The Effects of the Use of Explicit Number Names on Mathematical Understanding and Performance

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Abstract

If the explicitness of some languages in naming numbers contributes to better mathematical understanding, then how can teachers in the other languages compensate for the lack of explicitness? We have designed a pilot project of Pre-Kindergarten and Kindergarten classes in San Antonio, Texas, where we use a tens-and-ones scheme to name numbers. Measures of results include teacher interviews and assessment of the children's place value representation with manipulatives. The classes of children are followed through the years of elementary school with particular attention to progress in processes that rely on an understanding of place value.

This project began in the fall of 2004. To achieve generalizability will require a much larger project. We need similar projects in many classes using a variety of teaching styles and curricula so as to negate the effects of any one environment. To test whether this approach is applicable to other cultures and languages, we invite others to join us with similar projects.

Introduction

The superior performance of Chinese speaking countries in international tests in mathematics and science raises the question of what advantages there might be in the language itself. While many reasons for national differences in these tests can, should, and have been posited, the question of language advantage remains unanswered. A quantification of the number of words needed to name the numbers from one to one hundred was used to investigate correlation between this and position in national test rankings (Beauford, 2003). Languages considered were English, German, French, Spanish, Chinese, Japanese, and Korean. When learning to count to 100 in Mandarin Chinese, children use a total of 11 words. In English, the task requires 26 different words or word parts. Correlations were negative, strong, and significant. Almost without exception, the fewer words or word parts needed to name numbers to 100, the better was the position of the country in international comparison.

Miura and others have compared children whose primary languages were English or Japanese. In each study, the children using the more explicit Japanese number naming system showed better cognitive representation of number (Miura, 1987, 2001; Miura & Okamoto, 1989). Similar results were found when the study was expanded to include children from France, Japan, Korea, Sweden, and the U.S. (Miura, Okamoto, Kim, Steere, & Fayol, 1993). Seeing that the Arabic number name system was similar to that used in English, Alsawaie (2004) experimented with Arabic speaking children in first grade using three groups of instructions with and without explicit number names. Fuson, Grandau, and Sugiyama (2001) and Cotter (2000) report experiments with intervention strategies used with first graders with positive results.

Intervention

We patterned our project after the interventions described by Cotter (2000) and Fuson et al. (1997). Assuming that the effect of explicit number names would be most pronounced in

children with the least exposure to the traditional naming system, we chose to work with 4 and 5 years old in their early formal experiences with learning about numbers.

A small private elementary school in South Central Texas has proven to be a good place to conduct the experiment, with children in Pre-Kindergarten (4 years old) and Kindergarten (5 years old). Since 2004, the children in these classes have been learning about numbers using explicit names. In the Pre-Kindergarten class only the explicit naming system is used throughout the nine-month, full day class. In Kindergarten, explicit names are used for the first three months. Traditional names are then introduced and used along with explicit names for the remainder of the year. By first grade the children use traditional names almost exclusively. In second grade, as children are introduced to the ideas of regrouping in addition and subtraction, reference to the explicit names makes these tasks easier.

Original implementation of the program went smoothly. When permission had been received from the principal, the researcher met with the Kindergarten and Pre-Kindergarten teachers to explain the intervention. They were enthusiastic about the possibilities for such a strategy. They reviewed the materials that they had been using to alter what was necessary to make the change to explicit number names. In some cases, songs, posters, and rhymes were changed or their use postponed until time for the use of traditional names. Decisions were made to standardize what was done in each class. It was decided that counting in the Spanish classes for these children would follow the same pattern. Children were taught to count to ten and then continue with "one ten one, one ten two, . . . , two ten, two ten one, two ten two." This differs somewhat from the Mandarin system were 11 is expressed as "ten one" rather than "one ten one." The American teachers felt that the pattern would be more easily understood if it started in the numbers from 11 to 19 rather than to wait until the 20s to begin to enumerate tens. In an effort to build an investigation of the intervention free from other curriculum, no new instructional strategies were used other than the way the numbers were named.

An initial meeting with parents was included in the school orientation for Pre-Kindergarten and Kindergarten. The research was explained and supported with copies of Cotter (2000) article. Parental questions were few. In subsequent years, the intervention has been taken as part of the normal curriculum. School personnel explain the explicit naming of numbers to parents and answer any questions they may have. Teachers report that most parents use the explicit names in support of what the children are learning in school.

