Teaching Early Numeracy and Science to Students with Developmental Disabilities

Magdalena Marta Apanasionok

A thesis submitted in fulfilment of the requirements for the degree Doctor of Philosophy in Education and Psychology

University of Warwick

Centre for Educational Development, Appraisal and Research (CEDAR)

March 2021

Table of Contents

Table of Tables

Table of Figures

Acknowledgments

I would like to start by thanking my supervisors – Richard Hastings, Corinna Grindle and Richard Watkins. It has been an extreme privilege to complete this PhD under their guidance and I am forever grateful for their support, patience, and kindness. I have learnt so much from them and I am a better researcher and person because of it. I would also like to thank University of Warwick and Calthorpe Academy for funding my PhD.

I am very grateful to all students and teachers who participated in my studies. Working with Calthorpe Academy has been a very enriching experience and a privilege. I would especially like to thank Julie Neil and Lara Latham for sharing their wealth of knowledge and experience with me.

I would also like to thank my co-authors and collaborators - Barah Alallawi, Tom Bailey, Louise Denne, Lara Latham, Leanne Maguire, Julie Neil, Gemma Nicholls, Andreas Paris, and Darragh Staunton - for their time and invaluable contributions to this thesis. I would like to also give my thanks to Bev Jones who worked tirelessly on the TEN-DD and TEN-DD R teaching plans with me and was such a pleasure to work with.

I am also very grateful to everyone in CEDAR for making the department such an amazing place for students and for supporting me for the last four years. In particular, I would like to thank Mairi Ann Cullen for being the most supportive and kind personal tutor I could have ever asked for.

Finally, I would like to thank my family and friends for supporting me along this journey and always believing in me. Especially, my wonderful husband Andrew and daughter Lila who kept me going even in the most difficult moments. I am also very grateful to my friend Nikita Hayden who never lets me give up. Lastly, I would like to thank Liz Corbel and Andreas Paris for welcoming me to the CBS team and being such an important part of my PhD experience.

Declaration

This thesis has not been submitted for an award or degree at any university or institution. Where material has been derived from other sources, full bibliographical information has been provided.

The work submitted is the result of my own investigations conducted under the supervision of Professor Richard Hastings, Dr Corinna Grindle and Dr Richard Watkins. Additional supervisory support was also provided during the randomisation and drafting stage of Chapter six by Dr Tom Bailey, a Research Fellow in CEDAR, University of Warwick.

For chapters three, four, five and six I worked collaboratively with Calthorpe Academy and they have supported with planning and conducting the studies.

A version of study described in Chapter 2 has been published prior to submission - Apanasionok, M. M., Hastings, R. P., Grindle, C. F., Watkins, R. C., & Paris, A. (2019). Teaching science skills and knowledge to students with developmental disabilities: A systematic review. *Journal of Research in Science Teaching*, 56(7), 847-880. https://doi.org/10.1002/tea.21531

A version of study described in Chapter 3 has been published prior to submission in a peer-reviewed journal - Apanasionok, M. M., Neil, J., Watkins, R. C., Grindle, C. F., & Hastings, R. P. (2020). Teaching Science to Students with Developmental Disabilities Using the Early Science Curriculum. *Support for Learning* – as well as in a form of a summary in a teacher journal - Watkins, R. M., Apanasionok, M. M., & Neil, J. (2020). Teaching science to pupils with SEND: using an evidence-based approach. *Primary Science*, 165.

A version of study described in Chapter 3 has been published prior to submission - Apanasionok, M. M., Alallawi, B., Grindle, C. F., Hastings, R. P., Watkins, R. C.,

Nicholls, G., Maguire, L., & Staunton, D. (2021). Teaching early numeracy to students with autism using a teacher delivery model. *British Journal of Special Education*.

Summary

Students with DD have the same rights in education as their neurotypical peers. Due to the historical undervaluing of the abilities of disabled students however - as well as a scarcity of research on implementing evidence-based teaching strategies in ‘typical’ special school settings in the UK - there is a large gap in attainment between neurodivergent and neurotypical students (Department for Education, 2020b). This thesis focused on science and numeracy education for students with DD and explored adaptations that can be made to ensure evidence-based interventions are more accessible and feasible to implement in specials schools in the UK. Chapter 1 provided an overview of the literature on teaching academic skills to students with DD, explored how the bioecological model and the MRC complex intervention framework can inform educational research, and provided some considerations on implementing Systematic Instruction interventions in special schools. Chapters 2, 3 and 4 presented three empirical studies on teaching science and numeracy to students with DD. Chapters 5 and 6 described the development of a numeracy readiness programme for students with DD. Chapter 7 – the overall discussion – provided an overview of the findings and their implications, the limitations of this thesis, my own reflections on the thesis, and proposed recommendations for future research.

List of Abbreviations

ABA – Applied Behaviour Analysis

ABLLS-R - The Assessment of Basic Language and Learning Skills – Revised

DD – Developmental Disabilities

DT – Discrete Trial

DTT – Discrete Trial Teaching

EHC - Education, Health and Care (plan)

ES – Early Science (curriculum)

ID – Intellectual Disabilities

MR – Maths Recovery

MRC – Medical Research Council

PMID - Profound and Multiple Intellectual Disabilities

PMLD - Profound and Multiple Learning Disabilities

RCT – Randomised Controlled Trial

SEN – Special Educational Needs

SLD – Severe Learning Disabilities

SpLD - Specific Learning Difficulties

STEM - Science, Technology, Engineering and Mathematics

TA – Teaching Assistant

TEMA-3 - Test of Early Mathematics Ability-Third Edition

TEN-DD – Teaching Early Numeracy to children with Developmental Disabilities

TEN-DD R – Teaching Early Numeracy to children with Developmental Disabilities - Readiness

Chapter 1

Introduction

Introduction

Science and mathematics are core subjects in England's programmes of study (Department for Education, 2014a) and their influence on students' independence, living skills and employment prospects are well documented in the literature (Staves, 2019; Apanasionok et al., 2019 – Chapter 2). Students learn and generalise important life skills such as using number, measuring time and capacity, developing numerical reasoning, and understanding about the human body and the natural world, that contribute to their independence later in life (Department for Education, 2014b & 2015a; Staves, 2019).

