

The impact of preterm birth on mathematics achievement and schooling

Briefing notes and recommendations

About the authors

Dieter Wolke is a Professor of Developmental Psychology and Individual Differences at the University of Warwick, UK. His research interests lie in understanding the developmental pathways that lead to mental health problems across the lifespan, including the social and emotional development of children and adolescents, the long-term effects of bullying and different parenting styles, and the development of children who were born at-risk. Professor Wolke is a chartered psychologist and an Associate Fellow of the British Psychological Society.

Samantha Johnson is a Developmental Psychologist and Senior Research Fellow in the Department of Health Sciences at the University of Leicester, UK. Her research interests are in the long-term development of babies that are born prematurely, including understanding how premature birth affects children's mental health, learning and achievement at school. Dr Johnson is a chartered psychologist and an Associate Fellow of the British Psychological Society.

Julia Jäkel is a Developmental Psychologist and Assistant Professor in the Department of Child and Family Studies at the University of Tennessee, USA. Her research aims to identify the long-term mechanisms that underlie children's behavioral problems and learning difficulties, and to understand what puts children at risk or makes them resilient after they are born premature or when they face socio-cultural adversity.

Camilla Gilmore is a Developmental Psychologist and Reader in Mathematical Cognition in the Mathematics Education Centre at Loughborough University, UK. Her research is focused on understanding how mathematics skills develop and the impact of mathematics learning difficulties on children's achievement at school. Dr Gilmore is a chartered psychologist and an Associate Fellow of the British Psychological Society.

We would like to thank our collaborator Professor Neil Marlow, University College London and postdoctoral researchers Dr Vicky Strauss and Dr Maartje Basten for their invaluable input to the project.

About The Nuffield Foundation

The Nuffield Foundation is an endowed charitable trust that aims to improve social well-being in the widest sense. It funds research and innovation in education and social policy and also works to build capacity in education, science and social science research. The Nuffield Foundation has funded this project, but the views expressed are those of the authors and not necessarily those of the Foundation.



Contents

Foreword	3
Executive summary	4
The need for this research	5
Aims	6
Methods	6
Key findings	7
Recommendations	13

Foreword

A common theme in the research funded by the Nuffield Foundation in recent years has been understanding and addressing disadvantage within the education system. Put simply, we want every child to be able to achieve their full potential. The Foundation has made a significant contribution to the evidence base on many of the factors influencing the capacity of children to learn effectively when they start primary school: home environment; socio-economic background; oral language development, specific disorders and disabilities; and month of birth.

Premature birth is another key risk factor, where there is comparatively low awareness in the education system, not least because to date its importance has not been sufficiently disseminated to teachers and other professionals. Meanwhile, advances in neonatal care, demographic changes and growth in assisted reproduction have all contributed to increases in the number of children born prematurely. Compared to children born at full term, those born very preterm are more likely to experience difficulties in health and cognitive development, and to have poorer behavioural, emotional and social outcomes.

This report presents the findings of a project that used large-scale longitudinal datasets to explore the impact of being born prematurely on children's educational attainment and longer-term outcomes. Children born prematurely have poorer reading and mathematics skills than those who were born at term, and these effects are long-lasting: at the age of 42, adults who were born prematurely are more likely to have lower incomes and less likely to own their own home than those who were born at term. This is of particular interest since mathematics education and quantitative skills are such a priority for the Foundation. On average, any primary school classroom will include two children born prematurely, and yet the vast majority of teachers will not be aware of who they are, let alone receive any training about the impact of premature birth on children's development and learning.

I hope that this report sparks a debate about policy responses and potential interventions. There is an active campaign for delayed school entry to reduce the disadvantage faced by children born prematurely. The authors conclude that there is not sufficient evidence to justify this, and that delayed school entry may even place children born prematurely at further academic disadvantage in the early primary school years.

I look forward to continuing to debate these findings and their implications with the research team and with a wider group of stakeholders. It has been a fascinating project and one that the Nuffield Foundation has been delighted to fund.

Josh Hillman

Acting Director and Director of Education, Nuffield Foundation

Executive summary

Preterm birth increases the risk of long term adverse effects on children's learning and development.

