The Association between Students' Number Knowledge and Social Disadvantage at School Entry

Peter Gould
NSW Department of Education and Communities
<peter.gould@det.nsw.edu.au>

At the start of the Kindergarten year in NSW government schools, teachers gather information on several aspects of children's number knowledge to guide their teaching programs. This includes knowledge of the sequence of words used for counting, numeral identification, and using counting to solve problems. This study investigated the interaction between socio-economic disadvantage in NSW government schools and Kindergarten students' number knowledge on entry to school in 2013. There is a strong association between the measure of socio-economic disadvantage and the proportion of Kindergarten children starting school with limited number knowledge, underscoring the need for high quality early number programs in these communities.

Children from different socio-economic backgrounds enter school with very different skills (Duncan & Magnuson, 2011). Comparing children in the bottom and top quintiles of socio-economic status (SES) in the USA, Duncan and Magnuson report that low-SES children are 1.3 standard deviations lower than high-SES children in their kindergarten-entry mathematics skills. Not only do low-income children enter kindergarten well behind their middle-income peers on indicators of early number knowledge in the USA, but this gap does not narrow during the course of the school year (Jordan & Levine, 2009).

As early mathematics is a stronger predictor of later achievement than early reading or behaviour (Duncan et al., 2007) it is important to understand how closely early mathematics knowledge and social disadvantage are related in New South Wales. Moreover, interventions designed to assist students to reach the expected performance standards of the early years of school rely on knowledge of the factors particular to the cohort, as well as the individuals within the cohort—where they are starting from compared to the class and the rest of the state. Otherwise, children who start school significantly behind their peers may never be able to catch up (Stipek & Ryan, 1997).

In NSW, Kindergarten teachers in government schools interview every child in their class in the first five weeks of school, using the *Best Start Kindergarten numeracy assessment* (NSW DET, 2007), and enter that information in an online database. The aggregated information from the *Best Start Kindergarten numeracy assessment* provides a comprehensive portrait of the number knowledge children bring to school (Gould, 2012). It also provides an opportunity to ascertain if the number knowledge of students starting Kindergarten in NSW government schools is influenced by socioeconomic status and to what degree. In particular, are some components of number knowledge more susceptible to the influence of socio-economic status than others?

Assessing Number Knowledge

When using number, children must integrate many layers of verbal, procedural, symbolic and conceptual meaning. The *Best Start Kindergarten numeracy assessment* is used to gather information on students' knowledge of the correct sequence of counting

2014. In J. Anderson, M. Cavanagh & A. Prescott (Eds.). Curriculum in focus: Research guided practice *(Proceedings of the 37th annual conference of the Mathematics Education Research Group of Australasia)* pp. 255–262. Sydney: MERGA.

words, their ability to identify numerals, using counting to solve problems, and recognition of the repeated unit in a pattern (NSW DET, 2007). These different aspects of children's early mathematics knowledge encompass the use of counting words as numerical tools as well as the development of non-verbal number systems (Wiese, 2003).

The levels used to describe the progression of counting sequences are based on the work of Wright (1994, 1998). Advancement through the levels of knowledge of counting sequences relies on two features: being able to produce the correct sequence of counting words to progressively higher numbers (10, 30 and 100), and being able to recognise the pattern within the number words to produce the next number in the sequence without needing to reproduce the whole sequence. At the most basic level, a student who cannot consistently produce an oral count from one to ten is referred to as an emergent counter, or at the emergent level on knowledge of the forward number word sequences (Wright, Martland, & Stafford, 2006).

The use of number symbols can be described in terms of their production and recognition (Mark-Zigdon & Tirosh, 2008). The *Best Start Kindergarten numeracy assessment* gathers information on whether children can name the numerals, initially from 1 to 10 and then to 20 and beyond. Although words, objects and numerals can all be used to represent quantity, recent research suggests that the brain processes numeric symbols differently to number words (Shum et al., 2013).

A child's use of counting strategies to solve addition and subtraction problems develops through a series of well-documented stages (Fuson, 1992; Steffe, 1992). Over time children learn to recognise that a number word can replace the process of completing a count, enabling them to count-on or count-back to add and subtract. First, children need to be able to count objects. Being able to count objects relies on children being able to produce the correct sequence of counting words, matching each word to one and only one object, and recognising that the last number word stated corresponds to the total of the objects.