The purpose of science education is to help students build an understanding of the world around them through the systematic acquisition of subject-specific knowledge (i.e., chemistry, biology, and physics) and scientific inquiry skills (Department for Education, 2015a). Special attention is given to the development of students' curiosity of the world and their understanding of the processes through which they 'work scientifically' to find answers to questions. Science is taught through all key stages in England.

The mathematics' programme of study in England includes skills like number and quantity recognition, shapes and sizes, operations, and commutators (Department for Education, 2014b). Mathematics is taught through all key stages in England. In this thesis I am specifically focusing on the Number section of the national programme of study that I will refer to as 'numeracy'.

I focus on numeracy and science since both, despite their well-established and well-known importance in the development of children and young people, are still understudied when it comes to the education for disabled students[1] (Spooner et al., 2017; Grindle et al.,

---

[1] I am aware of the discussions around the use of person-first versus identity-first language and that there is not one universally accepted term for referring to disabled people. I want to respect wishes and

2020; Apanasionok et al., 2019 - Chapter 2). They form the foundation of science, technology, engineering, and mathematics (STEM) subjects that are core areas of focus in all mainstream programmes of study in England and internationally. Strong links of STEM subjects are also well documented in relation to further education and employment prospects.

Students with developmental disabilities

Prevalence and terminology

According to data from the Department for Education (2020a), in England 15.5% of all students have Special Educational Needs (SEN). Among them, 3.3 % have an Educational, Health and Care (EHC) plan, which means they have needs that cannot be met by the school alone. This translates to nearly 300,000 students across the country. Diagnoses of autism as well as moderate and severe intellectual (learning) difficulties are among the most prevalent for students with EHC plans. Educational provisions for students with SEN vary greatly in the UK depending on the individual needs. Some students might be enrolled in mainstream schools while receiving extra support, and others might be attending special schools. According to data from the Department for Education (2020b), the majority (43.8%) of students with EHC plans are enrolled in state-funded (funded by the local authorities) special schools, with only around 20% going to state-funded mainstream primary and secondary schools. For this reason, I concentrate on teaching in special schools in this thesis.

---

language preferences of different groups when referring to them in this thesis. Therefore, I will be using person-first language when referring to people with intellectual (learning) disabilities, developmental disabilities and special educational needs and identity-first language when referring to autistic people and disabled people in general. I acknowledge this might not be preferred language for all. Where necessary or appropriate for the context, I may swap the labels.

I focus on students with diagnoses of autism and/or intellectual disabilities (ID) in this thesis. Autism (referred to as autism spectrum disorder in the Diagnostic and Statistical Manual of Mental Disorders - DSM–5) is a neurodevelopmental condition that manifests in a person's behaviour and communication. Autistic students are characterised by differences in three main domains: social interactions, communication, and repetitive patterns of behaviour/restricted interests (American Psychiatric Association, 2013). ID is characterised by difficulties in the intellectual abilities that impact functioning in three broad domains: conceptual (e.g., memory and academic skills), social (e.g., communication and social skills) and practical (e.g., self-care and independence) (American Psychiatric Association, 2013). Due to the similarities in educational challenges that those two populations of students face, high comorbidity of both diagnoses and the fact that they are often referred to together in the research literature, I will be using an umbrella term developmental disability (DD) to refer to autistic students and/or those with ID throughout this thesis.

A framework for considering the learning needs of students with DD

According to Cullen et al. (2020) there are three main values underlying the ethos of working with students with DD (and SEN more widely): 1. Acceptance of the diversity by peers, educators, and schools more widely; 2. Understanding of the role of the environment in students' learning and development; and 3. The belief that all students can learn. Students with DD may experience difficulties with accessing mainstream education, depending on presentation and individual characteristics, therefore their needs should be regularly assessed and considered in curriculum planning. Those with moderate to severe DD are likely to need more extensive support and adaptations to help them access educational content (Staves, 2019); however, educators should have the same educational goals for them as they have for their peers (Cullen et al., 2020).

This ethos is consistent with the bioecological model (Bronfenbrenner & Morris, 2006) which I will be referring to throughout this thesis. This is an evolving model based on the assumption that humans' development is continuous and abides across the lifespan. Bronfenbrenner argued that there are four main elements influencing an individual's development (Bronfenbrenner & Morris, 2006; Rosa & Tudge, 2013):

1. Proximal processes (also referred to as the driving force of development) are described as everyday interactions with other people, objects, and symbols.
2. Personal characteristics can influence an individual's development in a positive (as a force generating development) or in a negative way (as a force impeding development). Personal characteristics directly influence the abilities of an individual to engage in the proximal processes. Bronfenbrenner distinguished three main types of personal characteristics – force (e.g., curiosity, reactiveness, impulsiveness, distractibility), resource (e.g., knowledge, skills, barriers) and demand (e.g., temperament).
3. Context, or environment, is an important factor influencing an individual's development and engagement in the proximal processes. The bioecological model, alongside its earlier versions, sees the environment as interconnected with the individual - constantly influencing each other and evolving. Bronfenbrenner described four main types of context:
    a. microsystem – the immediate environment in which the individual is situated in, such as home or classroom;
    b. mesosystem – is the interaction, or link, between two or more microsystems in which the individual is actively engaged in. It constantly evolves when a person enters or leaves a microsystem;

c. exosystem – the context that is influencing (or is being influenced by) the individual and its development but in which the person is not directly participating. An example of exosytem could be a teacher-parent meeting or a senior leadership meeting;

d. macrosystem – a broader systemic and cultural context that can influence an individual's development, such as the culture, the school system, or policies.

