WHAT DO 4 YEAR OLDS KNOW AND WHAT CAN THEY DO?

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Abstract

Introduction: Children typically enter state-maintained schools in England at the beginning of the school year following their fourth birthday, although legally they do not have to attend school until the start of term following their fifth birthday. As such, the overwhelming majority of children start school in the Reception class. This group of children will have had a diverse range of learning experiences before attending school. Some will have had little academic input; some may have attended nurseries where they have been taught in a more formal way. Some will have gained their knowledge by watching educational television or through educational apps. Given this diversity of experiences, it is important therefore, to find out what children know and can do on entry to the Reception class in order to provide them with appropriate learning opportunities. This paper describes the key findings from an analysis of data produced by a computer-based assessment carried out within the first few weeks of children starting school.

Method: Four-year-old children starting school in state-maintained schools in England were assessed using a computer adaptive assessment called BASE. BASE assesses early literacy and numeracy skills in an easy-to-use, child-friendly way. Children were assessed in each of the academic years beginning in 2016, 2017 and 2018. Item Response Theory was used to model dichotomous response data from the tests. This approach was used to account for missing data, introduced by stopping rules in the test. Resulting item difficulty values were converted to estimates of the classical item difficulty values, or the percentage of children expected to answer each question correctly. The results from over 70,000 assessments taken over the three academic years were combined and the estimated difficulty values were used to interpret what the 'typical' four-year-old knows, as well as the range of knowledge displayed.

Findings: The analysis revealed a wide range of levels of knowledge and understanding. Just over half of the children assessed could name four individual letters of the alphabet. Surprisingly, however, almost one fifth of children could already read some three-letter words. While around two thirds of children could point to a circle, a star, and a triangle when asked, a small proportion could even recognise a hexagon. Over half the children could recognise the digits 1 to 9, and just over half could count up to 8.

Conclusion: When children start in the Reception class in a state-maintained school in England, it is very easy to think of them as 'empty vessels' ready to learn from the very start of the curriculum. Our data shows that this is not usually the case. Children often learn many basic skills before they enter school and the sources and extent of this learning can be highly varied. The range of backgrounds and learning experiences mean that some children will need to start learning at the beginning of the curriculum, whilst others will be some way through the curriculum, even as they start school. Indeed, the 'typical' child knows a great deal. It is easy to overlook this, and to treat every child the same, but these findings strongly indicate the requirement for effective differentiation within the Reception classroom.

1 INTRODUCTION

Children typically enter state-maintained schools in England at the beginning of the school year following their fourth birthday, although legally they do not have to attend school until the start of term following their fifth birthday. As such, the overwhelming majority of children start school in the Reception class, with a very small minority of children beginning in Year 1.

Children entering the Reception class will be taught a curriculum which meets the standards set out in the Early Years Foundation Stage Framework. This national framework is intended to provide children with the knowledge, understanding and skills needed to access the National Curriculum from Year 1.

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A requirement to conduct a baseline assessment of all children starting in the Reception class was initially mandated in September 2015. In response to this requirement, the Centre for Evaluation and Monitoring (CEM) created a new baseline assessment named BASE which was accepted as one of three assessments that schools could use to fulfil their statutory duties. The assessment was offered to all CEM schools currently using an earlier baseline assessment and to new schools who chose to use BASE from the three options available. The first year of assessment was the academic year beginning in September 2015.

Following the first pilot year, a small number of items in the BASE assessment were reviewed and replaced in response to user feedback, making the first stable year for BASE the academic year starting in September 2016. This assessment is still being used today, but by far fewer children in state-maintained schools in England, as the mandatory nature of baseline assessment has moved on to different requirements.

Since its inception in 2015, the BASE assessment has also been offered to other CEM assessment users, such as those in independent schools, international schools, and schools in Scotland. As the number of state-maintained schools using the assessment has diminished, the rise in other schools taking up the assessment has changed the demographic representation of the sampled population. Despite the changing composition of schools and pupils taking the BASE assessment, it has remained popular, being taken by an average of 26,000 pupils each year since 2016

It is important to remember that the group of children taking the BASE assessment will have had a diverse range of learning experiences before attending school. Some will have had little academic input; some may have attended nurseries where they have been taught in a more formal way. Some will have gained their knowledge by watching educational television or through educational apps.