Our study found that moderately, very and extremely preterm children, born before 34 weeks of gestation, are more likely to have cognitive deficits and learning difficulties than children born at term. The risk for such difficulties increases with decreasing gestation at birth.

Preterm children's learning problems in primary school, in particular difficulties with mathematics, are associated with lower wealth in adulthood.

Many parents consider delayed school entry as one intervention that may help their preterm children to do better at school. Our findings, based on the largest investigation to date, do not support this. Rather, preterm children may benefit from entering school at the appropriate age but receiving additional support in school.

Teachers and educational psychologists receive little formal training about preterm birth and are often not aware of appropriate strategies to support preterm children in the classroom. Informing teachers about the special constellation of problems following preterm birth is crucial in preparing them to support the growing number of preterms entering schools in the coming years.

Our findings lead us to recommend that all preterm children born before 34 weeks of gestation should have regular follow-up. Interventions are required around the time of school entry to facilitate preterm children to have an optimal start to their schooling career. Delayed school entry is not recommended on current evidence, but more research is needed. Education professionals require more training about the specific difficulties faced by preterm children, and tailored new approaches to teaching preterm children are needed.

The need for this research

Globally, 15 million babies are born preterm each year, representing 11% of all live births (Figure 1). In the UK, around 7% of children are born preterm each year. This means that, on average, one in 14 babies is born preterm, and two children in an average sized primary school class were born preterm.

Completed weeks of gestation																			
22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
															Term				
All Preterm																			
Very Preterm										Moderate			Late						
Extremely																			
22 to 27 weeks Babies born extremely preterm are at high risk for intellectual impairment and physical disability later in life. Although the vast majority attend mainstream school, just over half require some degree of special educational support.						22 to 31 weeks Children born very preterm are at high risk for cognitive deficits and attention, behaviour and emotional problems at school age.				32 to 36 weeks Most preterm babies are born late and moderately preterm. Even these babies born a few weeks early are at slightly higher risk of developmental problems than babies born at term.			Preterm birth In the UK, around 7% of babies are born preterm each year. This means that two children in an average sized primary school class are likely to have been born preterm.						

Figure 1. Prematurity: Definition of Terms.

The total number of preterm births has increased in the last twenty to thirty years and more preterm babies are now surviving than ever before. But for those babies that overcome the immediate health risks during the neonatal period, survival may come at a cost. The risk of brain injuries and altered development following preterm birth means that those who survive are at risk for a range of health and developmental problems later in life. Do preterm children outgrow problems that emerge early in childhood, or do these problems have long term effects into adulthood? Are there limits to compensation and plasticity of the brain and are these related to the degree of prematurity at birth? How can we support preterm children to achieve their potential?

The most common adverse outcomes following preterm birth are cognitive problems (e.g., lower IQ, poor executive function and working memory), learning difficulties, social difficulties (e.g., autism spectrum disorders, difficulties interacting and forming relationships with peers), behavioural problems (e.g., attention problems, attention deficit/hyperactivity disorders), emotional problems (e.g., anxiety disorders, phobias), and poor motor coordination (e.g., cerebral palsy and clumsiness). These kinds of difficulties can impact a child’s performance and integration at school. As a consequence, very preterm children are at increased risk for poor academic attainment and special educational needs (SEN) compared with their term-born peers, and poor achievement in mathematics has been reported to be especially common among very preterm children. Children’s mathematics skills have been suggested to be important for their future health and wellbeing, employment prospects and income as an adult.

The World Health Organization recently asserted that an “increased awareness of the long-term consequences of preterm birth is required to fashion policies to support these

survivors and their families as part of a more generalized improvement in quality of care.” Prematurity incurs substantial economic costs as the annual cost of preterm birth to the public sector in England to age 18 is estimated to be £1.24 billion, with total societal costs estimated at £2.48 billion. After discharge from hospital, the greatest costs associated with preterm birth lie not in healthcare but in education. With increasing survivors of preterm birth, unprecedented demands will be placed on education systems worldwide as teachers are increasingly faced with identifying and providing appropriate support to children with a range of developmental, social and learning difficulties. To develop strategies and policies to tackle this challenge, key issues need to be addressed.