4. Time, referred to as the chronosystem in the earlier versions of the model, is the last factor influencing the individual and its development. Bronfenbrenner refers to both past and present time but also to the future as being influential.

Based on the interpretation of the bioecological model in the context of the educational system and the needs of students with SEN, Cullen et al. (2020) proposed a set of guidelines for the schools. The main focus should be placed on the environment (context) to adapt and optimise to meet the needs of individual students. This includes paying special attention to the proximal processes by setting up meaningful, accessible, and engaging activities as well as facilitating and encouraging interactions. Efforts should be focused on the immediate environment (microsystem) and student's behaviours within that (proximal processes) to identify any strengths and barriers (personal characteristics) which can then inform teaching planning.

I acknowledge that bioecological model provides a robust conceptual framework that enables us to study many areas of an individual's development. However, in this thesis I will be mainly focusing on the alternations to the student's microsystem and the increase of proximal processes.

Students with DD in the educational system

Historical assumptions and attainment of students with DD

Historically, many educators and researchers undervalued the abilities of students with DD to acquire academic knowledge and skills. It was often assumed that mathematics education for students with DD (especially moderate to severe) comes down to teaching very basic money skills and number recognition (Browder & Spooner, 2011; Spooner et al., 2019; Grindle et al., 2020). The provisions and guidelines on teaching mathematics were scarce and the abilities and learning potential of the students were often undervalued. Staves (2019) suggests that historically students' skills and progress in mathematics (similarly to the other academic subjects) were assessed with inappropriate and not fully accessible assessments. This negatively influenced educators' perceptions of students' capacities and their learning goals. The field of science education for students with DD has been similarly underdeveloped. Typically, the provision for science education for students with DD is characterised by the use of sensory approaches and focused on functional skill training (Apanasionok et al., 2019 - Chapter 2). It still appears that educators overlook the fact that students with DD can learn scientific knowledge and successfully use science inquiry skills, a foundation of science education in England and internationally. In a new study exploring the perceptions about people with ID in the USA, only around half of the responders agreed that individuals with ID are capable of graduating from secondary school or having a paid or unpaid job (McConkey et al., 2020).

Rights of students with DD

Current policies and standards in the UK are clear – students with DD have the right to access high-quality education. In fact, The Equality Act 2010 mandates schools to make all reasonable adjustments to ensure disabled children and young people have equally meaningful access to teaching as their peers (Department for Education, 2014c). The Equality Act 2010 goes as far as saying that schools may treat disabled students more favourably than neurotypical students to ensure equal access to education. The goal of the educational provisions for students with SEN is to: (1) Enable students to fulfil their potential; (2) Enable students to become fulfilled and confident individuals; and (3) Enable students to successfully transition to adulthood, either further education or employment (Department for Education, 2015b). Schools should ensure that students with SEN have equally meaningful access to activities and opportunities as neurotypical students (which is consistent with my overarching theoretical stance). Educators are advised to assess students' progress frequently in order to set ambitious, but attainable goals. The Special Educational Needs and Disability code of practice also recommends that educators should be making decisions about educational provisions for students with DD based on the best available evidence (Department for Education, 2015b). International policies also focus on the equal and meaningful access to education for disabled students. As part of the Education 2030 agenda, UNESCO wants disabled students, along with other historically excluded groups, to be fully included in educational systems around the world by 2030 (United Nations Educational, Scientific and Cultural Organization, 2017).

Attainment of students with SEN

Despite clear legislations on the rights of students with SEN in education, in 2019 only 5.9% of adults with ID were in the paid employment in England (Department for Education, 2020b). The results of the historical and cultural attitudes towards the expected attainment of students with DD (and disabilities more widely) can be observed in their attainment levels now. In the school year 2018/2019 in England, only 33% of students with SEN achieved the expected level in mathematics in Key Stage 1, compared to 84% for students with no SEN (Department for Education, 2020b). Similarly for science, 42% of students with SEN achieved the expected standard, compared to 90% for students with no SEN. Comparable discrepancies can be observed for Key stage 2 – only 22% of students with SEN achieved the expected level in reading, writing and mathematics, in contrast to 74% for students with no SEN (Department for Education, 2020b). The attainment data look equally concerning in further education. In 2019, in England attainment in Level 2 was 52.8% for students with SEN, compared to 86.7% for students with no SEN. This indicates that students with no SEN were one and a half times more likely to achieve Level 2 by the age of 19 than students with SEN (Department for Education, 2020c). Similarly, 36.3% of students with SEN attained Level 3, compared to 62.2% for students with no SEN, which means those students were twice as likely to achieve Level 3 by the age of 19 than students with SEN (Department for Education, 2020c). Although the attainment gaps have reduced slightly over the last 10 years, they still remain unacceptably large and have lifelong consequences to individuals with SEN. It is worth noting that the attainment data reported by the Department of Education refers to the whole population of students with SEN, and the attainment gap for students with DD is likely to be even larger.