2 WHAT TYPE OF LEARNING IS APPROPRIATE FOR 4 YEAR OLDS?

The importance of knowing what children can do when they start school is based on the philosophy of teaching in the early years. Some teachers believe that early years education should be predominantly play based, while others take the view that although play is important, a more structured approach is required. A recent report by the OECD [1] reported that even within a play based curriculum, some areas were more play based than others. Some young children associated play with doing whatever they felt like doing, and that activities initiated by teachers were not really ‘play’ at all. Whether play is the principal vector for learning or not, teachers must be involved in order to direct the child’s learning in order to provide an opportunity for the child to progress.

The provision of appropriate learning goals based on previous knowledge is known as differentiation and has roots in work by the developmental psychologist, Lev Vygotsky [2]. His major contribution is the concept of the zone of proximal development (ZPD). The ZPD is an area of learning which is just beyond that which a learner can do on their own, but that they can do with structured help, perhaps from a teacher. Vygotsky called this ‘intellectual imitation’ [2] – by imitating someone else more able you learn to do the task yourself. Differentiation therefore, is using evidence from a child’s current learning to make a decision about the appropriate next step. Differentiation is vital in the Reception classroom to ensure that children are engaged and challenged in their learning. When deciding on the next step for a child, two things are important. The first is to use a suitable baseline assessment such as BASE to discover what individual children can do, and second it is important to reference a curriculum that defines what children of a particular age should be learning. In the case of English state-maintained schools, these requirements are enshrined in national Early Learning Goals. Using these two sources of information together can provide the basis for deciding appropriate learning goals for each child.

3 THE EARLY LEARNING GOALS (ELG)

The ELG are part of a statutory framework, the Early Years Foundation Stage (EYFS) mandated by the UK government for all Early Years providers in England [3]. These goals define what children should know and be able to do by the time they reach their fifth birthday.

Some of these specific goals are: (Sections marked with an asterisk are assessed by the BASE assessment).

3.1 Word Reading

Children at the expected level of development will:

- Say a sound for each letter in the alphabet and at least 10 digraphs; *
- Read words consistent with their phonic knowledge by sound-blending; *
- Read aloud simple sentences and books that are consistent with their phonic knowledge, including some common exception words. *

3.2 Number

Children at the expected level of development will:

- Have a deep understanding of numbers to 10, including the composition of each number; *
- Subitise (recognise quantities without counting) up to 5; *
- Automatically recall (without reference to rhymes, counting or other aids) number bonds up to 5 (including subtraction facts) and some number bonds to 10, including double facts. *

3.3 Numerical Patterns

Children at the expected level of development will:

- Verbally count beyond 20, recognising the pattern of the counting system; *
- Compare quantities up to 10 in different contexts, recognising when one quantity is greater than, less than or the same as the other quantity; *
- Explore and represent patterns within numbers up to 10, including evens and odds, double facts and how quantities can be distributed equally.

4 THE BASE ASSESSMENT

BASE is an assessment of Early Literacy and Numeracy, which has been developed by the Centre for Evaluation and Monitoring (CEM), a department of Cambridge University Press and Assessment in the UK. The assessment is administered within the first few weeks of the child starting in the Reception class. It is taken on a computer on a 1:1 basis with a teacher or other suitable adult. The computer asks questions and the child answers, either verbally or by pointing to an object on the screen. The response is then marked by the teacher. The assessment uses a simple adaptive algorithm, ensuring that if questions get too hard, further questions of greater difficulty are not asked. Once a child's level of ability is reached in a particular section the assessment moves on to the next topic. Reports are then generated showing which questions the child answered correctly and a score showing where they stand in the overall ability range for children starting in the Reception class that year. If required, the child can be assessed again at the end of the year and measures of progress can be established.

The BASE assessment consists of a number of sections, but due to the adaptive nature of the assessment, not all children will see all the questions in each section. The questions chosen for analysis in this investigation were mostly drawn from the initial section in each assessment area (maths, literacy etc.), ensuring that the majority of the children would be offered these questions.