Are children born late and moderately preterm also at increased risk for poor academic attainment compared with their term-born peers, as has been reported for very preterm children?

What are the long term consequences of preterm children’s learning difficulties? Do mathematics difficulties put them at particular risk for poorer outcomes in adulthood?

Parents of preterm children are particularly concerned about the transition to school and many have campaigned for delayed or deferred school entry for their child. What is the impact of delayed school entry on preterm children’s learning and achievement at school?

How prepared are teachers and educational psychologists to support the growing numbers of preterm children in the classroom, and what are their information needs?

Aims

To answer these questions we conducted the Preterm Birth: Impact on mathematics and achievement (PRIME) Study. The overarching aim of this research was to explore the impact of preterm birth on children’s achievement and schooling. This encompassed four objectives:

1. To understand the nature of cognitive and learning difficulties in children born across the full spectrum of preterm gestations;
2. To explore the long-term consequences of preterm birth on children’s academic attainment and their wealth in adulthood;
3. To investigate the impact of delayed school entry on children’s educational outcomes;
4. To survey education professionals’ knowledge and information needs related to the educational management of preterm children.

Methods

The PRIME study used a mixed methods approach including secondary analysis of large population based cohort studies and new data collection with online survey methods. Full details of design, methods, instruments, participants and statistical analyses can be found in the published articles referred to below.

The major cohorts used in primary analyses (objectives 1 and 3) included two geographical population-based cohorts of preterm children, the German Bavarian Longitudinal Study (<http://www.bayerische-entwicklungsstudie.de/>) and the UK and Irish EPICure Study (<http://www.epicure.ac.uk/>).

To address objective 2, we conducted secondary analyses of data from two UK national cohort studies, the 1958 National Child Development Study and the 1970 British Cohort Study (<http://www.cls.ioe.ac.uk/>) using data collected from birth to 42 years.

To address objective 4, a survey of the knowledge and information needs of education professionals was carried out. An email was sent to the head teacher of every school in England inviting their teaching staff to participate and providing the web link for the online survey. To solicit the views of educational psychologists, an email was sent to all members of the UK Association for Educational Psychologists. Social media resources were also used to publicise the surveys and invite professionals to participate.

Key Findings

The nature of cognitive and learning difficulties in children born across the full spectrum of preterm gestations

How does the degree of prematurity relate to children's IQ, basic mathematics processing and mathematics attainment in primary school?

- Adverse effects on basic mathematics processing at primary school age were found for almost all preterm children, that is, all those born at less than 36 weeks of gestation. However, a significant decline in IQ and mathematics attainment was apparent only for children born moderately preterm, that is at 33 weeks of gestation or less. Below these “change points” we saw a consistent decline in performance with each weekly drop in gestational age at birth down to 27 weeks of gestation, while the decline was minimal above the “change points” (see Figure 2).

Are the effects of preterm birth on IQ and mathematics universal? That is, can we accurately predict the effects of preterm birth from one cohort of children to another, the latter being born in another country and a decade later?

- Using Bavarian Longitudinal Study data, we accurately predicted the effects of gestational age at birth on IQ and basic mathematics processing among EPICure study children born one decade later and at extremely preterm gestations. However, EPICure Study children had better mathematics attainment than was predicted using data from the Bavarian cohort (Figure 2).
- The ability to predict IQ and mathematics processing scores from one cohort to another between children cared for in different eras and countries indicates that universal neurodevelopmental factors explain the effects of gestation at birth. In contrast, the effects of gestation at birth on mathematics attainment may be moderated by schooling.