Grindle et al. (2020) lists five reasons as to why students with DD might be underperforming in mathematics, and these factors are likely to be equally applicable to science education and other academic subject areas: (1) Students are not given enough opportunities to learn academic skills; (2) More focus may be placed on the functional skills training as opposed to more structured teaching of the academic skills; (3) Educators do not feel prepared to teach the academic content to students with DD; (4) Educators may struggle to deliver teaching due to students' inattention or behaviours that may challenge; and (5) Educators may find it difficult to gather the evidence needed to monitor student's progress and identify gaps as well as to interpret research findings and apply evidence-based teaching strategies.

Ongoing change

In recent years there has been an increasing focus on researching effective teaching strategies for students with DD. Available research clearly shows that students with DD can successfully learn academic content (Spooner et al., 2017). Moreover, in contrast to some previously held views on the balance of functional versus academic skills, we now know that teaching academic skills can be equally as meaningful as functional skills training. This in turn have a positive impact on the independent living skills and employment prospects of students. Grindle et al. (2020) suggest that students with DD can be taught even quite complex skills as long as appropriate, evidence-based teaching procedures are used. More schools now place a clear emphasis on systematic teaching programmes, catch-up interventions, and adaptations to regular school curricula to ensure students with DD have equal (and meaningful) access to the academic content. Educators and researchers focused on science education are also beginning to understand that students with DD can successfully learn science knowledge and use scientific inquiry skills to find things out (core components in many science curricula around the world), especially if they are taught in a systematic and structured manner (Rizzo & Taylor, 2016; Apanasionok et al., 2019 – Chapter 2; Apanasionok et al., 2020 – Chapter 3). As suggested by Browder and Spooner (2011), even students who lack some of the skills to access grade level materials (for example, those students who cannot yet read) can still access the content by utilising different methods, for example read-alouds.

Teaching academic subjects to students with DD

Theoretical perspectives on learning

There are four main perspectives on child development and knowledge acquisition that help frame educational systems (McGinnis & Kahn, 2014):

1. Developmental – patterns of thinking vary greatly between individuals and evolve throughout the lifespan, meaning that students learn at a different rate;
2. Behavioural (e.g., Systematic Instruction) – learning is focused on observable and measurable behaviours. Students work towards clearly defined goals until they reach the prescribed mastery criterion;
3. Sociocultural – individual’s development is influenced by multiple factors such as the culture or the environment as well as their interaction with each other;
4. Cognitive (i.e., constructivist or inquiry-based learning) - focuses on the construction of the understanding of the world through exploration. This theory highlights the importance of cognitive processes – memory, perception, attention, and metacognition – in the process of knowledge formation.

Currently the two most prominent perspectives considered in the education literature are constructivism and Systematic Instruction (for the definition see below). Although they share some similarities - mainly in the focus on the teaching process and the identification of the students’ existing knowledge and skills as formative starting points - there are also some key differences (Grindle et al., 2020). They differ predominantly in ‘how’ the teaching is organised and delivered. The constructivist approach is focused on enabling the student to explore and experiment in order to build their understanding of concepts and ideas. This theory follows the Piagetian principle that knowledge is actively constructed through practical interaction with objects and the physical world (Piaget, 1959). However, in recent decades this theory of learning has come under increasing scrutiny by researchers who question how well it explains how children learn (Kirschner et al., 2006; Steffe & Gale, 1995). Constructivism is often thought of as the student led approach and, in effect, some researchers view constructivism as a theory of learning rather than a framework for effective teaching. Systematic Instruction, on other hand, highlights the importance of systematic teaching strategies led by the teacher and informed by student progress and feedback information (Grindle et al., 2020). The perspective on students' motivation also differs significantly between both approaches. In the constructivist approach, the motivation is internal to the student and sustained by the process of discovery. In Systematic Instruction, however, motivation can sometimes be external and mediated by the educator. Both approaches highlight the importance of social interaction between the educator and the student (referred to as proximal processes in the bioecological model). However, verbal communication and abstract thinking - two areas of functioning that individuals with DD often struggle with - are essential parts of the constructivist theory of learning and, therefore, might be inaccessible for some students (Rizzo & Taylor, 2016; Grindle et al., 2020). In those instances, Systematic Instruction might be a more promising teaching approach.

It is crucial to consider individuals' needs and preferences, as well as the available evidence when choosing the most appropriate teaching approach. This is consistent with the overarching theoretical perspective in this thesis (based on the bioecological model) which highlights the influence of personal characteristics and context on the proximal processes (and as a result - knowledge and skills acquisition as well as individuals' development).

Introduction to the evidence

Although the research on teaching academic subjects to students with DD is scarce compared to the research on neurotypical individuals, some research has been published over recent years. In 2015, Spooner and Browder called Systematic Instruction (for definition see section below) one of the most significant advancements in the education for students with severe DD (next to the increased focus on functional and meaningful skills and teaching of the academic content). Spooner et al. (2017) in their summary of the evidence, suggested that Systematic Instruction is the most promising approach to teach students with severe disabilities a range of skills, including those linked to numeracy and science.

In a review of evidence on teaching mathematic to students with DD, Spooner et al. (2019) identified 36 studies of high or adequate quality. They concluded that Systematic Instruction is an evidence-based practice. Similarly, for science, Spooner et al. (2011) identified 17 studies, all of which used Systematic Instruction procedures. Spooner et al. concluded that it is an evidence-based practice for teaching science to students with DD. Rizzo and Taylor (2016) analysed literature on inquiry-based instruction and concluded that it is not an effective teaching strategy for disabled students on its own but can be successfully used when paired with explicit (systematic) instruction. We have also conducted a systematic review on teaching science to students with DD (Apanasionok et al., 2019 - Chapter 2) and identified three promising teaching approaches – Systematic Instruction, self-directed instruction, and comprehension-based instruction. All methods were found to be effective and were positively viewed by the educators, however Systematic Instruction was used the most frequently and to teach the widest variety of skills.