Methodology

Devising valid and reliable ways to assess cognitive representation has required the most effort and creativity by the researchers. It was quickly discovered that methods used with first graders in earlier studies were not appropriate for the younger children unable to grasp the abstraction needed to model numbers with the base-ten blocks used in earlier studies. The use of straws that were physically bundled in groups of ten, but still able to be counted by the children seemed to work better for our purposes. They had seen their teachers bundle groups of ten straws and had themselves made groups of ten other small items as they counted them in class activities.

Distractibility and shyness of young children also proved problematic. However, familiarity and experience with researchers have contributed to an improved assessment scenario. The researchers have learned to visit the children several times before assessment so the students are more comfortable with the assessment process.

Changes in teaching staff and turnover in school children also threaten reliability and validity. The student population in this small school has been more stable than might be expected in public schools. The Kindergarten teacher has remained the same since the beginning of the

project. However, the Pre-Kindergarten teacher has changed each year. Teacher ability, personality, and dedication to the project can be seen to make differences from year to year.

The children have been tested at the end of each semester to record progress in their abilities to recite the counting numbers, use them in counting objects, read and represent numerals. The teachers were consulted throughout the year and formally interviewed with semi-structured protocol at the end of 2006-2007 school year. The interviews were conducted in two settings—first and second grade teachers together and Kindergarten and Pre-Kindergarten teachers together.

Results

The first and second grade teachers were interviewed together to talk about the long-term results they see in their children as a result of the project. The children in the second grade had experience using the explicit names for numbers exclusively only during the first three months of their Kindergarten year, and then along with traditional names during the remainder of the year. Their teacher described the class as challenging. She does not use explicit names at all, but reports, "Sometimes when adding and subtracting, students will say how many tens and ones are modeled with the manipulative but [they] never use explicit names in conversation." The first grade children experienced a full year of using explicit names for numbers during their Pre-Kindergarten class. Their teacher reports that they understand place value better than the class before them. She expressed concern in the early part of the year that not all students used traditional names for numbers. She uses only traditional names and reports that she never hears explicit names used by the end of the year.

The Kindergarten teacher has now completed her third year with the project. She has become quite comfortable with it, but seems to prefer the use of traditional names when the time comes. She refers back to explicit names when talking about place value, but not often otherwise. She reports that the children will revert to explicit names if they don't remember the traditional name. No stigma is attached to the use of either naming system. She has noticed that the children seem to make a clearer distinction between digits and letters, but sometimes confused the number 1 and the letter l.

The Pre-Kindergarten teacher uses explicit names exclusively for the full year. Her students focus on understanding, counting, and reciting numbers. She reports that the children are easily learning to identify "ten and something else" as they investigate numbers. The use of explicit names seems to result in less cognitive interference. The teacher notices stronger ability to read numbers, better understanding of 0 as a place holder, better differentiation between number and digit, not as much confusion between numbers and letters. "The association of the name with the number is really there."

Two formal assessments were made of the children in our study during the 2006-2007 school year. The first was conducted in the fall, November, 2006, and the second in the spring, May 2007. Nineteen Pre-Kindergarten students were assessed in November (n=19). Three Pre-Kindergarten students were not assessed in May (n=16). Twenty-one Kindergarten students were assessed in November (n=21), but seven were missing in May (n=14). Both classes were predominantly female, with 14 girls each. The Pre-Kindergarten had 5 boys and the Kindergarten had 7 boys.

The Kindergarten children used predominantly traditional number names in both assessment periods. The Pre-Kindergarten children used predominantly explicit number names in both assessment periods. We found interesting differences between the two groups of children that might be accredited to number name use.

Recitation counting. The Pre-Kindergarten teacher reported a goal for the class to be able to count to 30, both in recitation and with objects. The Kindergarten teacher expected her class to be able to recite the number to 100, with mastery to 30. When asked to "count as far as you can," the Pre-Kindergarten

children counted to a mean of 17.3 in the fall and 64.7 in the spring with ranges from 6 to 59 and 10 – 100 respectively. Four Pre-Kindergarten children did not meet the goal of counting to 30 by the end of the year. The Kindergarten children counted to a mean of 63.3 in the fall and 79.7 in the spring with ranges from 10 to 100 in the fall and 20 – 100 in the spring. Two Kindergarten children did not meet the goal of counting to 30 with mastery by the end of the year.

Correctness of recitation of numbers was recorded as "correct," "with minor errors," "with decade errors." Minor errors included reversing contiguous numbers and skipping a number. Skips of a large sequence of numbers were recorded with the last correct number as the final number. Errors when transitioning from one decade to the next were recorded as a "decade error." In the first assessment in November, minor errors were rare in both grade levels. Decade errors occurred only for children in using traditional number names.