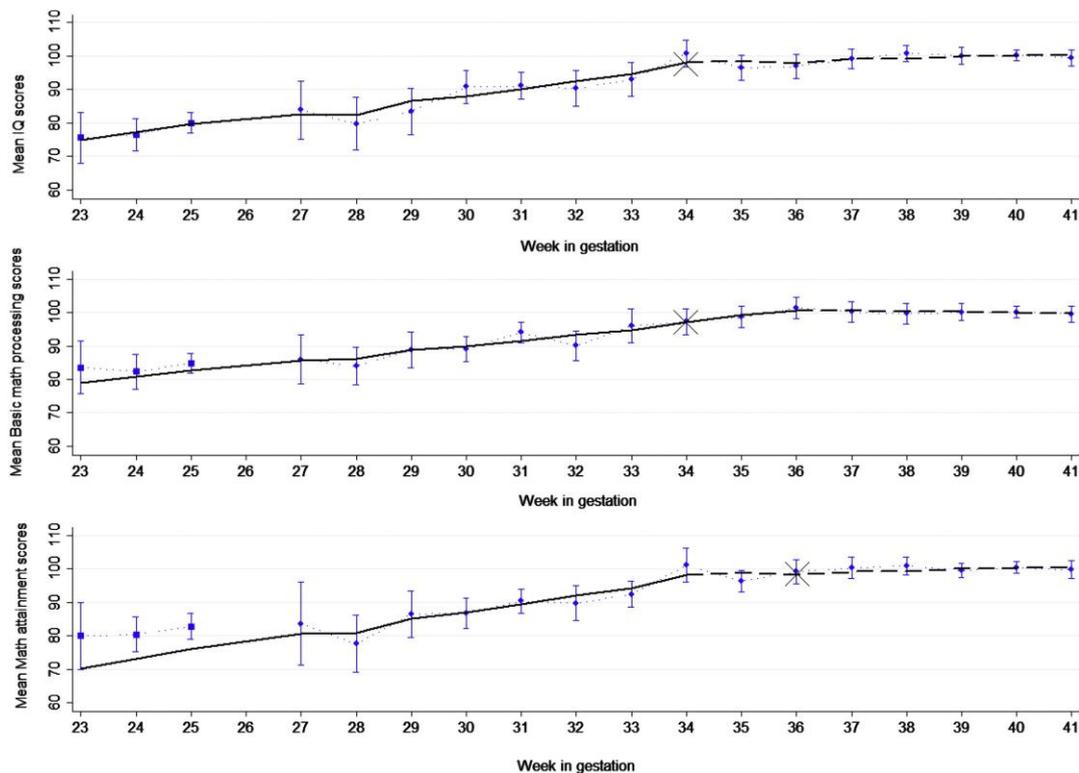


Figure 2. Observed and predicted mean change in outcomes according to GA at birth in the Bavarian Longitudinal Study (Germany; 27-41 weeks GA) and observed and predicted scores for the EPICure cohort (UK, 23-25 weeks GA). Blue vertical lines: 95% CIs of observed means (circles); X: GA change points; black solid horizontal lines: predicted means below the GA change point; dashed horizontal lines: predicted means above the GA change point.

To read the full results, please see our publication in the *Journal of Pediatrics* (Wolke, Strauss, Johnson, Gilmore, Marlow & Jaekel, 2015)

The long term consequences of preterm birth on academic attainment and wealth in adulthood.

Although a large number of studies have documented cognitive problems and learning difficulties in preterm children at school age, far less is known about the longer term consequences of preterm birth.

Do preterm children's poorer reading and mathematics skills adversely affect their wealth in adulthood?

- We used data from two large British population-based cohort studies, the 1958 National Child Development Study and the 1970 British Cohort Study, to allow for replication of findings between the two datasets. The findings were consistent across the two cohorts. The best fitting model is shown in Figure 3.