Based on the available evidence, Browder and Spooner (2011) propose eight indicators of high-quality educational provisions for students with DD:

1. Inclusivity;
2. A good relationship between the parents and the school;
3. Collaboration between different professionals in care planning;
4. Use of Systematic Instruction methodology;
5. Use of Positive Behaviour Support;

6. Encouraging self-determination in students;
7. Teaching academic skills; and
8. Teaching functional skills.

What is a Systematic Instruction?

Definition and overview

Systematic Instruction is a teaching strategy derived from principles of behavioural science. It defines learning as an event that exhibits an increasingly consistent response in the presence of certain stimuli (Browder & Spooner, 2011). Browder (2001) described Systematic Instruction as "teaching focused on specific, measurable responses that may either be discrete (singular) or a response chain (e.g., task analysis), and that are established though the use of defined methods of prompting and feedback based on the principles and research of applied behaviour analysis (ABA)" (p. 95). An important quality of Systematic Instruction is that it focuses on teaching behaviours that are meaningful to the student.

Systematic Instruction targets measurable and observable behaviours (responses), and a strong emphasis is placed on setting up operationally (clearly) defined learning goals. When planning teaching, the educator considers three main components:

1. Antecedent – what happens just before the behaviour. In education that is often the instruction delivered by the educator;
2. Behaviour – the student's response. In education this is what the educator is looking to teach or improve; and
3. Consequence – what happens immediately after the student's response (behaviour). In education this is usually praise (if correct) or an error-correction (if incorrect).

Progress is frequently assessed to ensure effectiveness of the employed teaching methods. Educators using Systematic Instruction often break down complex skills into smaller, more achievable steps (i.e., by creating a task analysis). This methodology employs prompting and prompt-fading procedures to enhance acquisition and ensure students do not become over-reliant on an educator's help. Strong emphasis is also placed on promoting generalisation (an ability to apply learned skills in a new context) and maintenance of acquired skills. In fact, Collins (2012) calls generalisation the most important component of teaching for students with DD.

Systematic Instruction has been used to teach range of functional and academic skills to students with DD as well as managing behaviours that may challenge. There is very sound evidence of its effectiveness in the research literature (Spooner et al., 2017; Apanasionok et al., 2019 – Chapter 2; Grindle et al., 2020). Systematic Instruction has been successfully used in a range of settings like schools (both mainstream and special), colleges, and in the wider communities, both in individual and group contexts (Browder & Spooner, 2011).

What does the teaching look like in practice?

Teaching set up may vary depending on the setting and the needs of the individual students, however there are several fundamental elements of Systematic Instruction teaching that remain unchanged. Firstly, environment plays an important part in behavioural science so close attention is given to how students' immediate surrounding is organised (e.g., by clearing all the unnecessary distractions from the teaching space). The pace of the teaching is also important in Systematic Instruction. As a consequence, it is often recommended that the educator prepares all the required materials beforehand and is familiar with the teaching procedure. Teaching usually starts with a clearly defined antecedent. This can be an instruction given by the educator, but also a visual, tactile, or other auditory stimulus that cues to the student that a response is expected (e.g., a worksheet). A clear emphasis is placed on operationally defining the target behaviour (i.e., goal) to ensure consistency. For new or not yet established behaviours, the educator might deliver a prompt (i.e., cue) to increase the chance the student will engage in the correct response. The student's behaviour (response) is always followed by a consequence. This can take a different form depending on how established the target behaviour is and whether the student was correct or not. For an accurate response, the student is usually praised and sometimes receives a token or a small reward. When the student responds with an error the educator immediately employs a pre-designed correction procedure to prevent incorrect responding in the future. The educators can employ other methods as needed. The most frequently used strategies are:

1. Constant time delay – a prompt is delivered after a specific number of seconds following the instruction;
2. Prompting hierarchy – a system of prompts (cues) delivered by the educator arranged from the least intrusive to the most intrusive or vice versa;
3. Task analysis – a method of breaking down complex skills into smaller, more achievable steps that are taught in order;
4. Embedded instruction – incorporating structured teaching during an on-going, often leisure or play activity; and
5. Explicit instruction – an active teaching method that incorporates guiding and modelling of the behaviours.

From the student's perspective, teaching strategies that employ the Systematic Instruction methodology are usually undertaken at a quick pace and in short bursts of time with frequent breaks. The student always receives feedback from the educator, whether the response is correct or not. The educator actively tries to set the student up for a success through the appropriate use of prompting and error-correction procedures (among other things). The goal of this is not only to accelerate the acquisition, but most importantly to ensure a positive learning experience and the sense of achievement for the student, in turn increasing their motivation. The student's individual responses are all taken into consideration when planning the teaching, to ensure meaningful and positive access to the target content.