In May, minor errors were still rare. One Pre-Kindergarten and three Kindergarten students made decade errors. Pre-Kindergarten students were observed counting on their fingers or in their heads (whispering) to decide which decade came next. Such problem solving was not apparent in the Kindergarten children using traditional number names.

Reading two digit numerals. Children were shown cards with the numerals 12, 26, 15, 43, and 30. In November the Pre-Kindergarten children made some errors 56% of the time and 7% of the time no attempt was made to read the numeral. Only one Pre-Kindergarten child read one numeral using the traditional name. The Kindergarten children made errors 23% of the time and made no attempt 5% of the time. Interestingly, two children (10% of the reading attempts) chose to use explicit number names in the reading. Digit reversal occurred only with the use of traditional names.

By May the errors from Pre-Kindergarten at decreased significantly. Only 18% of the readings were wrong is some way. Three (4%) of these were a reversal of digits. Twice a child merely read the digits left to right. The rest of the errors occurred when a child misread a digit, for example, read 26 as "1 ten 6." Because of interruptions in the school day, it was not possible to assess all the Kindergarten children. The Kindergarten children made errors in 14% of the readings. Five (7%) were reversal of digits. The other errors involved a misreading of digits. One child did not attempt to read any of the numerals; another did not attempt the first two.

Identifying the tens and ones digit. In the spring assessment, children were asked to point to the digit that "tells us how many tens" and "how many ones" in the numerals 14 and 23. The Pre-Kindergarten children were much more willing or able to answer the questions than the Kindergarten children. Pre-Kindergarten children answered correctly 66% of the time they attempted to answer. They did not answer 14% of the time. For each numeral, one Pre-Kindergarten child answered "1+4=5" and "2+3=5." Kindergarten children answered correctly 51% of the time they attempted to answer. They did not answer 37% of the time.

Modeling numbers. After watching the researcher model the numbers 14 and 23 with bundles of ten straws and single straws, the children were asked to do the same with 11, 28, 13, 42, and 30. We recorded whether the child read the numeral correctly and how the number was represented. In general, there were three types of responses: the child either modeled the number with the correct number of tens-bundles and units, or modeled the number correctly using all single straws, or did not model the number correctly. Those occurrences where the proper number of single straws were place in the "tens bucket" were recorded separately. Separate errors were recorded for reversing the numbers of bundled and single straws required. Most errors involved miscounting or putting some number of straws in the buckets with no apparent meaning.

In November, the Pre-Kindergarten assessment resulted in only 19% of the models correct using bundles of tens and single straws and no children modeled the numbers correctly using single straws. In three models, children used only single straws, but put the correct number of single in the ten-bucket (to model 13, they used one straw in the tens-bucket and three straws in the units bucket). Errors were recorded in 78% of the models. The Kindergarten students were able to model 17% of the numbers correctly using bundles and units. They also modeled the numbers correctly using single straws 23% of the time. Occurrences of reversed digits and single straws in the tens bucket were more common, too. Only 44% of the models were completely incorrect.

By May the Pre-Kindergarten children had caught up with the Kindergarten students with 31% of the models correct with bundles and single straws. The ability of some Pre-Kindergarten students to model using single straws also improved with 13% of the models in this category. There were more examples of single straws in the tens-bucket and reversed digits with fewer 44% with completely incorrect representations. The Kindergarten class did not show much improvement over the year. They had 30% of the models correct using bundles and units and 21% correct using single straws. There were no reversals and only one use of single straws in the tens bucket. Errors remained steady at 44% of the models.

Summary of Results

The teachers reported that using the explicit names was beneficial to children's learning. They noted less interference, less confusion between numeral and number and between digits and letters. They were pleased to see that children had a better grasp of the use of 0 as a place holder. Although all children assessed in 2006-2007 had experienced the use of explicit number names during Pre-Kindergarten, children using explicit number names during assessment made fewer decade errors. They were also better able to identify the tens and units digits in two digit numbers. With a clearer number naming pattern, they used the pattern to decide how to move from one decade to the next when reciting numbers.

Possibilities for Transfer to Different Environments

Since the beginning of the project in the fall of 2004, we have worked to develop strategies and techniques to improve the validity and reliability of assessment of these young children. While the site has proven to be a valuable learning laboratory for research strategy, the small size dictates that it can only be considered a pilot project. To achieve generalizability will require a much larger project. We need similar projects in many classes using a variety of teaching styles and curricula so as to negate the effects of any one environment. We plan a larger project involving many more children in the fall. To test whether this approach to is applicable to other cultures and languages, we invite others to join us with similar projects.

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