complex aspects of multiplicative reasoning. Several studies have addressed the question of representation, such as: equal groups, arrays, region models, and more effective transfer to situations involving decimals (Norbury, 2002).

Among studies of multiplicative thinking, Jacob and Willis (2001, 2003) describe developmental phases in multiplicative thinking through the analysis of assessment data with upper primary students. Mulligan and Wright (2000) describe the development of a six-level framework for multiplication and division knowledge based on previous longitudinal research (Mulligan & Mitchelmore, 1997). This framework distinguishes levels of counting and grouping in accordance with descriptors for arithmetical learning. Mulligan (2002) extended her investigation of multiplicative structure using
longitudinal case studies of 24 students from Years 2 to 5, representing extremes in mathematical ability. Low ability students represented multiplicative situations without using a structure of equal grouping and persisted with these representations through to Year 5. High ability students used notational representations with well-developed structures identified from the outset in Year 2, with dynamic imagery featuring strongly in their responses.

Sullivan, Clarke, Cheeseman, and Mulligan (2001) examined the issue of children's models of multiplicative situations. Sullivan and his colleagues used ENRP interview data on the progress of multiplicative learning by 5- to 8-year-olds in order to explore the nature of this development. The numbers of children who had been classified as being at the Modelling growth point (i.e., they were at a stage where they could make a concrete model of a multiplicative situation) in March were compared to the numbers of these children who were classified in November as being at the Abstracting stage (i.e., they were able to discern multiplicative situations). Of the 3410 children assessed in March, 841 remained at the Modelling growth point at the end of this period. Furthermore, 70% of those classified as Modelling in March were still at this classification in November. The researchers believe this indicates that the achievement of the Abstracting growth point is a significant barrier for many children, suggesting the need for teaching and learning experiences that assist children to develop visualisation, and that explicitly remove concrete models of multiplicative situations.

In order to pinpoint early developmental problems more accurately, Mulligan and Prescott (2003) are conducting a longitudinal study of children in Years 1 and 2 which examines structural relationships between children's early number and spatial concepts, as well as their mathematical representations.

The review of the last 4 years reveals that explication of phases of development in more complex multiplicative thinking has been a major thrust of current Australasian research. It is to be expected that, as with research into the development of addition and subtraction, this research will be extremely fruitful in the coming years.

Mental Computation

The development of children's mental computation strategies has been a major focus of a small but active group of Australasian researchers. While much of the work would appear to address similar issues, there are subtle differences in approach and perspective that enrich the reviewed works.

Heirdsfield (2000, 2001a, 2001b) reported on different aspects of an in-depth study of Year 3 children's mental computation strategies for addition
and subtraction, with the aim of developing a comprehensive model of mental computation. The study found that children deemed to be proficient in mental computation had access to a rich network of cognitive and cognitive strategies. Students who were deemed accurate, but lacked flexible strategies, were found to have a more limited and less connected knowledge base and were unable to select a strategy, and relied on teacher-taught strategies. Those features characterising the mental computation of children deemed proficient and those deemed accurate but inflexible, were used to develop a model for each group of children. According to Heirdsfield (2001b) and Heirdsfield and Cooper (2002), the study showed the importance of connected knowledge for proficient mental computation and the need for children to formulate their own strategies.

A different approach to that of Heirdsfield (2001b) and Heirdsfield and Cooper (2002), was taken by McIntosh (2002) in a study that examined the most common errors made by 3,035 students in Grades 3 to 10 in responses to mental computation questions. Items were administered via a tape recorder, with children writing their responses on an answer sheet. No written working was allowed and time limits were imposed. The patterns of errors were closely connected to vulgar and decimal fraction, percentage, and whole number. A more detailed analysis of these data was reported by Callingham and McIntosh (2002). The object of this analysis was to confirm the developmental nature of the mental computation construct and to establish reasonable expectations for student outcomes in each year from 3 to 10. The student data were placed on a single scale using Rasch model techniques and a variable map produced showing the distribution of and students along a mental computation variable (for details of this procedure, see Callingham & McIntosh, 2001). Eight levels of mental computation development in terms of content and skill demand were identified, with student achievement across the years mapped onto levels. While there was a general increase in ability across the years, growth was greatest between Years 3 and 4, with a plateau in growth in the later years. However, there was a wide spread of abilities within years, indicating considerable overlap between years.

