Hurdles in Acquiring the Number Word Sequence

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Learning the sequence of number words in English up to 30 is not a simple process. In NSW government schools taking part in *Early Action for Success,* over 800 students in each of the first 3 years of school were assessed every 5 weeks over the school year to determine the highest correct oral count they could produce. Rather than displaying a steady increase in the accurate sequence of the number words produced, the Kindergarten data reported here identified clear, substantial hurdles in the acquisition of the counting sequence, as well as a number of acquired potholes.

A fundamental part of learning to quantify exactly, in contrast to the approximate number system, is being able to produce the number words in the conventional order. That is why acquiring the sequence of counting words is considered one of the most important tools of early mathematics learning. To support children's developing number knowledge it is important to ascertain how well children can generate and use the counting sequence, not only when they start school but also during the initial years of school. For example, in NSW approximately 87% of children start school being able to produce an oral count at least to ten (Gould, 2012). How then does command of the counting sequence develop over the first year of school?

Children's counting has been described as having two phases that overlap: an acquisition phase and a later elaboration phase (Fuson, 1988). In the acquisition phase, children learn to say or recite the sequence of counting words correctly. In the elaboration phase, children learn to pick up the count from any point, identifying the number word that comes before or immediately follows any counting word. The two phases, acquisition and elaboration, overlap because the initial part of the sequence may be undergoing elaboration while later parts are still being acquired. In particular, the counting sequence to 10 may be elaborated while children are still struggling with the teens.

The idea of children having accurate counting sequences that increase in length over time has led to the creation of a number of models of levels of knowledge of the counting sequence (e.g. Siegler, & Robinson, 1982; Fuson, Richards, & Briars, 1982; Wright, 1994). Siegler and Robinson described the counting of children 3–5 years of age as falling into one of three groups of responses by examining the ranges of their highest counts. One group of responses was for children who stopped counting by the number 19, another group stopped between 20 and 99, and one group proceeded beyond 100. They noted that the groupings were highly, but not perfectly, correlated with age (p. 252).

When Fuson and colleagues outlined the acquisition of the sequence of number words, children's counting was described as having an accurate sequence, a stable incorrect portion and a variable incorrect portion (Fuson, Richards, & Briar, 1982, p. 35).

> The most common form of sequences up to thirty is the following: an initial group of words that is some beginning part of the conventional sequence (e.g., "one, two, three, four, five"), a next group of words, which deviates from the conventional sequence but which is produced with some consistency by a given child (e.g., "seven, nine, ten, twelve"), and a final group of words, which has little consistency over repeated productions (e.g., "fourteen, eighteen, thirteen, sixteen, twenty").

Wright's (1994) model of the development of children's number word sequences was an adaptation of Fuson's (1988) study of children's acquisition and elaboration of number word

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sequences, effectively synthesising the acquisition and elaboration phases. Initially, Wright's early levels of knowledge of forward number word sequences focused on children producing an oral count to 20, similar to Siegler and Robinson. Wright later revised the early levels of forward number word sequences to emphasise the elaboration of the sequence to 10, and then to 30 (Wright, 1998; Wright, Martland, Stafford, & Stanger, 2002).

Beyond 20, the sequence of number words is well structured in that the same cycle of number words (i.e., one, two, … nine) is appended to the term used for the relevant multiple of ten (e.g., twenty-one, twenty-two, … twenty-nine). Children face two challenges when counting across the decades—being mindful not to continue past nine when creating compound number words and so avoiding incorrect constructs like "twenty-ten" and, knowing the name of the next multiple of ten. The names of the multiples of ten are irregularly formed and add to the demands of crossing the decades.

Challenges in Learning to Count to 30

To understand the challenges children face in learning to produce an oral count, it must be acknowledged that the number-naming system in English is more difficult than it is in many Asian languages that make the underlying base-ten structure obvious (Miura & Okamoto, 2003). When children learn to say the counting words in English, it is quite common for them to experience problems understanding the *teens*. As well as reversals in the construction of the number words in the teens, where the smaller value is named before the larger value (e.g. the *four* comes before the *ten* in *fourteen*) students need to interpret two different modifications of "ten": namely "teen" and "ty", neither of which is heard as ten. Students must learn that nine*teen* follows eigh*teen* but twen*ty* follows nine*teen*. Further, for no apparent reason that students can fathom, the number between fourteen and sixteen is not "fiveteen".