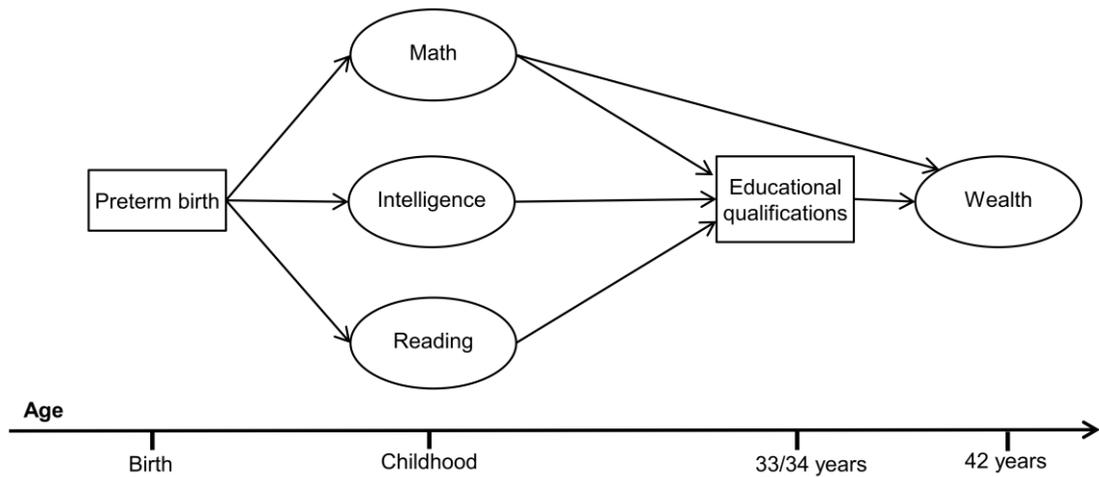


Figure 3. Pathways of indirect effects of preterm birth on wealth at 42 years of age.

- Preterm children born less than 37 weeks of gestation had poorer mathematics and reading skills and lower IQ in childhood than children who were born at term.
- Preterm children’s poorer mathematics and reading skills in primary school were associated with lower academic qualifications by 33/34 years of age and lower wealth at 42 years of age. Individuals born preterm were more likely to be manual workers (i.e. NCDS: 32.5% preterm versus 25.1% full term), more likely to be unemployed (3.3% versus 2.5%), more likely to report financial difficulties (34.5% versus 28.5%), had below average family income (57.6% versus 49.1%) and were less likely to own a house (22.3% versus 15.5%) than those who were born at term.
- Mathematics achievement in school had a direct independent effect, over and above school qualifications, on wealth in adulthood. The strongest indirect effect of preterm birth on adult wealth was via mathematics achievement in school.
- The same findings in both cohorts suggest that the negative effects of mathematics skills on wealth in adulthood are time invariant and may affect children born preterm today.

For the full results please read our published article in *Psychological Science* (Basten, Jaekel, Johnson, Gilmore, & Wolke, 2015) and our report on the implications for education in *The Conversation* (<http://theconversation.com/premature-birth-linked-with-lower-wealth-how-education-could-help-bridge-the-gap-46992>).

The impact of delayed school entry on children's educational outcomes

Within the same academic year, the youngest children in class have lower academic achievement compared with the oldest children in class. In countries such as Germany, paediatricians assess children's school readiness and may recommend that children who fail such tests should enter school a year later.

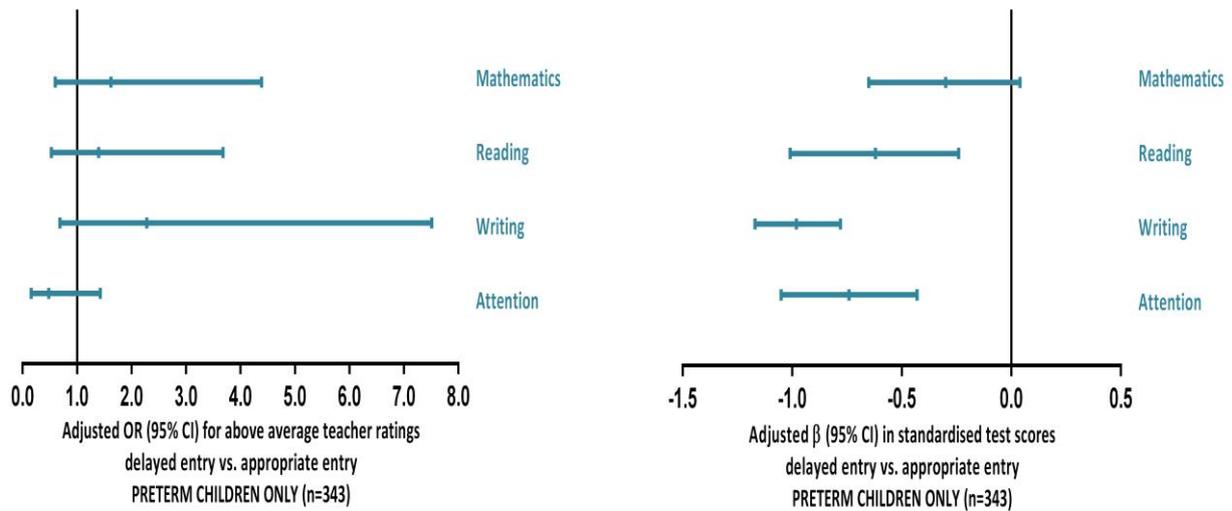
Very preterm children may be born up to four months before their due date and may have to enter school less mature than their peers. Thus the issue of delayed school entry is particularly pertinent for parents of preterm children who often enquire whether they can delay school entry as they believe it would benefit their child to enter school a year later.