5 METHOD

BASE item-level data for the academic years beginning 2016 (32,047 individual pupils), 2017 (22,127 individual pupils) and 2018 (16,457 individual pupils), (total 70,629 individual pupils) were obtained and the responses were restricted to those from state-maintained schools in England only. Initial sections of the assessment were chosen for analysis, covering the first stages of Literacy and Numeracy. These are shown in Table 1.

Table 1 Sections of the BASE assessment.

Area	Concept	How it is assessed
Literacy	Concepts about Print (CAP)	The child is asked to point to individual letters, words, where to start reading and some punctuation in a page of text shown on the screen.
Literacy	Letter Recognition	The child is shown letters of the alphabet, some as lowercase and some as uppercase. An acceptable response is either the sound or the name of the letter
Literacy	Word Recognition	Here the child is shown very short (two or three letter) words and asked to read them out loud.
Literacy	Vocabulary	The child is shown a series of pictures and asked to point to specific objects within each picture.
Numeracy	Shapes	The child is shown a picture containing many different shapes and is asked to point out specific ones (square, triangle etc.).
Numeracy	Number Recognition	The child is shown single digit, then two digit and higher numbers and asked to name them.
Numeracy	Counting	The child is asked to count items of varying numbers starting from four and increasing to numbers in the thirties.
Numeracy	Numeracy 1	The child is asked to do simple arithmetic such as addition or subtraction.

The BASE assessment includes a partially adaptive algorithm that stops children seeing more difficult questions if they start to get questions wrong. This meant that not all the children see all the questions and more importantly, only the most able children would see the hardest questions. This could affect the difficulty estimates for those questions. Therefore, a method of estimating the individual difficulty of each question was required. Trial simulations were run in R [4] using three different models for estimating this: the Conditional Maximum Likelihood model (CML), the Joint Maximum Likelihood model (JML), and the Marginal Maximal Likelihood model (MML). Only the MML model using the R mirt package produced unbiased estimates of item difficulty. The other two models did not. An R script that used MML to estimate item difficulty was used to calculate values for each item and for each academic year. A further calculation was carried out on the sample as a whole. The resulting difficulty values are presented as percentages and represent the percentage of children who were able to answer a particular question correctly.

6 RESULTS

6.1 Concepts about Print

Table 2 shows the item difficulties for each year and all children combined when they were asked to point to specific items on a page of text.

Table 2 Concepts About Print items and difficulties.

Item	2016	2017	2018	Combined	Combined SD
Which bug is writing?	71.78	71.02	70.10	71.15	0.45
Which bug is reading?	60.32	59.63	59.84	59.99	0.49
Can you point to a word on the page?	54.19	51.19	49.87	52.24	0.50
Can you point to some writing?	51.42	48.20	47.57	49.51	0.50
Can you point to a letter of the alphabet?	45.77	43.34	41.65	44.05	0.50
Where should I start reading?	19.99	18.75	17.47	19.02	0.39
Can you point to a capital letter?	14.81	14.14	14.04	14.41	0.35
Can you point to a full stop?	6.82	6.13	6.51	6.53	0.25

The easiest item required the child to point to someone who was writing. 71% of pupils could do this. The next easiest was pointing to someone who was reading. 59% of pupils could do this. However, only just over 50% could point to a word on the page.

18% of pupils could indicate where to start reading a passage, 14% could point to a capital letter and only 6% could recognise a full stop.

6.2 Letter Recognition

Table 3 shows the difficulty values for each year and combined for each letter of the alphabet. Note that some letters are capitals and some are lower case. For expediency, the assessment does not ask children whether they recognise each letter as lower case and then again in upper case as it would be extremely time consuming. Moreover, the time for which young children can concentrate on a single task type is limited.

Table 3 Letter Recognition items and difficulties.