In an exploratory study conducted in Tasmania and the ACT, (2002) used a case study methodology to investigate the mental computation competence of students in the middle school. Three students in each of Grades 3 to 10 were interviewed, with four middle-school students being chosen for each case study analysis. Students were interviewed individually using a structured protocol. A case-by-attribute matrix was constructed, which enabled several contrasting content and performance features to be distinguished. The more competent from the less-competent students
identified. Competent students were distinguish by the following features: they made use of elementary number work and extended number facts, they used repeated addition and related doubling strategies in preference to place value strategies, they were less likely to translate vulgar fraction questions into language more closely associated with decimal fractions, they were more confident in dealing with errors, and they recognised and used information to formulate computational plans.

Analysis of data from a case study, investigating factors influencing children’s strengths and weaknesses in mental computation, revealed that while some factors appeared to be essential for flexibility, additional factors were necessary for accurate employment of strategies (Heirdsfield, 2002). Further, there were qualitative differences between the mental strategies employed by the students who were accurate and those who were inaccurate. These analyses also showed that inaccuracy resulted from disconnected and deficient cognitive, metacognitive, and affective factors, and that children’s choices of mental strategies resulted from different forms of compensation for varying levels of deficiencies. Importantly, there was evidence that connected knowledge, including domain specific knowledge, and metacognitive strategies are important for proficient mental computation, but that children’s invented procedures were more accurate and showed greater number sense than teacher taught strategies.

In another study, Heirdsfield (2003b) used the mental computation conceptual framework that she had developed previously (Heirdsfield, 2003a) to explain the difference between proficient (accurate and flexible) mental computers and accurate, but not flexible, mental computers. Although the 16 children from Year 3 and Year 4 were selected for their accuracy with mental computation, not all employed efficient mental strategies. Responses from structured and semi-structured clinical interviews were analysed for strategy choice, flexibility and accuracy, with the results confirming earlier findings. In particular, flexible students had more integrated and extensive conceptual structures to support their mental computation and their accuracy was strong as a result of their use of self-developed strategies.

Although researchers into mental computation have clearly defined differences in their research focus and methodologies, there is a consistency within their individual and collective findings that set a firm foundation for both further research and effective practice.

Number Sense

Number sense is inextricably interwoven with other aspects of number, particularly aspects linked to computation. The research reviewed here
represents only those studies that have a clearly defined focus on number sense.

In a Tasmanian study, McIntosh and Dole (2000a) administered separate pencil-and-paper tests for mental computation, number sense and general mathematics. They found that students who score highly on mental computation tests and general mathematics tests may not be developing a sense of numbers, but students who do not score highly on written tests of mental computation, number sense and general mathematics may still have good strategies for mental computation and a lot of sense about numbers.

Research into number sense has been strengthened by the development of a number sense framework (Reys et al., 1999). Using this framework, McIntosh and Dole (2000b) developed an item bank for assessing the number sense of students aged 8 to 14 years in Australia, the United States, Sweden and Taiwan. Among the conclusions drawn were that number sense can be assessed by written tests, but written questions testing number sense—as opposed to skill acquisition or instrumental understanding—are difficult to devise. Further, even when using written tests, individual interviews are needed to explicate students’ thinking. The analysis of the data revealed that children’s conceptual understanding of decimals was weak generally, and conceptual understanding of fractions was very weak.

Swan and Bana (2000) explored the computational choices made by 75 children in Years 5 to 7 in Western Australia. Data were collected on the computational choices made, and a record kept of the success rate for the various computational choices. Children were interviewed to determine the reasons for making particular computational choices. The results of this study showed that student choice was based on the magnitude of the numbers involved, the child’s knowledge of table facts, and, in particular, the influence of their teacher. In summary, the authors considered that students were making hasty decisions from within a limited set of choices.