Adding to the confusion of the changing naming order, the teen number words often sound very similar to other number words; for example, thirteen sounds similar to thirty, fourteen to forty, fifteen to fifty, and so on.

This study was designed to address the research question, how does the highest correct oral count change as Kindergarten children acquire the sequence of counting words over the first three terms of formal school?

Method

To determine whether children abstract the less-than-obvious structure of the string of counting words and are able to use this knowledge to extend their counting, changes over time in the highest count they can achieve provide useful insights. If children make no use of the structure of the teens then all of the highest counts recorded in this range to 20 would be equally likely. Similarly, making use of structure beyond 20 would see common stopping points occurring in students' counts before the transition to a new decade.

Participants

During 2015, 16 of the schools taking part in *Early Action for Success* were supported by the appointment of dedicated Mathematics Instructional Leaders to work in the early years. The Mathematics Instructional Leaders were selected on the basis of successful experience in instructional leadership that resulted in improved learning outcomes for students. All of the schools serve lower socio-economic communities with the majority of students from language backgrounds other than English. In the Kindergarten classes in these schools 15% of students could not count to 10 at the start of the year, which is a little higher than 13% across all NSW public schools. Among other aspects of number knowledge, the acquisition of the counting word sequences was very closely monitored for students in these schools.

Data Collection and Organisation

In the fifth week of the first school term in 2015 the highest number word each Kindergarten, Year 1 and Year 2 student could correctly reach in the counting sequence when counting from one was recorded. This process was repeated at week 10 of the first school term and again in weeks 5 and 10 of the second and third school terms. In total, this created six data collection points. In looking at the highest count achieved, this study investigates the acquisition of the forward number word sequence, not its elaboration. Only the Kindergarten data are reported in this paper.

One of the schools missed the first data collection due to a delay in the recruitment of the instructional leader. This resulted in the first data collection having fewer than 800 students. However, missing data in longitudinal studies are common and the statistical model used for the analysis influences the ways missing data are handled. As a student's highest count is not an interval measure, the popular longitudinal method of analysis of variance is not appropriate for this study. Instead, an initial trend analysis will be used. Comparing the data distribution with and without the sixteenth school indicated that including the data did not change the shape of the distribution. This supported the use of *available case analysis* to maximise sample size, as most published studies in the development of children's counting have relatively small cohorts. Student data were only used in the analysis if the highest counts were entered on at least three out of six occasions for a student.

Results and Discussion

Highest Count Week 5 Term 1

It is clear from the graph of the highest count achieved by Kindergarten students (Figure 1) that progression through the acquisition of the sequence of counting words does not appear to be smooth.

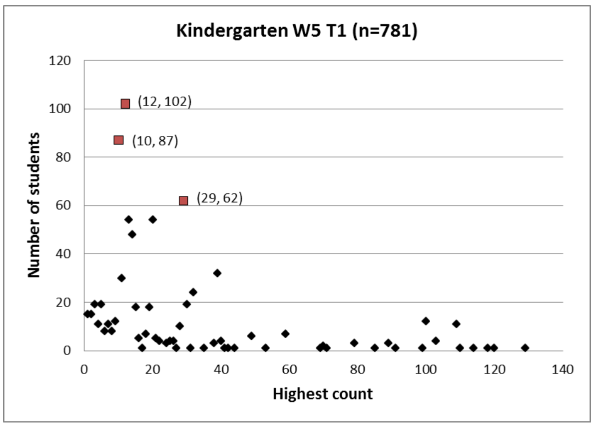


Figure 1. Kindergarten students' highest count recorded in Week 5, Term 1.

The most frequent stopping place when counting for this group of Kindergarten students was 12, with 102 students (13%) ending their correct oral count at this point. Being able to correctly continue counting in the teens is a high hurdle for Kindergarten students at the start of the school year. This result strongly contrasts with the findings of the smaller study by Siegler and Robinson (1982). Their participants were 13 3-year-olds, 19 4-year-olds, and 10 5-year-olds assessed on four occasions, each occasion separated from the next by about 10 days. Siegler and Robinson concluded that "children who did not count as high as 20 showed no obvious pattern in their stopping points" (p. 259).

The next most frequent stopping point for the Kindergarten students' counting is 10, again demonstrating a common pattern within the count to 20. For 87 students (11%), 10 was the highest oral count achieved. This may well be influenced by prior to school experiences and expectations of counting. After all, learning to count to 10 is a significant achievement before starting school. It is possible that for some children, completing the *count to ten* signals achieving all that is expected of the act of counting.