Delaying school entry may be beneficial because teachers may not be able to provide differential support for the less mature children in class, and thus they may not receive developmentally appropriate teaching if they start school at the age-appropriate time. Delayed entry may therefore prevent psychological pressure and negative feedback due to developmental immaturity. Conversely, delayed school entry may disadvantage children as it denies them the opportunity to receive the early intellectual input and support they may need to catch up with their peers.

Given that there are no randomised controlled trials, we applied propensity score matching to observational data within a natural setting as this provides a method for reducing selection bias. We analysed data from the Bavarian Longitudinal Study using propensity score matching to select two groups of children who were matched in baseline characteristics but differed in whether they entered school at the age appropriate time or had experienced delayed school entry following paediatricians' recommendations.

Does delayed school entry benefit preterm children's school performance?

- Delayed school entry had no advantage on teacher ratings of academic performance at the end of Year 1. That is, children who had delayed school entry by one year did not perform better in teacher ratings of their academic attainment at the end of Year 1 although being on average 8 months older than children who had entered school at the age appropriate time.
- Delayed school entry was associated with poorer performance in standardized tests of reading, writing, mathematics and attention when assessed at 8 years of age. This was only partly explained by the fact that children who delayed school entry had 8 months less school experience on average at the time of assessment.



For details of findings for preterm children only see Figure 4. **Figure 4.** Odds ratios (95% CI) of teacher ratings above average (left figure) and achievement tests means (z-scores; 95% CI) (right figure) of appropriate school entry (zero vertical line) and delayed entry school entry children.

The study is published in *Developmental Medicine and Child Neurology* (Jaekel, Strauss, Johnson, Gilmore, & Wolke, 2015); see also editorial comment (Fastenau, 2015).

School teachers' and educational psychologists' knowledge and information needs related to the educational management of preterm children

Two children in an average sized UK primary school class are likely to have been born preterm. Thus, nearly every teacher will be responsible for supporting preterm children. We surveyed teachers in England and educational psychologists in the UK to explore their knowledge and information needs relating to the developmental and educational consequences of preterm birth. We compared their knowledge to what neonatal health professionals knew about the developmental problems of preterm children.

- Teachers and educational psychologists had significantly poorer knowledge of the long term consequences of preterm birth on children's health and development than neonatal professionals. Educational psychologists and teachers with a special educational needs role had greater knowledge than other teaching staff, but this was still far below that of neonatal professionals.
- Both teachers' and educational psychologists' areas of poorest knowledge related to the most common difficulties faced by children born preterm, namely mathematics difficulties, attention deficits and difficulties interacting with peers. This may mean that preterm children may not receive appropriate support in the areas they need it the most.

- Over 80% of teachers and over 50% of educational psychologists had received no formal training about preterm birth (see Figure 5).
- Over 80% of both teachers and educational psychologists requested more information about the educational consequences of preterm birth to better equip them to support preterm children in school.
- Training education professionals about preterm birth is crucial in preparing them to support the growing numbers of preterm children entering schools in the coming years.