Warren (2003) investigated a less obvious aspect of number sense, that of the role of the equals sign in number problems. She examined the change over a 3-year period in 76 Year 3 children’s understanding of equals as equivalence, and the children’s ability to express this understanding in real-world problems. Data were collected at the end of each of the 3 years, with all children completing a written test and being interviewed. A number of the test items were common across the 3 years. The analysis revealed that approximately one third of the sample had an understanding of equals as equivalence, and were capable of interpreting equivalent situations and recognising these in real-world contexts. However, for others in the sample the difficulties and misunderstandings they experienced in Year 3 persisted to the end of Year 5. As the children moved from Year 4 to Year 5, many more
were able to find correct answers for unknown elements of equations, and more could give appropriate stories using equality. A significant number of children could pose relevant real-world problems by the end of Year 5, but those who were unsuccessful exhibited language problems that mirrored their responses.

Although there appears to be little research completed in this area during the last 4 years, the close links between number sense and other aspects of computation suggest that one should look closely at research studies to be found in the sections on aspects of computation for a broader perspective on this topic.

**Fractions and Decimals**

Our review of the research into fractions and decimals over the past 4 years revealed few studies with a major focus on fractions. Chinnapan and Lawson (2002) examined the quality of Year 3 children's understandings of fractions. Data from individual interviews with 24 children were analysed in terms of the children's performance with respect to identification of fraction words, knowledge of labels, representing fractions in symbols, meaning of fraction words, representing fractions as diagrams, meaning of \( \frac{a}{b} \) symbols, relating and ordering fractions, and explaining fraction ordering. The analysis showed a great disparity in Year 3 children's knowledge, with the results, when compared to curriculum expectations and past research, suggesting a lack of progress in the teaching of fractions.

Anthony and Walshaw (2003) viewed videotapes of 60 Year 4 and 50 Year 8 students, randomly selected from the New Zealand's National Education Monitoring Project bank of student responses. From children's responses to rational number questions, the researchers identified the role that context plays in the development of fraction understanding. An inventory of all solutions was produced and it was found that informal experiences, in varied contexts, played a major part in many Year 4 students' deliberations. Children often gave contextual details. However, Year 8 students appreciated that a mathematical response was required and seemed more readily able to divorce themselves from contextual influences.

In a similar study related to the learning of decimals, Irwin (2001) investigated the role of students' everyday knowledge. She found that students who worked on contextual problems made significantly more progress than those who did not. Moreover, an analysis of dialogue between students working in pairs revealed greater reciprocity when pairs worked on contextual problems, partly because less able students used their everyday knowledge of decimals. Irwin postulates that students who solved contextual
problems were able to build understanding by reflecting on their use of everyday knowledge in their calculations.

The importance of teachers spending time teaching and reviewing the basic meanings of fractions and decimals, and the interrelationships between them, is emphasised in a New Zealand study by Irwin and her colleagues (Irwin, 2000; Irwin, Lauaki, Jacobs, & Marino, 2000). Pre- and post-tests of place value and decimal knowledge, suitable for assessing a wide range of understandings, were used to assess progress. Teachers taught a topic for 3 weeks, keeping detailed records of their planning and samples of student work. Findings showed that every teacher taught differently, including those who planned together. Every class and the vast majority of students made progress. The main factors leading to students' improvement appeared to be careful planning, the use of a clear model that students could use to visualise decimals, together with careful bridging from visualisation to numerical forms.

With regard to the models used to represent decimals, Helme and Stacey (2000) carried out a small-scale study, with minimal intervention, in which four teachers made use of a different concrete model for decimals, Linear Arithmetic Blocks (LAB). The authors argue that LAB is a simpler model than MAB since the representation is based on length rather than volume. Teachers who used the Linear Arithmetic Blocks achieved an encouraging improvement in children's decimal understanding, measured against previous performance in the school over some years. This result appears to indicate that deliberate attention to decimal concepts can make a difference. Further, in a study comparing the use of LAB and MAB in two teaching experiments involving 30 matched students, Stacey, Helme, Archer, and Condon (2001) found LAB to be considerably more accessible for students, with more active engagement by students, and deeper discussion.