Item	2016	2017	2018	Combined	Combined SD
s	62.98	61.41	61.61	62.19	0.48
o	60.73	58.32	58.81	59.58	0.49
m	59.72	58.11	58.35	58.94	0.49
a	52.44	51.85	51.20	51.98	0.50
e	50.40	48.93	50.25	49.94	0.50
c	48.91	48.13	47.61	48.39	0.50
r	46.49	45.94	45.32	46.08	0.50
L	46.39	46.16	43.39	45.64	0.50
F	41.47	40.87	41.08	41.22	0.49
z	41.55	40.61	40.99	41.15	0.49
x	40.56	41.20	39.72	40.58	0.49
K	40.55	40.16	38.98	40.08	0.49
t	40.39	39.35	39.05	39.76	0.49
P	39.28	38.48	39.00	38.97	0.49
B	39.56	38.23	38.45	38.91	0.49
i	38.11	37.58	37.77	37.87	0.49
w	36.52	34.23	33.77	35.17	0.48
H	33.60	33.39	32.80	33.36	0.47
n	33.87	32.04	33.08	33.12	0.47
J	33.25	30.95	31.09	32.05	0.47
d	29.67	29.73	29.32	29.62	0.46
G	28.74	27.36	26.46	27.80	0.45
v	28.25	27.67	26.32	27.63	0.45
u	27.16	26.89	26.54	26.95	0.44
Y	19.29	19.17	18.87	19.17	0.39
Q	16.90	16.49	15.35	16.42	0.37

The most commonly recognised letters were lower case ‘s’, lower case ‘o’ and lower case ‘m’. Around 60% of children were able to recognise them. The hardest letters for children to recognise were upper case ‘Y’ and upper case ‘Q’. Fewer than 20% of children could recognise those letters.

6.3 Word recognition

Table 4 shows the words that children are asked to read. Although the words themselves seem remarkably simple, learning to read involves a great deal of mental gymnastics. The reader must know the sounds associated with each letter and then have the ability to combine them to produce an overall sound – the complete word.

Table 2 Word recognition items and difficulties.

Item	2016	2017	2018	Combined	Combined SD
dog	20.29	19.65	19.15	19.82	0.40
pin	19.83	19.50	18.76	19.47	0.40
cat	19.89	18.86	18.81	19.31	0.39
car	15.49	15.13	15.25	15.32	0.36
ball	15.50	15.36	14.80	15.29	0.36
tree	10.70	10.12	9.74	10.29	0.30
up	8.34	8.32	8.27	8.32	0.28
it	8.48	8.27	7.66	8.22	0.27
run	7.41	7.41	6.99	7.31	0.26
see	4.65	4.73	4.14	4.55	0.21

Being able to read whole words was a skill that only around 20% of children could do on entry to the Reception class. The easiest item for those who could read simple words was 'dog' and the hardest was 'see'.

6.4 Vocabulary

The ability to put names to objects is fundamental to learning about the world around you. Table 5 shows the difficulty of the vocabulary items asked in the BASE assessment and the proportion of children that could recognise that item in a picture onscreen.

Table 3 Picture vocabulary items and difficulties.

Item	2016	2017	2018	Combined	Combined SD
window	95.59	95.42	95.93	95.62	0.20
tree	95.27	94.83	95.61	95.21	0.21
flower	94.88	94.79	95.14	94.91	0.22
kite	95.43	94.14	93.93	94.68	0.22
cloud	93.71	93.20	93.83	93.58	0.25
bowl	87.80	86.28	85.88	86.89	0.34
pigeon	87.10	85.78	86.71	86.60	0.34
wasp	86.59	82.96	85.96	85.32	0.35
anchor	71.00	73.28	74.24	72.57	0.45
path	72.18	69.69	69.95	70.90	0.45
bush	68.64	68.54	68.49	68.59	0.46
padlock	61.42	60.10	62.33	61.24	0.49
vehicle	48.39	60.13	65.17	55.68	0.50
toadstool	42.60	36.87	36.17	39.32	0.49
luggage	18.30	22.14	26.96	21.53	0.41
globe	18.97	21.80	22.65	20.77	0.41
musician	13.97	13.28	15.13	14.06	0.35
garment	6.48	6.34	6.95	6.55	0.25
cattle	4.55	3.83	3.84	4.16	0.20

English vocabulary contains many synonyms, some of which cause issues with vocabulary tests. For one child it is a 'pan', for another child it is a 'pot'. However, most children (around 95%) could point to a window, a tree, a flower, a kite and a cloud. Very few children (less than 10%) understood the words 'garment' and 'cattle'.