The study is published in *Developmental Medicine and Child Neurology* (Johnson, Gilmore, Gallimore, Jaekel, & Wolke, 2015); see also editorial comment (Huddy, 2015)

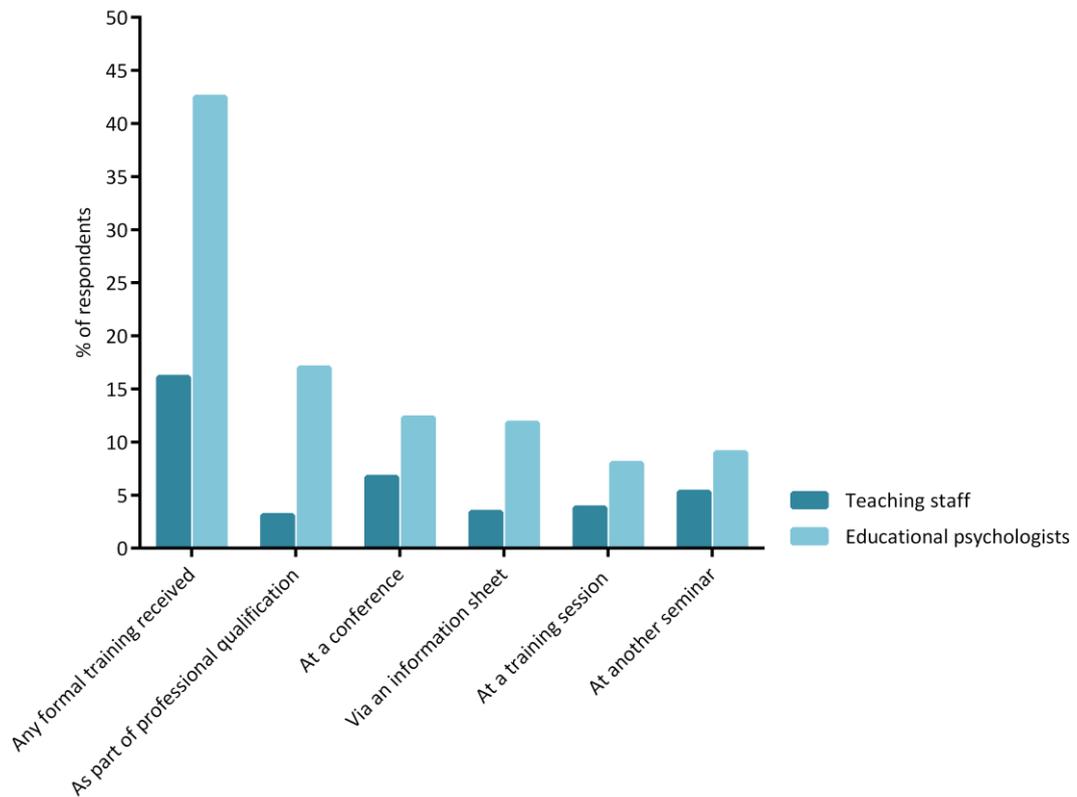


Figure 5: Training received about the educational needs of preterm children.

RECOMMENDATIONS

- **Follow-up assessments** to identify early cognitive, social, emotional and behaviour problems should be offered to moderately and very preterm children, and should extend into the late preschool and primary school years.
- **Interventions** are required around school age, either before or shortly after school entry to facilitate preterm children to perform at their potential.
- **Delayed school entry** is, according to our current evidence, not recommended for preterm children. Considering the demand by parents for delayed school entry, there is a need for a randomised controlled trial to evaluate whether it improves or is detrimental to preterm children's academic and social outcomes.
- **Training teachers** about the long term consequences of preterm birth is needed to enable them to understand the special constellation of problems faced by children born preterm.
- **New teaching approaches** need to be developed to deal with the special educational and social needs of preterm children in the classroom.