Considerations on using Systematic Instruction in schools in the UK

There are number of potential challenges that need to be considered before implementing interventions employing Systematic Instruction in schools in the UK. Perhaps the most important consideration is related to educators' attitudes and preconceptions about Systematic Instruction. Historically, behaviour analytic interventions were seen as overly restrictive or diminishing the opportunities for exploration and the inquiry-led teaching (Heward, 2003). That is still the case now for some educators, and is especially the case for science education, where constructivist or inquiry-led teaching remains preferred teaching paradigm (Apanasionok et al., 2019 – Chapter 2). However, the growing evidence base and the statutory mandate of the Special Educational Needs and Disability code of practice (Department for Education, 2015b), has resulted in more educators now being willing to consider using Systematic Instruction as a classroom strategy. The problem remains, however, that many are still discouraged by the limited research literature on implementing the Systematic Instruction interventions in settings 'typical' for the UK (i.e., state-funded special schools) and the availability of comprehensive teaching programmes that align with national standards (Grindle et al., 2020). The majority of the studies on the effectiveness of behaviour analytic interventions, such as Systematic Instruction, were conducted on teaching isolated skills rather than a more comprehensive range of skills. Often, they were conducted in settings with high staff to student ratios (often one-to-one) which is not representative of most educational providers for students with DD in the UK. During many of the research studies, educators received comprehensive, tailored training packages, and these were often far longer than is possible to accommodate during annual training available in 'typical' special schools in the UK. The interventions are also often implemented with the ongoing assistance of research teams. This is not an accurate representation of 'typical' educational provisions for students with DD in the UK. There is a scarcity of evidence-based teaching programmes adapted to be used by educators with no or little previous experience in using Systematic Instruction and/or in settings with a high staff to student ratio. In state funded schools, training is usually also limited to few days per school year and financial restrictions usually prevent accessing ongoing support. This can be discouraging to educators considering incorporating Systematic Instruction methodology in their teaching.

Given the controversies surrounding ABA, it is also important to explore some of the concerns voiced by people with DD about Systematic Instruction. The autistic community in particular has expressed apprehension about the use of ABA-derived teaching methods (e.g., McGill & Robinson, 2020). There are reports of ABA being used to attempt to diminish autistic traits and 'normalise' the individuals by encouraging masking (e.g., teaching eye contact, discouraging self-stimulatory behaviours such as hand flapping, limiting access or discouraging conversations about special interests). Masking has been found to have a negative impact on the mental health of autistic people while increased self and external acceptance of autistic traits can be a protective factor against depression (Cage et al., 2018). 'Normalising' contradicts values held by the neurodiversity movement and the vast majority of professionals, including the author of this work. This discussion is especially prominent in relation to early intervention for children with DD but is also relevant in the educational context. I think it is important to highlight one of the most important aspects of ABA/ Systematic Instruction – the focus on behaviours that are meaningful and significant to the individual, not to the larger community. Thus, it aims to diminish barriers to learning and address accessibility issues by considering an individual's strengths. The overarching aim of Systematic Instruction is to provide meaningful access to the teaching content and, as a result, help the individual reach their full potential, not change who they are.

This is of course one of many concerns raised by the autistic community in relation to ABA (McGill & Robinson, 2020). There are many accounts of negative experiences of individuals with DD of ABA-derived interventions – some experiencing trauma due to poor supervision and quality measures available to identify and correct bad practice in time. Many accounts also mention feeling voice-less and as if decisions about them were being made without them. We as a field must do better to include the voices of people with DD and their families. When consultations with the individual are not fully possible due to communication difficulties, then experts by experience should be consulted. As a former ABA practitioner and an autistic person, I think there is a real value to listening to the concerns raised by people with DD about ABA and engaging in meaningful discussions to improve as a field.

Thesis purpose and rationale

There is an emerging evidence base for using Systematic Instruction to teach numeracy and science to students with DD. However, to date, there is a scarcity of teaching programmes and curricula adapted to be used in the UK. The existing programmes that use Systematic Instruction have either not been tested in the UK or are not adapted to our educational system. In this thesis we want to contribute to this field of study by working with a large special school in the UK to test the feasibility of implementing evidence-based programmes to teach numeracy and science to students with DD.

Medical Research Council complex intervention framework

Educational interventions, especially for people with DD, are widely seen as complex due to the number of components, such as students' characteristics, learning history, type of educational provision and educators' experience and skills that interact with each other and influence outcomes. Interventions are also often tailored, rather than fully standardised, to suit the needs of the individual students. For those reasons, this thesis follows the Medical Research Council (MRC) complex intervention framework (Craig et al., 2008) to help guide the planning and evaluation of interventions in this thesis. Although the framework has been initially developed for the medical sciences, it works well for other areas of research, including educational interventions.

There are number of considerations relevant to the educational context that need to be made when developing and evaluating complex interventions (Craig et al., 2008). Firstly, a good understanding of the theoretical basis and the interacting components is needed to explain the mechanism of change. Larger sample sizes and multiple outcome measures are often preferable due to the possible variability of the individual data, as often observed in the complex interventions. It is also recommended to allow some tailoring of the intervention to suit the context, rather than using a more standardised approach.

According to the MRC complex intervention framework, the best practice is to develop interventions based on the available evidence as well as the theoretical approach and then move on to a carefully planned, phased evaluation (Craig et al., 2008). There are four key elements to this process - development of the intervention, piloting and feasibility, evaluation, and implementation. Those elements often do not follow from one to another in a linear manner, but rather interact and inform each other. Focus groups and consultations with stakeholders can be especially useful during the development process. Once the intervention is refined, the general recommendation is to start the evaluation process with a series of pilot/feasibility studies. Those are usually smaller scale studies that help to answer questions in regard to the intervention itself as well as the most suitable outcome measures, the recruitment strategy, the sample size, and the research design. According to Craig et al. (2008) a mixed methods design is often useful at this stage as it allows for further exploration of the key questions and the potentials barriers, including the recruitment process and the user satisfaction after using the intervention. After the piloting process is finished, the next step is often to conduct larger scale exploratory studies which aim to gather some initial evidence on the effectiveness of the complex intervention, its cost-effectiveness, and the mechanisms of change. When the results from all previous studies are encouraging and the main uncertainties around the recruitment process and the design are resolved, the researchers often move on to carrying out a definitive trial with a follow-up. The choice of the most appropriate research design at this stage depends on the setting, the target population, and the nature of the intervention (although trials involving randomisation are often recommended). The last stage is the dissemination of the findings and continued monitoring of long-term outcomes of the intervention.

