From Research Tool to Classroom Assessment Device: The development of *Checkout/Rapua*, a shopping game to assess numeracy at school entry

Jenny Young-Loveridge
Education Studies Department, University of Waikato, Hamilton, New Zealand

This paper describes the development of a procedure for assessing numeracy at school entry. What began more than decade ago as a research tool consisting of a collection of tasks to assess children's numeracy, has developed into a classroom assessment device in which various numeracy tasks are embedded within a shopping game, with the potential to assess a broad range of mathematical understandings in addition to those included in the game itself.

The New Zealand Curriculum Framework identifies Numeracy Skills as one of the eight groupings of essential skills which all students need to develop throughout the years of schooling (Ministry of Education, 1993). These skills are thought to be important for ensuring that students achieve their potential and participate fully in society, including the world of work.

If teachers are to identify children's learning needs and plan programmes which will meet those needs, they need to find out about the knowledge and understanding which children bring with them to school. The New Zealand Curriculum Framework has identified school entry at age five as one of the key transition points for students entering the schooling system, and numeracy as one of the skills to be assessed at this point (Ministry of Education, 1993). The purpose of gathering information at a point such as this is to enable resources to be targeted more effectively by teachers and the government.

Research on children's numeracy skills

Over the past couple of decades, research on children's mathematical thinking has increased rapidly. Such studies provide a detailed picture of the kinds of numeracy skills which are within the repertoire of many five-year-olds (see Visser & Bennie, 1996; Wylie, Thompson & Kerslake Hendricks, 1996; Young-Loveridge, 1987a, 1987b, 1988, 1989a, 1991a, 1993, 1995). Several features about the numeracy skills of five-year-olds are particularly striking.

1. The numeracy skills of five-year-olds are often extraordinary

Research done over the last couple of decades shows that many five-year-olds have considerably greater understanding and skill with numbers than their teachers realise (see Young-Loveridge, 1987a, 1987b, 1988, 1989a, 1991a, 1993). In a study undertaken in New Zealand schools ten years ago, teachers were asked to make judgements about which numeracy skills and concepts their new entrant children possessed. These judgements were then compared to children's actual performance on particular tasks (Young-Loveridge, 1987b). The study found that many teachers underestimated their pupils' numeracy skills, and this was particularly noticeable for operations (ie, addition and subtraction), both with real and with imagined objects (see Young-Loveridge, 1987b, 1988, 1989a). Consequently, many children were being given lots of practice doing mathematics which they already knew, rather than being challenged to develop more advanced concepts and skills. British researchers found a similar pattern (Bennett, Desforges, Cockburn & Wilkinson, 1984). As a result, a great deal of time and opportunity for learning more advanced mathematical skills was probably being wasted and achievement may have been lower (Bruner, 1960). Higher ability students in particular seem to be hurt by the slow pace at which teachers move through instructional materials (Barr, 1974, 1975).

2. *The numeracy skills of five-year-olds are highly variable*

Research shows that there are huge differences between the *most* and the *least* competent five-year-olds (see Young-Loveridge, 1987b, 1988, 1989a, 1991a). For example, some five-year-olds can rote count to 100, form a group of 9 objects, and add and subtract mentally, whereas others have little or no knowledge of the number sequence, or of how to form small groups of objects. A longitudinal study of New Zealand children from ages five to nine found that the least capable children took about two years to reach the point which the most capable children had already reached on entry to school (see Young-Loveridge, 1991a). But, after two years at school, the "experts" had made further progress and by then were substantially better than the "novices" at other skills such as counting forwards in multiples of 5 of 10, or backwards in ones. They were also better at naming 3- and 4-digit numerals, explaining the meaning of equations, explaining the place value meaning of 1 in the tens position and 2 in the hundreds position, and recalling addition and subtraction number facts with single digit numbers. Two years further on, the "experts" were substantially better than the "novices" at multiplication and division problems (including the use of more sophisticated strategies, such as multiple counting or number fact retrieval, in preference to a simple "counting by ones" strategy), as well as operations involving time and money, and fractions of sets.