Hunter and Anthony (2003) undertook a 6-month classroom teaching experiment on the hypothetical learning path for decimal understanding. Following individual interviews, four students were selected for case studies to represent the range of misconceptions about decimals common to students within the middle school age group. The recursive and non-linear paths taken by students in their construction and reconstruction of decimal concepts subsequently influenced the choice of further activity in the teaching and learning cycle.

In a much larger study, Steinle and Stacey (2002) used a Decimal Comparison Test with over 3000 students in Years 4 to 10. Each item on the test required students to select the larger of a pair of decimal numbers. The cross-sectional and longitudinal components of the study meant that the paths, which students take in terms of the coding of their error patterns, could
be traced. The paper reported on the cross-sectional incidence and longitudinal incidence of two of the twelve codes: A2 where students were successful on core items but unsuccessful on more unusual comparisons; and U2 where students almost completely consistently selected the smaller decimal as the larger one. The U2 group were small in number, but increased through secondary school, with most students not improving at successive attempts at the test. According to Steinle and Stacey, the fact that the A2 group was quite large suggests that teachers need to continue to attend to place value issues in junior secondary school. In a further analysis of data from the use of the Decimal Comparison Test, Steinle and Stacey (2003a) found that, even among the task experts, some students had little generalised understanding of decimals, while many students in the other categories did not have a coherent view of the quantitative meaning of decimals, suggesting that students need many number line activities, instruction in place value extending beyond hundredths, and opportunities to generalise to very large and very small numbers.

Steinle and Stacey (2003b) reported a further analysis of the data set from their study of over 3000 students in Years 4 to 10. These students had been tested at 6-monthly intervals from 1995 to 1999 and this report focused on two aspects of the data: prevalence of specific misconceptions at different year levels, and the persistence of specific misconceptions over time, namely “longer-is-larger” (i.e., students believe 4.63 > 4.8) and “shorter-is-larger” (i.e., 5.62 > 5.736). They found that the prevalence of both misconceptions dropped as the year level increased from 4 to 10. However, the persistence of the “longer-is-larger” misconception was short-lived, with younger students leaving the misconception behind as they moved up the year levels. On the other hand, the “shorter-is-larger” misconception had adherents throughout all the year levels.

In an effort to enhance students’ learning about decimals, McIntosh, Stacey, Tromp, and Lightfoot (2000) designed two computer games that focused on aspects of decimal understanding. These games were found to be effective in challenging children’s misconceptions, with students being assisted by their teachers to develop strategies for dealing with decimals.

Given the extent to which money and measurement systems are based on the decimal system, and the difficulties students and adults have in understanding the decimal system, there is still a need for further research into decimals and the common fractions which they both rely on and replace.

Conclusion

We may well ask what should be the research direction for the next 4 years and beyond? While as researchers, we would want to encourage the
continuing support of governments through funding of large-scale, system-based initiatives, it is critical that we do not neglect pure, basic research linked to student learning of specific aspects of number. Clearly, we need a balance between large-scale research, which contributes directly to policy, and small-scale research that creates knowledge and can form the basis for future policy initiatives.

Two aspects of number research methodology that are less well represented in this review are longitudinal and meta-analytic studies. For example, longitudinal studies focused on the evaluation of student learning could examine student progress as a means of evaluating the long-term impact of earlier number learning research and development programs. The reports of longitudinal research in this section clearly demonstrate the richness and power of this form of research.

Meta-analyses of previous research can provide highly productive results, as it combines the work of a wide range of researchers. This form of research is cumulative in a way that is hard to achieve through other approaches. Although new research questions would need to take account of the differences between studies, meta-analyses of current research findings might well prove to be another productive form of collaborative research.

Many smaller projects have grown from previous Australasian studies on children's number learning, disseminated widely in the 1980s and 1990s (see reviews by McIntosh & Dole, 2000c; Wright, Mulligan, Stewart, & Bobis, 1996). We would hope that future researchers find this review a valuable resource for their endeavours.

References