Structure of the Thesis

The remainder of this thesis consists of six chapters – five chapters describing the empirical studies and an overall Discussion. Chapters 2, 3 and 4 have been published in peer-reviewed journals. There is a degree of overlap between the chapters and some of them inform one another. However, each chapter can also be treated as a stand-alone body of work. Together they contribute to the existing knowledge on science and numeracy education for students with DD.

Consistent with the MRC complex intervention framework, this thesis commences with a review on the existing science education literature to help inform later studies. Chapter 2, therefore, is a systematic review of literature on teaching science to students with DD. The aim of this chapter was to establish what interventions have been developed to teach science, as well as what were the views and experiences of the students and their teachers of using them. In this study we describe the latest research in this area and synthesise the findings alongside the existing research literature on teaching students with DD. We also draw some practical recommendation for science educators working with this population of students. The study followed PRISMA guidelines (Moher et al., 2009; see Appendix 1) for conducting and reporting the findings from the systematic review.

Following on from the findings of the systematic review, Chapter 3 describes the implementation of an evidence-informed science curriculum called Early Science. Studies piloting the use of this curriculum were identified as part of the searches for the systematic review (Chapter 2). Early Science is a curriculum created to teach students with DD the science standards in the USA. However, it also maps well against the various science programmes of study in the UK. It utilises Systematic Instruction to teach science skills and knowledge. The goal of the study described in Chapter 3 was to pilot the use of the Early Science curriculum in a special school in the UK (as part of the piloting stage of MRC complex intervention framework). Apart from collecting outcome data from the students, we also conducted some informal interviews with the educators working on the project as recommended by Craig et al. (2008). Based on that we proposed changes that can be made in order to use the Early Science more effectively in the UK special school context and plan larger scale evaluations. Paper describing this study has been published in a peer-review journal. However, we are aware of the importance of publishing in journals for teachers/practitioners, so we have also published a summary of this study in Primary Science journal (see Appendix 2).

Chapter 4 describes the implementation of the Teaching Early Numeracy to students with Developmental Disabilities (TEN-DD) programme. TEN-DD uses Systematic Instruction to teach numeracy to students with DD. Although there is some initial data on the feasibility and effectiveness of using the programme in the schools in the UK, previous evaluations were conducted in different educational settings than those usually used for students with DD (i.e., state-funded special schools). For this reason, in Chapter 4 we specifically focus on establishing the feasibility of implementing TEN-DD as a teacher-led model before a larger scale evaluation can be planned (as recommended in MRC complex intervention framework). We achieved this by setting up a mentoring system in the participating school and closely collaborating with the educators and the leadership team. In this study we describe initial students' numeracy outcomes, as well as suggestions for improvements made by the educators. We also offer suggestions on ways in which TEN-DD can be implemented in the future to reduce researchers' involvement.

As part of the project described in Chapter 4, I have also worked on a qualitative study with another PhD student. This involved interviews with educators exploring their views and experiences of using the TEN-DD programme. Findings from this study are described in the thesis of a PhD student I collaborated with and attached in Appendix 3.

Following on from the successful implementation of TEN-DD, Chapters 5 and 6 describe the new programme that focuses on learning-to-learn and numeracy readiness skills. Teaching Early Numeracy to students with Developmental Disabilities – Readiness (TEN-DD R) follows the same structure and teaching methodology as TEN-DD and can be treated as preparatory or as a stand-alone intervention. Following the suggested development process described in the MRC complex intervention framework and the Six

Steps in Quality Intervention Development (6SQuID) model, we describe how the programme was developed, its structure and how to implement it.

After the TEN-DD R programme was developed, we followed the next stage of the MRC complex intervention framework – piloting and feasibility – by planning a feasibility randomised controlled trial (RCT) to gather some initial data on its feasibility. However, shortly after the intervention was introduced, schools in the UK were closed due to Covid-19 pandemic. Therefore, in Chapter 6 we describe the study protocol and reported baseline data and participants' characteristics. Based on our experiences of the participants' recruitment, the staff training and the intervention implementation, we also propose how the study could be carried out to in the future, especially when planning larger scale evaluations.

Chapter 7 is an overall Discussion of the thesis where each study is evaluated for their wider contribution to the existing knowledge on teaching numeracy and science to students with DD. The thesis concludes with an evaluation of how the studies relate to the MRC complex intervention framework alongside suggestions for future research.

Chapter 2

Teaching Science Skills and Knowledge to Students with Developmental Disabilities: A Systematic Review[2]

This systematic review was carried out as a part of Doctoral Dissertation funded in collaboration by University of Warwick and Calthorpe Academy.

---

[2] A version of this study has been published in Journal of Research in Science Teaching as follows: Apanasionok, M. M., Hastings, R. P., Grindle, C. F., Watkins, R. C., & Paris, A. (2019). Teaching science skills and knowledge to students with developmental disabilities: A systematic review. Journal of Research in Science Teaching. 56: 847– 880. https://doi.org/10.1002/tea.21531.

Summary

A comprehensive review of the literature was conducted to identify current practice on teaching science to students with intellectual disability (ID) and/or autism in relation to two review questions—students' science outcomes and students' and teachers' experiences of the interventions. Six databases related to education, psychology, and science were systematically searched. A detailed protocol can be viewed on PROSPERO (registration number: CRD42017057323). Thirty studies were identified that reported on science interventions and 20 on student/teacher experiences of the interventions. The majority of the studies targeted science vocabulary and concepts. Other targets included inquiry skills and comprehension skills. The majority of the interventions used components of systematic instruction (n = 23). Five studies focused on self-directed learning and two on comprehension-based instruction. Students and teachers reported positive experiences of the interventions. The findings suggest that components of systematic instruction in particular might be effective in teaching science content to students with ID and/or autism. Further research is needed to explore the effectiveness of identified interventions on teaching more complex science skills and with students with severe disabilities. Some limitations related to the search strategy are highlighted.