Using the structure of the teens. Counting through the teens is a well-known area of difficulty for those learning to count in English. Children must learn the sequence of number names to twelve before they encounter the naming scheme for the teens. The suffix "teen" is effectively used to mean "and ten" with number words like fourteen. Within the seven "teen" number names, two have irregular prefixes—thirteen and fifteen.

Fuson (1988) has stated that there is some controversy in the literature as to whether children learn to use the structure of the teens (despite its irregularities) or the teen words need to be learnt as separate new words. She concludes, "Evidence of various kinds indicates that, except possibly for 18 and 19, the latter is the case for most children" (Fuson, 1988, p. 39). However, this statement is not supported by the Kindergarten data of the highest correct oral count achieved at the start of the school year. If each of the teen words needed to be learnt as separate new words one would expect roughly equal numbers of students with their highest counts recorded as 13 through 19. Compared to the number of Kindergarten students whose highest correct counting sequence ended at 13, only one-third of this number ended their count at 15. If a Kindergarten student could correctly count past 15 he or she was likely to be able to correctly count to at least 19. Accessing the more regular sequence in the teens of sixteen, seventeen, eighteen and nineteen might have influenced this reduced challenge in the tail end of the teens.

The third most frequent stopping point for the Kindergarten students' counting was 29, with 62 students (8%) ending their count here. This number word was identified as the most frequent stopping point for all of the students in the Siegler and Robinson (1982) study. However, the Siegler and Robinson study did not identify any peaks in the distribution of stopping points occurring at 12 or 10, perhaps because their study included a much smaller number of children (42) with a broader range of ages (3 years to 6 years old) and used four inputs from each child in the data set.

If we focus on the majority of students (84%) who could not count past 30 when starting school (Figure 2), a number of observations may be made. Rather than roughly equal numbers of students having their highest counts recorded as 13 through 19, which would produce a horizontal scatter through the teens, the distribution shows a pronounced v-shape centred on 17. This supports the position that not all of the teen words need to be learnt as separate new words.

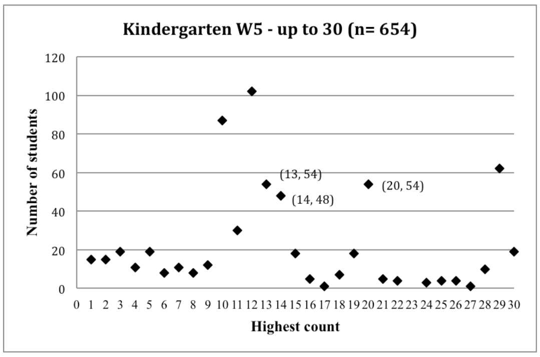


Figure 2. Kindergarten students' highest count recorded within 30 (Week 5, Term 1).

If students are able to abstract the repetitive cycle of the counting words, the frequencies of the stopping points in the acquisition of the counting word sequence are likely to be noticeably different immediately prior to a change in the multiples of ten: 19, 29, 39, and so on. This proposition is premised on the sequence of names of the multiples of ten being an additional sequence students must learn. However, more than twice as many Kindergarten students ended their count at 20 rather than 19. That is, knowing that 20 (the name of the second multiple of 10) follows 19 appears more likely than knowing 30 (the name of the third multiple of 10) follows 29.

The impact of the irregular prefixes used with *thir*teen and *fif*teen can be seen in the number of students who stopped their count at twelve and fourteen. Similarly, the relatively transparent structure that appears in the number word sequence beyond 20 is reflected in the low frequency of stopping points in the twenties before 29. If students were able to count past 20 they were unlikely to stop before reaching 29.

Five Weeks Later (Week 10 Term 1)

In Week 10 of Term 1 and subsequently, data were collected for Kindergarten students in all 16 schools. The top three most frequent stopping points identified (Figure 3) are 39, 29, and 12. To determine if the stopping points were influenced by the inclusion of an additional school's data, the highest count frequencies were recalculated with the final school excluded. The locations of the peaks of the highest count achieved did not change. In the recalculated results, the highest count of 39 still corresponded to the stopping point of 14% of the Kindergarten cohort.