3. *The numeracy skills of five-year-olds are extremely stable*

Research shows that there is a strong tendency for children who are the *most* competent initially to be the *most* competent several years later (see Young-Loveridge, 1991a). Similarly, the children who are the *least* competent initially, tend to be the *least* competent several years later. Research with New Zealand children shows that more than half of the differences in mathematical skill and understanding at age nine could be explained by differences in children's numeracy skills at age five when they entered school (Young-Loveridge, 1991a). This pattern varied as a function of gender, with the numeracy skills of girls being substantially more stable than those of boys (ie, for girls, more than two-thirds of the differences at nine could be explained by differences at five, whereas for boys, just under a third of the differences at nine could be explained by differences at five). Although this is good news for girls who arrive at school with extensive numeracy skills, it is not so good for those girls who begin school with relatively few numeracy skills.

The picture is not all gloomy, however. An intervention study with five-year-olds (Early Mathematics Improvement Study: Five-year-olds - EMI-5s, Young-Loveridge, 1993) showed that it may be possible to change some of these patterns. Children who were selected for intervention participated in a programme which used number books and games to enrich the mathematical experiences of five-year-olds, either in a daily withdrawal session to play number games and read number stories (school-based programme), or one which combined home visiting with parent workshops and a lending library of number books and games (home-based programme). The pattern of results suggests that the intervention programmes may have been responsible for weakening the relationship between early and later numeracy (and hence in the proportion of explained variance), by bringing about improvement in many children's numeracy levels, but at varying rates. It was interesting to note that it was the girls for whom the differences as result of intervention were the greatest (the variance in later numeracy which could be explained by early numeracy was virtually halved for the intervention children compared with their contrasts).

Problems with Current Assessment Practices for Mathematics at School Entry

It is difficult to know just exactly what assessment procedures teachers are currently using at school entry. A survey of school entry practices undertaken late in 1991 (Thackery, Syme & Hendry, 1992) found that almost two thirds of schools surveyed used Beginning School Mathematics (BSM) day-to-day recording sheets and/or checkpoints (Ministry of Education, 1985). Examples given of the range of mathematical concepts which teachers looked for in new-entrant children include classification, size, order, pattern, colour, shape, position and movement - all concepts from BSM Cycle 1.

Less than ten percent of the sample mentioned using forms of assessment from a topic-based approach, including such numeracy skills as rote counting, enumeration and numeral recognition. Data collected in April 1992 showed that the majority of teachers sampled (35 out of 40) monitored their pupil's progress in mathematics using BSM checkpoints and/or day-to-day recording (Visser & Bennie, 1996), and that virtually all of the children in their classrooms were working on Cycle three or earlier. By October 1993, almost all of the teachers in Visser and Bennie's study (37 out of 39) were using some combination of BSM checkpoints and/or day-to-day recording to monitor their students' knowledge and skills in mathematics.

A major problem with using tasks from the first few cycles of BSM for school-entry assessment is that, unless a deliberate effort is made to sample skills at a variety of levels, information about a child's understanding of concepts presented in later cycles will probably be missed. The likely result is that many children's abilities will be underestimated and programmes will not be sufficiently challenging for more able pupils.

Furthermore, some of the tasks provided in BSM checkpoints are, like Piaget's own interview method, dependent on children's understanding of particular vocabulary. Children who fail a particular task may really understand the concept but are simply confused about what the interviewer means by the words in the question (Miller, 1982). In the conservation of number task, a transformation in the arrangement of the objects followed by further questioning may mislead the child into thinking that the reason for the adult asking the conservation question again is that the quantity has changed (McGarrigle & Donaldson, 1974). Take for example, the task for Checkpoint 5, Number, Objective 1. Seven cubes are dropped in a disordered array in front of the child and the child is then asked to count the objects and say how many there are. The same objects are scattered again, and the child is asked "how many are there now?". The implication of this latter question is that the number of objects has changed.