Measuring SES in NSW Government Schools

Developing current, relevant and cost effective methods of measuring disadvantage in NSW government schools is not a simple task. The challenges have been highlighted through the development in Australia of the Index of Community Socio-Educational Advantage (ICSEA). In creating ICSEA as a nationally comparable measure, coordinating the data that contributes to the measure takes time. Consequently, as a measure of SES, ICSEA values reflect the previous calendar year rather than the current year.

Any measure of disadvantage also needs to be able to account for missing data values. For example, in calculating the 2012 ICSEA values, 14 per cent of schools had ICSEA values calculated based on census data on family background rather than direct parent data, which created variation in the comparability of index values. Further, as ICSEA is based on a regression technique that has difficulty dealing with outliers, there is year-to-year variation in ICSEA values for all schools. This variation in the measure of disadvantage led to the need to develop the Family Occupation and Education Index (FOEI) for NSW government schools (CESE, 2013).

FOEI is a school socio-economic index that is based on parents' highest level of school education, non-school qualification and occupation status. The index includes all students enrolled in all NSW government schools and represents each school's average socio-economic advantage relative to other NSW government schools. FOEI ranges from 0 to approximately 300, with a mean of 100 and a standard deviation of 50. Higher FOEI scores indicate higher levels of need (i.e., lower socio-economic status). FOEI only includes the core socio-economic factors of parental education level and occupation status, which accounts for more than 70 per cent of the variation in performance across schools (CESE, 2013, p. 2). FOEI is an interval variable and the best currently available SES measure for NSW government schools.

Method

The data from the *Best Start numeracy assessment* of 69 545 Kindergarten students in 2013 were matched to the Family Occupation and Education Index of the government school in which they were enrolled. FOEI was treated as the independent variable. Results for schools with the same FOEI value were combined. Where there were 10 students or fewer enrolled in Kindergarten for a given FOEI value, the point was excluded. This reduced the number of data points by 9 to 198 points.

An exploratory data analysis was carried out, investigating the strength of relationships between social disadvantage and aspects of number knowledge. Scatter plots were created to identify possible relationships between socio-economic status and each of the aspects of number knowledge. FOEI is an interval measurement and the percentage of students at a given level in an aspect of number knowledge is a ratio measurement. This satisfies the first data assumption required in using Pearson's correlation coefficient to measure the strength of any linear association, namely that the variables are at the interval or ratio level. Additionally, the variables should be approximately normally distributed.

The scatter plots were examined for linearity and variance in the spread of the points across the domain. To create a model of any relationship suggested by the data, it is necessary to consider the differences between the observed values and the values predicted by the model. These differences are known as residuals. The residuals in a linear regression model are expected to vary in a random fashion. That is, the model should predict values higher than those observed and lower than those observed with equal probability (homoscedasticity). To investigate the behaviour of the residuals, the standardised residuals were also plotted for each of the different aspects of number knowledge.

Results and Discussion

Forward Number Word Sequences

In assessing students' knowledge of the sequence of counting words (oral counting), the teacher asks the student to start counting from one. When children first learn to produce an oral count it usually has an accurate proportion which, over time, becomes progressively longer. The *Best Start numeracy assessment* seeks to determine how far a student can accurately count. Students who cannot produce a correct oral count to 10 are characterised as being at the emergent level. Figure 1 shows the distribution of the percentage of Kindergarten students who are at the emergent level on knowledge of the forward sequence of number words by socioeconomic background.

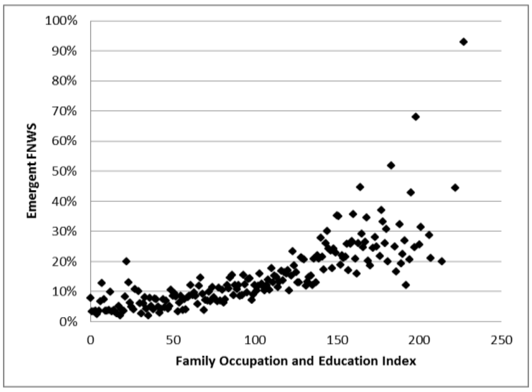

Figure 1. Percentage of Kindergarten students at the emergent level of forward number word sequences.

As the values of FOEI increase beyond 150 (Figure 1) the estimates of the percentage of emergent counters begin to vary markedly from a linear relationship. That is, not being able to count to ten on entry to school does not vary simply as a function of socio-economic status. A plot of the standardised residuals can be used to further interrogate the assumption that the variables have a linear relationship. The plot of standardised residuals (Figure 2) confirms that the variation from the linear model increases for larger FOEI values in a way that is not balanced around 0. That is, the scatter of the standardised residuals does not appear random but rather is heteroscedastic.