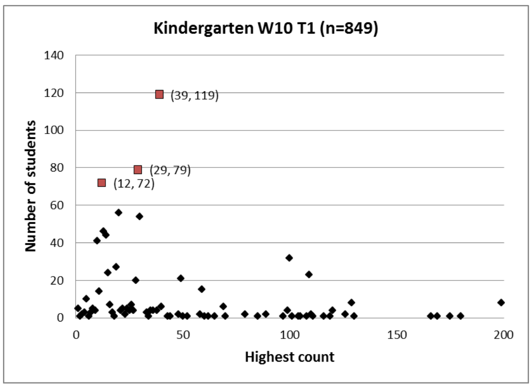


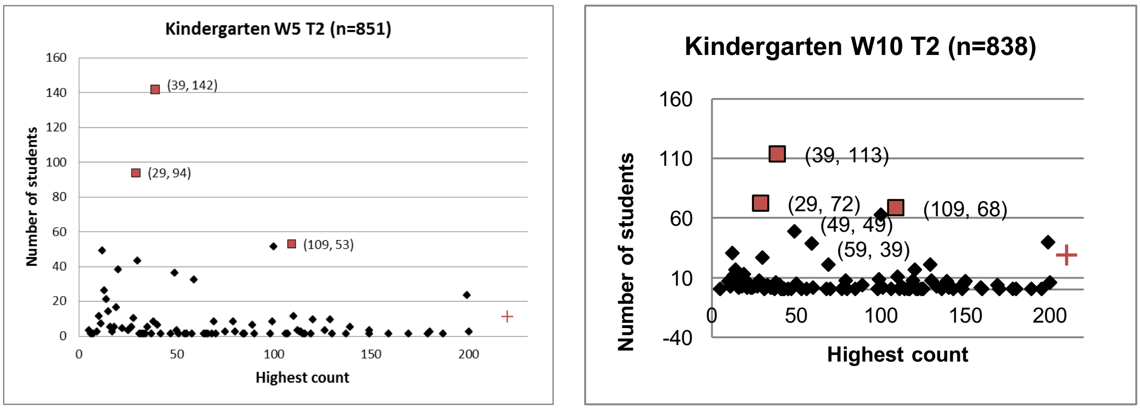
Figure 3. Kindergarten students' highest count (Week 10, Term 1).

The most frequent stopping place for an oral count for the Kindergarten students moved in 5 weeks from 12 to 39. By Week 10, 39 corresponded to the stopping point of 14% of Kindergarten, a marked increase from 4% in Week 5. More telling is the change in the order of the most frequently observed highest count, with 12 moving from first to third and 10 moving out of the top six.

The second most frequent stopping point for counting in Kindergarten was 29 in week 10 with 9% of students ending their count here. In 5 weeks, what had been the most frequent highest count (12) became the third most frequent stopping point with 8%. This shows quite rapid acquisition of the counting sequence in the first school term. After one school term, the three highest hurdles are the onset of the forties, thirties and the teens.

Kindergarten Term 2

Halfway through the second school term the highest correct count for 11 Kindergarten students exceeded 200. By the end of the term, 29 Kindergarten students' highest count exceeded 200. These groups are marked with crosses to the right of 200 (Figure 4).



(a) Week 5 of Term 2

(b) Week 10 of Term 2

Figure 4. Kindergarten students' highest count (Week 5 and Week 10 of Term 2)

The top three stopping points are 39, 29, and 109 in both data collections. In Week 5 of Term 2 only 6% of Kindergarten students ended their count at 12. Similarly, 17% of Kindergarten students stopped at 39, an increase from the 14% half a term earlier. What is particularly interesting is that the third most frequent stopping point has moved out to 109, rather than being at say, 49. This move of the third most frequent final count from 12 to 109 is well outside of the interquartile range (Table 1) for Term 1 data. Moreover, by the end of the second school term the highest correct count for the top quartile of Kindergarten students was 109 and one term later, a count of 109 has become the median. Although a highest count of 49 started to rise in the rankings, by the end of the term it was in fifth place between a highest count of 100 and 59.