Another related problem with BSM checkpoints is that some of the language used to give the tasks for the checkpoints is of the "guess what's in my head" variety. For example, in Checkpoint 4, Number, Objective 4, the child has in front of him or her a stylised number pattern card and a set of the same number of objects. The child is asked "what is the same about that set and that card?". The acceptable answer is "both got four" or "same amount" or "same numbers". However, there might be other (irrelevant) similarities between the objects in the sets, such as shape or colour on which children comment. Research shows that, of the very high proportion of teacher utterances that are questions, very few are questions to which the teacher does not already know the answer, and often there is only one answer that is really acceptable to the teacher (eg, Wells, 1983). Wells suggests that certain children may be at a greater disadvantages than others in their unfamiliarity with this kind of "talk". When such "talk" is used to find out about children's mathematical understanding, it may create difficulties for certain children who don't know the acceptable answers to the questions. Asking children to *demonstrate* their understanding of a particular concept using objects might provide a more valid measure of their understanding than getting them to explain their reasoning.

Another problem with many of the BSM checkpoint tasks is that they are special "school" tasks which bear little resemblance to things people do in the world outside of school. This may be particularly problematic for children who have just arrived at school, and even more so for those who have not attended an early childhood centre prior to school entry.

Research shows that New Zealand teachers of new entrants can make quite accurate judgements about what their pupils know based on observations, although they do not necessarily use that information to improve their classroom programmes (Young-Loveridge, 1987b, 1989a). Similarly, Bennie and colleagues (1990) found that, despite the fact that most teachers said they used evaluation in order to establish the point at which children should enter BSM, only 16 percent of teachers at the new-entrant and J1 levels were using BSM levels beyond cycle 4. Data collected in April 1992 for another study showed that the majority of new entrant children sampled (91%) were taught mathematics using BSM, and that virtually all of these children were working on Cycle three or earlier (Visser & Bennie, 1996).

Another problem with the way that assessment tasks for early mathematics are used which Visser and Bennie (1996) identified was that almost all of the monitoring by teachers in their study appeared to be retrospective (backward looking) in nature, and measured what the students had learned (or already knew) by the end of a particular lesson or group of lessons. They found that teachers appeared to do little, if any, monitoring of children's *existing* knowledge and skills *prior* to planning a new topic (or cycle/module) in mathematics.

It is difficult to know just how much teachers have changed the ways they assess and teach mathematics since these surveys were done (eg, Bennie et al, 1990; Thackery et al, 1992; Visser & Bennie, 1996), and hence whether there is still a marked mismatch between what children know when they enter school and the kinds of activities which are being provided for them in their classroom mathematics programmes. Anecdotal evidence suggests that the development of a national curriculum statement for mathematics (MiNZC, Ministry of Education, 1992), in which the learning outcomes for all students are specified, has led to the development of programmes which may be more relevant to the learning needs of the children. Schools are certainly more accountable now for the programmes they provide, and are obliged to show how their programmes meet the needs of *all* learners.

What numeracy skills should be assessed at school entry?

There is now considerable research, both in New Zealand and overseas, which show the kinds of mathematical knowledge and skills which children entering school are likely to have (see Young-Loveridge, 1987a, 1987b, 1991a, 1993). Over the past decade or so, the numeracy skills of more than 500 New Zealand four- and five-year-olds have been studied (see Young-Loveridge, 1987b, 1988, 1989a, 1991a, 1993, 1995). In a longitudinal study of children between the ages of five and nine, correlations over time show which particular numeracy skills at school entry were most strongly predictive of children's success in mathematics later on in school (see Young-Loveridge, 1991a). The best predictors of children's later success in mathematics were forming sets, numeral recognition, pattern recognition, rote counting, sequence forwards and backwards, and addition and subtraction with imaginary objects. These seven types of tasks together accounted for between half and two thirds of the variance in levels of numeracy at the ages of six through nine.

When the findings for children who were more and less capable were examined separately, a slightly different pattern of predictors emerged (Young-Loveridge, 1991a). For the less capable children, the best predictors of latter performance were those shown by the sample as a whole (forming sets, rote counting, numeral recognition, pattern recognition and sequence forwards). However, for the more capable children, the best predictors of later performance were addition and subtraction with imaginary objects, identifying the number just before another number in the sequence (ie, sequence backwards), as well as numeral recognition, rote counting, sequence forwards, and forming sets.