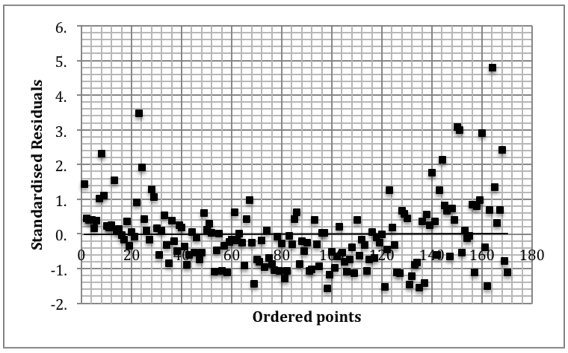

Figure 2. The standardised residuals of percentage of emergent FNWS as a linear function of FOEI.

Overall, less than 12% of Kindergarten students start school not being able to produce a correct oral count to ten. Being able to produce an oral count to 10 on entry to school does not appear to be an effective way of summarising children's counting knowledge when looking for variation by socio-economic background. Indeed, producing an oral count to 10 on entry to school predominantly measures long-term serial memory.

Another way to examine the data associated with oral counting is to compare those who can readily break the sequence of counting words and identify the next counting number from those who cannot. This is an important skill which contributes to using a number word to stand in place of a completed count to count-on or count-back. Is there a linear relationship between the percentage of each Kindergarten group who could not name the next number without recreating the count and socioeconomic status? Figure 3 shows a scatter plot of this relationship, which is clearly linear with a small number of outliers.

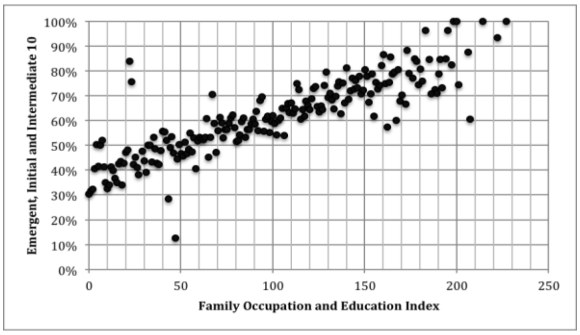

Figure 3. Percentage of Kindergarten not able to readily identify the next number word.

The standardised residuals of the plot of the percentage of students not able to readily break the chain of counting words (Figure 4) are balanced around zero with a few outliers evident (i.e., |standardised residual| > 3). The two measures are strongly correlated $r(197) = 0.87$, $p < 0.001$. The coefficient of determination (r^2) provides an estimate of the per cent of variation in one variable that is explained by the other variable. The coefficient of determination indicates that there is about 76% of common variation in FOEI and the percentage of students starting school unable to identify the number word that follows a stated number without recounting. Almost 57% of Kindergarten students started school not being able to state the next number word without recreating the counting sequence.

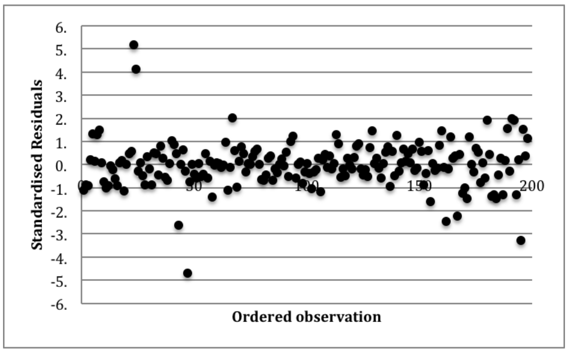

Figure 4. The standardised residuals by order of points (FOEI and identifying the next number word).

The outliers are worthy of further investigation as they identify locations where children are starting school with significantly more or less knowledge of counting words than is explained by the occupation and level of education of parents. For example, why would a school with a FOEI value of over 200 have a similar percentage of Kindergarten children not able to identify the next number word (without recreating the count) to schools with FOEI values 100 fewer?

Although the percentage of Kindergarten students being able to produce an oral count to ten is not closely associated with SES, being able to state the next number word without recreating the count does correlate strongly with FOEI. This suggests that Kindergarten students in schools serving disadvantaged communities might especially benefit from teaching programs that emphasise the ‘number word after’ and the ‘number word before’ activities over rote counting to ten.

Numeral Identification

In assessing numeral identification, we seek to ascertain whether children have formed the link between the verbal and the symbolic models of number. Numeral identification requires the student to name a numeral that he or she is shown. Numeral identification can represent an important advance in children's thinking.