6.5 Shapes

Table 6 shows the names of the shapes that the children were asked to point to.

Table 4 Shape recognition items and difficulties.

Item	2016	2017	2018	Combined	Combined SD
star	93.51	93.14	93.83	93.47	0.25
circle	85.69	85.35	85.97	85.65	0.35
square	72.83	71.50	71.56	72.12	0.45
triangle	68.40	65.95	65.55	66.97	0.47
rectangle	58.17	55.21	55.53	56.64	0.50
oval	46.63	45.23	45.61	45.96	0.50
hexagon	39.10	39.97	41.05	39.83	0.49

The most recognised shapes were the star and the circle. Over 85% of children could point to these. The most difficult was the hexagon, although around 40% of children knew this shape.

6.6 Number Recognition

The children were asked to name numbers as they appeared on the screen. As with most parts of the test, if they started to get the answers wrong the assessment would move on to another section of the test covering a different topic.

Table 5 Number recognition items and difficulties.

Item	2016	2017	2018	Combined	Combined SD
1	88.53	88.08	89.05	88.51	0.32
4	85.86	85.09	83.65	84.99	0.36
2	82.24	81.89	85.14	82.84	0.38
3	83.23	82.73	82.30	82.68	0.38
5	82.79	82.45	82.49	82.58	0.38
7	68.99	67.97	67.60	68.30	0.47
9	56.93	55.69	54.54	55.94	0.50
6	55.35	54.80	53.83	54.78	0.50
8	54.53	54.18	53.43	54.12	0.50
11	29.50	29.13	28.81	29.20	0.45
20	19.59	20.34	19.46	19.77	0.40
12	14.06	13.93	12.91	13.73	0.34
15	9.79	10.71	9.40	9.97	0.30
96	7.12	7.07	6.85	7.03	0.26
45	6.48	6.76	6.05	6.46	0.25
23	6.46	6.62	5.87	6.36	0.24
1000	4.46	4.94	5.81	4.84	0.21
300	3.59	3.52	3.92	3.63	0.19
996	2.68	2.05	2.11	2.34	0.15
579	1.40	1.14	1.32	1.29	0.11
1049	1.00	1.30	1.03	1.01	0.10
4231	1.08	1.34	0.81	1.00	0.10
231	1.02	0.90	0.97	0.97	0.10

Interestingly, the difficulty of recognising individual digits was found not to correspond with their numerical order. Around 80% of children knew the numbers 1 to 5, but only 55% of children could

recognise the number 6. Slightly more children were able to recognise the numbers 7 and 9. Fewer than 10% of children understood numbers greater than 15.

6.7 Counting

Children were asked to count the spots on the back of a ladybird. This method is preferred over counting on a number line as children can be observed pointing to each spot as they count, and it is easier to see those who count the same spot twice, miss a number or do not know where to stop.

Table 6 Counting items and difficulties.

Item	2016	2017	2018	Combined	Combined SD
Count four spots	88.38	87.91	88.09	88.16	0.32
Count six spots	73.09	72.36	72.43	72.71	0.45
Count eight spots	51.19	51.00	51.04	51.10	0.50
Count 11 bugs	44.72	45.30	44.54	44.86	0.50
Count 14 bugs	30.02	29.93	29.07	29.77	0.46
Count 20 bugs	18.01	17.81	17.14	17.74	0.38
Count 35 bugs	2.88	3.16	2.77	2.94	0.17

Counting is a complex activity, combining as it does the requirement to count items in order, remember which items you've already counted and which you have yet to count, and understand that the last number you mention is also the cardinal value of the set. Many children (88%) were able to count four items and slightly fewer (73%) could count six items.

6.8 Numeracy

Not many children of this age have been introduced to formal arithmetic, but some have, and this section of the assessment allows the teacher to observe how children attempted addition and subtraction problems.