The consequences of not assessing children's numeracy

Some writers argue that tests encourage teachers to adjust their teaching to match what is on the tests (eg, Kamii, 1990). Taken to its absolute extreme, this argument means never trying to find out what children actually know for fear of discovering that the classroom programme might need to be modified to match the needs of certain children better. What is important is not whether or not children are assessed, but the nature of those assessments and the purposes for which they are used. There is a delicate balance to be found between doing no assessment and subjecting children to a barrage of inappropriate procedures.

If children's numeracy skills on entry to school are not assessed appropriately, then less capable children may continue to struggle with mathematics because their particular needs are not identified (see Young-Loveridge, 1991a). They may fall further and further behind their peers in mathematics (particularly if they are girls), and develop negative attitudes towards maths which may make it impossible for them to benefit from help that might be offered later in their school years. More capable children may also lose interest in mathematics because their need for challenge is not being met.

The Development of the Shopping Game *Checkout/Rapua*

Checkout/Rapua was developed as an assessment tool for mathematics at the school entry level (see Young-Loveridge, 1994, 1997; Ministry of Education, 1997). It is based on a collection of tasks which have been used as research tools in three large studies by the author and by several other researchers (eg, Peters, 1991; Visser & Bennie, 1996; Wylie et al, 1996; Young-Loveridge, 1987b, 1989a, 1991a, 1993, 1995). Over the past decade or so, some of the tasks have been changed slightly, but each of the main types of tasks (numeral recognition, pattern recognition, forming sets, rote counting, sequence forwards and backwards, and addition and subtraction with imaginary objects) has been included in the various versions of the task-based interview.

In 1991, at the completion of a longitudinal study of children in Christchurch, an abbreviated "test" version called the School Entry Numeracy Skills Interview (SENS) was developed and made available to interested teachers (Young-Loveridge, 1991b). In 1994 a "game" version was developed (The Supermarket Maths Game) in which the tasks were embedded within the context of a board game based on supermarket shopping (see Young-Loveridge, 1994). Since then the game version has undergone further development, with the help of teachers in Hamilton and Wellington, resulting in the most recent version of the Game, described in this paper (*Checkout/Rapua*).

The current version of *Checkout/Rapua* is now somewhat different from the version that was originally proposed (see Young-Loveridge, 1994). A decision was made to eliminate the board and the dice throws, because the "moves" were difficult and frustrating for some children and slowed down the assessment process substantially. *Checkout/Rapua* now consists primarily of cards, objects, and shopping baskets. At each turn, the child picks up a card and follows the instructions on the card (depicting either numerals and/or pictures of the objects, or words which the teacher reads out to the child), getting a certain number of objects from the supermarket to put into the shopping basket in the process. Numeracy skills which are revealed by *Checkout/Rapua* include getting a certain number of objects (*forming sets*), naming numerals (*numeral recognition*), naming stylised number patterns (*pattern recognition*), saying the sequence of number names in order (rote counting), and identifying the number just after or just before another number in the counting sequence (sequence forwards and backwards, together with rote counting referred to *number sequence knowledge*), and joining and separating groups of imaginary objects (addition and subtraction with imaginary objects, together referred to as *mental operations*). The objects used in the game (many of which are miniature versions of objects found in real life) have high levels of familiarity and appeal for children. They include carrots, bananas, sausages, birthday cards and candles, sponges, pegs, buttons, nuts, dice, and notebooks. These have been selected because of their varying properties of shape, colour, texture, and weight, and because they can be used to assess mathematical concepts other than those included in the game. For example, the nuts might be put in order of size, or weighed. Buttons can be sorted in various ways, including by size and colour. Sandwiches can be put together to form a square or oblong. The dice can be ordered by set size from one to six. The names and properties of differently shaped objects can be discussed (including circle, square, oblong, hexagon, triangle). Pegs or candles can be used as non-standard units of measurement. The birthday cards can be ordered from 1 to 12, or matched with the appropriate number of candles, and so on. These concepts can be explored before, during, or after playing the game itself. These options allow for diversity in assessment practices and encourage a broadening of the curriculum. The numeracy record sheet provides space for the teacher to note how the child goes about the task. A list of faulty procedures is included on the record sheet to alert teachers to common problems they might need to look out for.