Table 1
Highest Count Quartiles

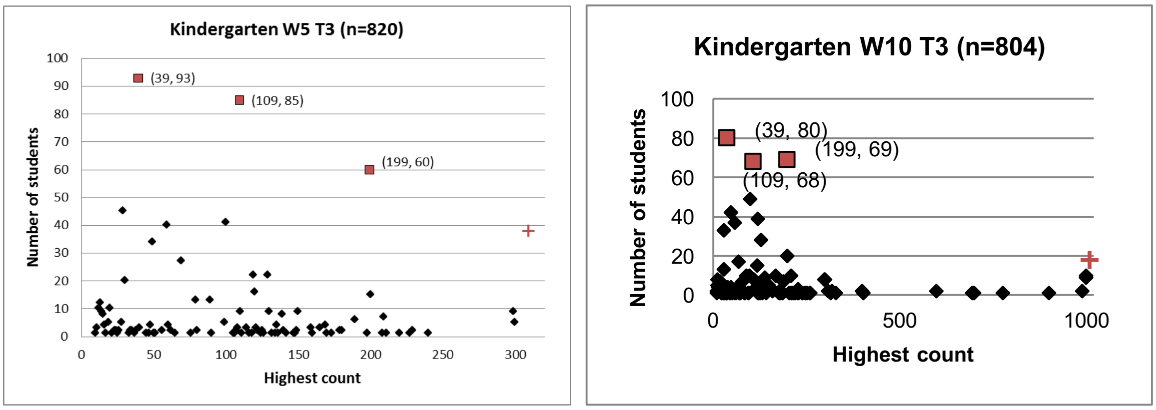
Collection Period	Quartile 1	Quartile 2	Quartile 3	Interquartile Range (Q3–Q1)
W5 Term 1	10	13	29	19
W10 Term 1	14	29	39	25
W5 Term 2	27	39	89	62
W10 Term 2	30	50	109	79
W5 Term 3	39	100	129	90
W10 Term 3	49	109	179	130

The interquartile range measures the spread of the middle 50% of data. The interquartile range continued to grow across each successive data collection. It appears as though as more students overcame the hurdle at 39, they were able to make use of the common structure of the decades up to 100.

Additionally, the mid-year data provided a number of clear markers of progress. Those Kindergarten students not able to count to 10 by the middle of the school year were in the bottom one percent. A stopping point of 12 corresponded to the 2nd percentile and the 5th percentile for Kindergarten by the middle of the year was a stopping point of 13.

Kindergarten Term 3

The most significant hurdle in Term 3 remained a stopping point of 39 (Figure 5).



(a) Week 5 of Term 3

(b) Week 10 of Term 3

Figure 5. Kindergarten students' highest count (Week 5 and Week 10 of Term 3)

The substantial challenge of students not knowing the number word following 109 in the counting sequence, continued to be prominent in Term 3. It is joined at the end of the term by the difficulty of naming the second completed hundred. While changing the unit name produces an expected challenge, the prominence of the hurdle of naming the successor for 109 is less anticipated. Not knowing that 110 follows 109 might be influenced by this being the first time *ten* is re-used in the forward counting sequence. Indeed, students are actively discouraged from using *ten* earlier in the counting sequence: *Thirty-ten does not follow thirty-nine.*

Potholes

The notes that accompanied the students' recorded highest count highlighted another challenge. Sometimes when developing counting sequences students create a consistent count, which omits one number. These omissions are like potholes in the counting sequence. What has not been previously reported is how persistent these potholes can be. The highest correct count for one student was 29 in Week 5 Term 1. However, he could count to 100 when told the number after 29. His highest count remained 29 in Week 10 Term 1 and in Week 5 Term 2. However, in Week 10 Term 2 the same student recorded a stopping point of 299. When this pothole was filled in, the student's correct counting range grew substantially. He did not stop at 129 or 229.

Rather than having an accurate sequence, a stable incorrect portion and a variable incorrect portion in the counting sequence, some children just have a *pothole*. The existence of potholes in children's number word sequences imposes limitations on the simple use of growth points or levels to measure rates of growth in learning to count.

Implications

Knowing where significant hurdles and potholes are located in students' acquisition of the counting sequence assists teachers in the design of assessment and targeted teaching in early number. When a student has a pothole in his or her counting sequence (i.e. a missing number word) this should be identified and addressed through targeted teaching. Further, the size of the hurdles children face in acquiring the counting sequence identified near 10 and 12, suggests that using a rote count to at least 20 as a marker of growth might be too coarse a measure. The findings of this study refine our understanding of the challenges children face when learning to count. In particular, teachers need to be aware that crossing the decades when counting are not all equally challenging for students and, counting past 109 is a major hurdle in the construction of the forward number word sequence.

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