References

- Basten, M., Jaekel, J., Johnson, S., Gilmore, C., & Wolke, D. (2015). Preterm Birth and Adult Wealth: Mathematics Skills Count. *Psychological Science*. doi:10.1177/0956797615596230
- Jaekel, J., Strauss, V. Y.-C., Johnson, S., Gilmore, C., & Wolke, D. (2015). Delayed school entry and academic performance: a natural experiment. *Developmental Medicine & Child Neurology*, 57(7), 652-659. doi:10.1111/dmcn.12713
- Johnson, S., Gilmore, C., Gallimore, I., Jaekel, J., & Wolke, D. (2015). The long-term consequences of preterm birth: what do teachers know? *Developmental Medicine & Child Neurology*, 57(6), 571-577. doi:10.1111/dmcn.12683
- Wolke, D., Strauss, V. Y.-C., Johnson, S., Gilmore, C., Marlow, N., & Jaekel, J. (2015). Universal Gestational Age Effects on Cognitive and Basic Mathematic Processing: 2 Cohorts in 2 Countries. *The Journal of Pediatrics*, 166(6), 1410-1416.e1412. doi:10.1016/j.jpeds.2015.02.065

Commentaries

- Fastenau, P. S. (2015). Are the data on delayed school entry compelling enough to change policy or even pediatrician recommendations? *Developmental Medicine & Child Neurology*, n/a-n/a. doi:10.1111/dmcn.12774
- Huddy, C. (2015). Preterm birth and the school years. *Developmental Medicine & Child Neurology*, 57(6), 502-503. doi:10.1111/dmcn.12741

PRETERM BIRTH: IMPACT ON LEARNING AND EDUCATION

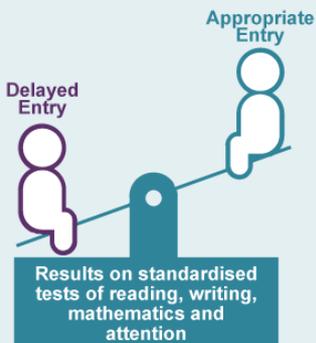
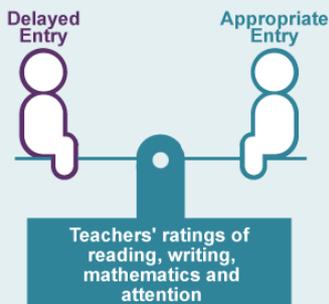
1 2 children in an average UK primary school class are born preterm



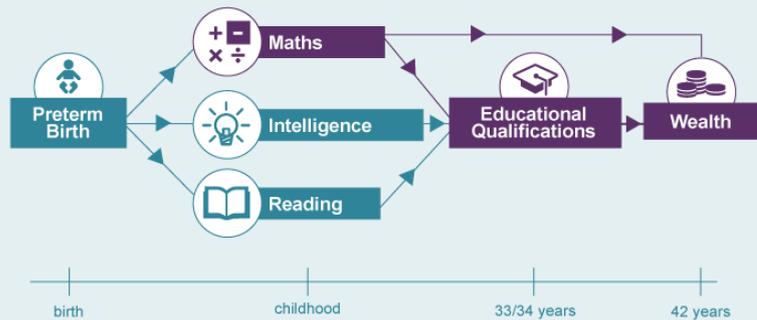
2 Children's IQ and mathematics scores in relation to the degree of prematurity at birth



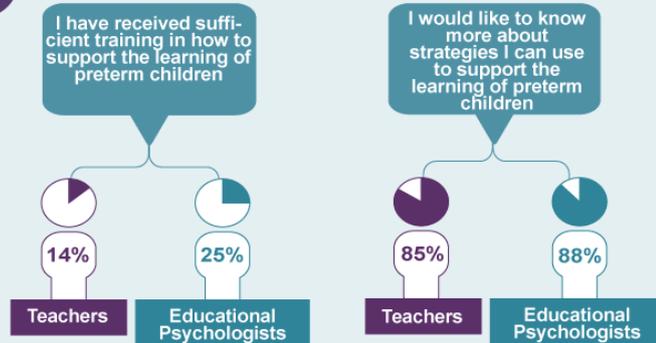
4 Delayed school entry may not affect Year 1 teacher ratings but does affect test scores at 8 years



3 Preterm children's lower mathematics skills lead to lower wealth in adulthood



5 Education professionals need more information about preterm birth



For more information contact: Dieter Wolke - D.Wolke@warwick.ac.uk

www.prime-study.org

Pr⁺_xME
Preterm birth: Impact on Maths & Education