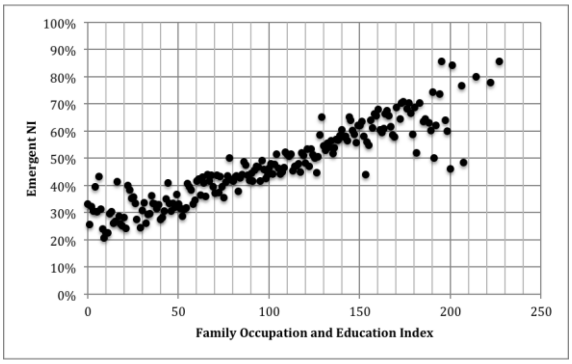

Figure 5. Percentage of Kindergarten enrolment not able to identify the numerals 1 to 10.

The association between not being able to identify the numerals from 1 to 10 and socio-economic background appears quite strongly linear (Figure 5). In 2013, Kindergarten students identified as emergent at numeral identification corresponded to 42.3% of the cohort.

The standardised residuals of the linear model associated with Figure 5 are generally balanced around zero with only 4 outliers. The underpinning assumption of linear regression is that the theoretical residuals are independent and normally distributed. Just on 11 standardised residual points out of 198 are beyond ±2 standard deviations. That is, 94.4% of the standardised residuals are within 2 standard deviations suggesting that the residuals can be considered as approximately normally distributed. Even if the theoretical residuals are not absolutely normal, with a sample size of almost 200, inferences based on the assumption of normality will still be approximately correct.

As the data in Figure 5 suggests a very strong linear relationship, the Pearson product-moment correlation coefficient was computed to assess the relationship between socio-economic status as measured by FOEI, and the percentage of students who could not identify the numerals 1 to 10 on entry to school. There was a very high positive correlation between the two variables [$r = 0.92$, $N = 198$, $p < 0.001$]. The coefficient of determination indicates that there is about 85% of common variation in the Family Occupation and Education Index (FOEI) and the percentage of students starting school unable to identify the numerals 1 to 10.

In government schools serving higher SES communities (those 2 standard deviations or more away from the mean FOEI measure) about one-quarter of the children start school not being able to identify the numerals 1 to 10. This percentage grows by approximately 11% for each standard deviation change ($\sigma = 50$) in FOEI.

Object Counting

Object counting is quite a complex skill, as it requires the coordination of the counting words with objects and being able to make the shift from using words to label individual objects, to use the final number word as a summary of the count. When children integrate counting and cardinality they begin to use their counting to address questions of "how many?" Figure 6 shows the percentage of Kindergarten students who were emergent counters on entry to school by Family Occupation and Education Index of the schools.

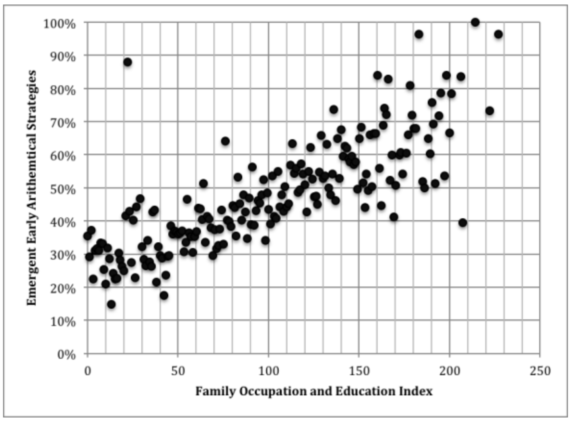

Figure 6. Percentage of Kindergarten enrolment not able to count 8 objects.

The degree of association between the percentage of emergent object counters and the family occupation and education index is not as tightly clustered around a line of fit as the percentage of students who cannot identify the numerals 1 to 10. However, the percentage of children starting school not able to count 8 objects and the Family Occupation and Education Index are also highly correlated [$r = 0.81, N = 198, p < 0.001$].

The three measures of number knowledge—being able to state the next number without recreating the count, identifying the numerals 1 to 10, and object counting—are all strongly correlated with the FOEI measure of socio-economic background.

Conclusion

Knowing which components of number knowledge are most strongly associated with socio-economic status in NSW Government schools contributes to the evidence base needed to optimise early intervention programs. Teaching programs in early number need to address the significantly different background knowledge children bring to school as early as possible. Carefully designed experiences in early number are particularly important in preschool settings servicing low socio-economic communities to reduce the disparities in the background knowledge that have been identified in this study. Investigation of outliers in the data could identify locations where this has been achieved.