Table 7 Basic mathematics items and their difficulties.

Item	2016	2017	2018	Combined	Combined SD
3 minus 1	66.12	65.30	66.08	65.86	0.47
4 minus 1	50.30	50.08	49.79	50.11	0.50
3 plus 1	37.84	37.16	37.31	37.50	0.48
2 plus 1	35.22	34.68	34.49	34.88	0.48
6 minus 3	20.06	19.88	19.43	19.86	0.40
4 plus 3	7.20	7.06	7.18	7.15	0.26
6 plus 5	1.59	1.79	1.68	1.68	0.13

Just over 50% of the group were able to subtract 1 from a number. Far fewer (around 36%) could add 1, and even fewer (<10%) still could add a number other than 1.

7 DISCUSSION

As has been indicated in the results section, children enter the Reception year at school with a wide range of abilities. Most have an understanding of simple shapes, some single digit numbers and a basic vocabulary. This knowledge is generally aligned with the Early Learning Goals, although in some cases the pupil has the knowledge and understanding on entry to the Reception class that would be appropriate on completion of the Reception year. It also seems that the results are remarkably stable from one year to the next – a good indication that BASE is a robust and reliable assessment.

Some issues do arise though. In schools, letters and letter sounds are often taught initially using synthetic phonics schemes which begin with the letters 's', 'a', 't', 'p', 'i' and 'n'. The rationale for this is that these are common letter sounds and many simple words can be created by combinations of those

letters. As may be seen from the analysis of BASE data, although the letters 's' and 'a' are reasonably well known among school starters, the letters 't', 'i', and 'n' are not. (BASE asks children to recognise the upper case letter 'P'). Ironically, it may be the most familiar letters that are problematical. Phonics teaching applies very specific sounds to each letter that are unlikely to have been taught by parents. Therefore, it may be that the better-known letters cause more difficulties in phonics learning than those that are yet to be learnt.

Similarly, we see a link between digit recognition and counting. More than half of the children entering the Reception class could recognise the digits 1 to 9, but Table 7 shows that the order of difficulty does not follow the natural order of the numbers. For instance, fewer children could recognise the number 6 than could recognise the numbers 7 or 9. Following on from this, counting (the application of number) shows that the majority of children could count 4 and 6 spots on the back of a ladybird, but counting 8 or more was much more difficult.

The area where most pupils starting in the Reception class struggled was in arithmetic. Although around half the pupils could take 1 away from a small number, far fewer could carry out additions of any type, or subtraction of numbers larger than 1. This type of insight is extremely useful in informing pedagogy. Why is it that children who have understood the concept of subtraction find it more difficult to subtract numbers larger than 1? If they are counting back in single digits from the given number, then is there too much cognitive overload to keep track of the number of times they have to count back, and the final result? Would a deeper understanding of general number facts help?

8 CONCLUSIONS

When children start in the Reception class in a state-maintained school in England, it is very easy to think of them as 'empty vessels' ready to learn from the very start of the curriculum. Our data shows that this is not usually the case. Children often learn many basic skills before they enter school and the sources and extent of this learning can be very varied. Some will be taught by their parents or other relatives and carers. Some will attend playgroups or nursery schools. Even those without these advantages may be able to learn a great deal from the excellent learning resources readily available from a range of digital providers. What is apparent is the astonishing amount the average child does know and can do when they enter the Reception class. It is easy to overlook this, and treat every child the same, rather than aiming to differentiate groups according to their individual learning needs.

If children have learnt some basic concepts before they reach school, then it is important to find out what they know and can do – each child's experience is different – and provide them with appropriate learning opportunities based on their current level of knowledge and experience. The BASE assessment was never designed to 'label' children, it was designed to allow teachers to discover the skills and knowledge already possessed by children and to help them to build upon this. BASE provides an opportunity to objectively and comprehensively assess a class of children in a range of basic skills. The results are often surprising as initial perceptions of what children can or cannot do are frequently challenged. This diversity of experience prior to entering formal schooling is why it is important to establish a baseline for children entering the Reception class.

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