An important development with *Checkout/Rapua* has been the introduction of alternative ways to play the game. These include two children playing together while the teacher observes, and one child playing against the teacher (helping the teacher with her turn while the teacher observes). (Note: a version of the game in which one child goes through all the activities alone while the teacher observes was trialed during the development phase, but is not recommended because some of the important "game" elements, such as turn-taking, are missing and it is more like a test than a game.) The version in which one child plays against the teacher, but in helping the teacher with her turns actually completes all of the activities, is substantially quicker than the two-child version, and does not require that a pair of children be available to play. This one-child version has obvious advantages for rural schools where new entrants often arrive at widely spaced and irregular intervals, and in other schools where there is difficulty pairing new entrants who have comparable skills.

The current version of *Checkout/Rapua* takes about 10 minutes to use with one child, and abut 20 to 25 minutes with two children at a time. *Checkout/Rapua* yields valuable diagnostic information as well as information of predictive significance, including information about performance and strategies used for individual tasks. Scores for each type of task can be aggregated, allowing an examination of strengths and weaknesses in particular areas (eg, forming sets, numeral recognition, pattern recognition, number sequence knowledge, mental operations). It is also possible to calculate a total score for the purpose of comparing children within a class in terms of overall number skills. Data from earlier versions has been used to provide broad indicators, with children in the upper quartile described as experts in using numbers for their age, children in the two middle quartiles described as quite competent in using numbers, and those in the lower quartile described as novices in using numbers. *Checkout/Rapua* was designed to yield a large amount of information, including things about personal and social development, as well as other aspects of mathematics such as measurement, geometry, statistics, algebra, and mathematical processes, in addition to numeracy.

Important Features of *Checkout/Rapua*

1. Child-centred

Checkout/Rapua gives the children the opportunity to collect up a variety of objects with high levels of appeal. The children dictate the nature and pace of the game. Their enjoyment of the game takes precedence over the information-gathering purpose for which the game has been developed.

2. Meaningful context

Because *Checkout/Rapua* is set within a supermarket context, it should be a reasonably familiar and meaningful context to most children. The items in the supermarket have been chosen as objects which most, if not all, children have experienced in their everyday lives.

3. Process as well as product

Children's strategies and approaches to particular problems in *Checkout/Rapua* are just as important as whether or not they give the correct responses. Valuable diagnostic information, which can assist teachers in planning programmes, is provided by the game.

4. Usefulness to teachers

Checkout/Rapua has the flexibility to allow the inclusion of additional concepts and skills which teachers regard as important. The objects in the game have been deliberately chosen because of their potential for assessing other mathematical concepts and skills besides those included in the game itself. Teachers will be able to make decisions about what other concepts and skills are important, and use objects in the game to assess those.

5. Based on research

The five main types of tasks used in *Checkout/Rapua* have been developed on the basis of extensive research, both in New Zealand and overseas. There is substantial data about the appropriateness and usefulness of each of the tasks from more than 500 New Zealand children in the four- to five-year-old age group, including data on the levels of difficulty, discrimination, and predictive validity of almost all of the tasks (see Young-Loveridge, 1994). The reliability of the tasks used in the Game is high (.95 to .96: for details, see Young-Loveridge, 1987b, 1989, 1991a, 1993).

6. *Unobtrusive*

The recording process is intended to be as inconspicuous as possible. Teachers are encouraged to record as much as possible of what the children do and say, and to avoid putting ticks until after the activities have been completed.

At the time of writing, the professional development programme designed to train teachers in the use of *Checkout/Rapua* (as part of the School Entry Assessment package) had only just begun. The distribution of the resource to all primary schools in New Zealand in conjunction with the professional development programme will take some time. Further research is needed on the usefulness of the game for teachers and the ways they adapt it to suit their purposes.

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