The strong predictive value of early mathematics knowledge for later academic achievement highlights the importance of well-structured interventions in schools serving low socio-economic communities. Well over half of the variation in the percentage of Kindergarten students starting school with limited knowledge of object counting, identifying numerals, and flexible use of oral counting is accounted for by the Family Occupation and Education Index of the school.

Acting early to ameliorate the problem of children starting school behind their more affluent peers offers better, more cost effective social and economic outcomes for society than interventions later in the lifecycle of the problem. However, although the association between socio-economic background and the number knowledge with which children start school is clear, early childhood educators have different opinions about intentionally teaching mathematics to young children. Not only is the appropriateness of teaching mathematical concepts to children in early childhood settings contested, but what to teach is subject to debate (Cohrssen, Church, Ishimine, & Tayler, 2013).

The strong association between children's object counting, knowledge of the next number in the counting sequence and particularly being able to articulate the names of numerals, with socio-economic background, identifies what needs to be addressed to reduce the risk of those starting behind in their mathematics learning staying behind in their mathematics learning. Determining the most effective ways of reducing the risk to students commencing school in low SES communities needs further research.

References

Centre for Education Statistics and Evaluation (CESE). (2013). *Getting the Funding Right: Using the Family Occupation and Education Index (FOEI) to Identify Disadvantage in NSW Government Schools*. Retrieved from http://www.cese.nsw.gov.au/images/stories/PDF/CESE_Learning_Curve5_FINAL_FOEI.pdf.

Cohrssen, C., Church, A., Ishimine, K., & Tayler, C. (2013). Playing with maths: Facilitating the learning in play-based learning. *Australasian Journal of Early Childhood, 38*(1), 95-99.

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., … Japel, C. (2007). School readiness and later achievement. *Developmental Psychology, 43*(6), 1428–1446.

Duncan, G. J., & Magnuson, K. (2011). The nature and impact of early achievement skills, attention skills, and behaviour problems. In G. J. Duncan & R. J. Murnane (Eds.), *Whither Opportunity? Rising Inequality, Schools, and Children's Life Chances.* (pp. 47-69). New York: Russell Sage Foundation.

Fuson, K. C. (1992). Research on whole number addition and subtraction. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching & learning.* (pp. 243-275). New York: MacMillan.

Gould, P. (2012). What number knowledge do children have when starting Kindergarten in NSW? *Australasian Journal of Early Childhood, 37*(3), 105-110.

Jordan, N. C., & Levine, S. C. (2009). Socioeconomic variation, number competence, and mathematics learning difficulties in young children. *Developmental Disabilities Research Reviews, 15*, 60-68.

Mark-Zigdon, N., & Tirosh, D (2008). Kindergarten and first graders' knowledge of the number symbols: Recognition and production. *Focus on Learning Problems in Mathematics, 30(*1), 1-11.

NSW Department of Education and Training (DET). (2007). *Best Start Kindergarten Assessment Numeracy – A parent's guide*. Retrieved from http://www.schools.nsw.edu.au/media/downloads/languagesupport/best_start/numeracy/english.pdf.

Shum, J., Hermes, D., Foster, B. L., Dastjerdi, M., Rangarajan, V., Winawer J, Parvizi J. J. (2013). A brain area for visual numerals. *The Journal of Neuroscience, 33*(16), 6709-6715.

Steffe, L. P. (1992). Learning stages in the construction of the number sequence. In J. Bideaud, C. Meljac & J. Fischer (Eds.), *Pathways to number: Children's developing numerical abilities.* (pp. 83-88). Hillsdale, NJ: Lawrence Erlbaum.

Stipek, D. J., & Ryan, R. H. (1997). Economically disadvantaged preschoolers: Ready to learn but further to go. *Developmental Psychology, 33*(4), 711-723.

Wiese, H. (2003). *Numbers, Language and the Human Mind.* Cambridge: Cambridge University Press.

Wright, R. J. (1994). A study of the numerical development of 5-year-olds and 6-year-olds. *Educational Studies in Mathematics, 26*, 25–44.

Wright, R. J. (1998). An overview of a research-based framework for assessing and teaching early number learning. In C. Kanes, M. Goos, & E. Warren (Eds.) *Teaching Mathematics in New Times* (Proceedings of the 21st annual conference of the Mathematics Education Research Group of Australasia, Gold Coast, pp. 701–708). Sydney: MERGA.