Introduction

Like other contemporary education practice, science education has moved away from a standard model of schooling focused on learning facts to a pedagogy that aims to promote a deeper understanding of key science concepts (Sawyer, 2008). An example of this move is embodied within the Next Generation Science Standards (NGSS), a set of core values adopted by states to improve the provision for teaching scientific content and skills through more practical scientific experiences (National Research Council, 2013). More recent thinking in science education has also moved toward the development of a balanced science curriculum based on ‘big ideas’ in science, aimed at promoting science as an interesting and relevant subject that is central in the creation of ethically aware and critically informed young people (Harlen, 2015). It is within this context that science remains an important subject to be understood by all students regardless of gender, culture, ethnicity, or disability.

How students learn science

McGinnis and Kahn (2014) report four main perspectives on learning that have shaped current thinking on teaching science to students with SEN:

1. Developmental - the thinking of children and adults is different, and it changes throughout the life;
2. Behavioural - learning is the result of connection between stimuli and behaviour, and it continues until prescribed mastery criteria are reached;
3. Sociocultural - individuals' development is a result of interactions between multiple factors such as culture and environment; and
4. Cognitive - focus is placed on mental processes, such as memory, perception, attention, and metacognition.

According to McGinnis and Kahn (2014), many practitioners favouring a cognitive (constructivist) perspective use teaching approaches that enable students to build their understanding of scientific ideas by undertaking practical scientific inquiry tasks (often called inquiry-based learning), whereas those preferring the behavioural model place a greater emphasis on teaching more knowledge-based learning programs aimed at attaining mastery of predetermined learning objectives. Inquiry-based learning based on the principles of cognitive science is commonly referred to as constructivism where learners construct their own understanding of concepts and ideas from minimal information (Kirschner et al., 2006; Steffe & Gale, 1995). It is important to note, however, that the term constructivism in science education refers to a theory of learning rather than a clearly defined theory of teaching. In practice, the division between the behavioural and constructivist approaches is often more nuanced than the binary division commonly outlined in the literature.

Of more practical significance than the discussion on how students learn science is the distinction between how students learn science (i.e., inquiry-based learning) and their ability to ‘work scientifically’ (i.e., undertaking the process of science inquiry where learners apply their science knowledge and skills to answer questions). The ultimate goal of teaching science is to equip students with the knowledge and skills to enable them to carry out the process of science inquiry to answer testable questions and/or gather information in a systematic manner. Whether learners have acquired the necessary science skills through inquiry-based or direct teaching approaches is perhaps of secondary importance to the main goal of ensuring students are able to apply these skills to enable them ‘work scientifically’.

More recent research has tried to draw together findings from cognitive and developmental psychology to describe a set of core skills that underpin children's early learning in science (Tolmie et al., 2016). The proposed core components of initial science learning for young children are:

1. Accurate observation;
2. The ability to extract and reason explicitly about causal connections; and
3. Knowledge of mechanisms that explain these connections.

This work details the important part of language acquisition and group work play in supporting children's emergent scientific ideas, especially for the skills of predicting and reasoning associated with casual observations.

Science and the rights of disabled students

In the United States, 13% of all school-age children have disabilities (Snyder et al., 2018). In England, 15.5% of all students have SEN (Department for Education, 2020a). Despite disabled students being a significant minority in the school-age population, they are still underrepresented in research studies in the field of education, especially students with more severe disabilities (Spooner & Browder, 2015). McGinnis and Kahn (2014) report that there is also an overrepresentation of students from ethnic minorities among students with disabilities or SEN which might be related to poverty, students' academic achievement being devalued, and language use (e.g., with multiple languages being spoken at home).

Internationally, policy and guidance is clear about the inclusion of disabled students in science education. The No Child Left Behind Act (2002) emphasized schools' obligation to provide high-quality education to all students and required schools in the United States to assess all students' progress in reading, mathematics, and science. The Every Student Succeeds Act (2015) shifted accountability to individual States and left much more flexibility to how students' knowledge is being assessed while continuing to emphasize the use of evidence-based practice in teaching disabled students. UNESCO's Education 2030 agenda envisions inclusion of all historically excluded pupils, including those with disabilities, by 2030 together with the creation of more safe and accessible educational establishments (United Nations Educational, Scientific and Cultural Organization, 2017). The central point of the international agenda is the right of every learner to equal access to education. In the United Kingdom, under the Equality Act 2010, schools have an obligation to provide access to education to all students and make reasonable adjustments for disabled students (Department for Education, 2014c). Teaching should be personalized to ensure meaningful access to the curriculum for all students. Teachers are encouraged to frequently assess students' progress and set goals that are achievable yet ambitious (Department for Education, 2015b). Moreover, the Special Educational Needs and Disability code of practice (Department for Education, 2015b) recommends the choice of teaching approaches based on available evidence.

Teaching Science

In the late 1990s, the United States National Science Education Standards (NSES) shifted attention to the use of inquiry-based instruction (learning focused on students posing questions, exploring, and testing ideas to enable them to construct their own understanding) and emphasized that ‘learning science is an active process’ (National Research Council, 1996, p. 20). The NSES requires science education to cover eight standards including science concepts; science inquiry; physical, life, and earth and space science; science technology, history of science, and social and personal perspectives on science (National Research Council, 1996). The NGSS identify core standards within all grades on three dimensions: core ideas, practice, and crosscutting concepts (National Research Council, 2013). The standards focus on the development of students' comprehension of key science concepts and processes as well as their ability to develop and test hypotheses and evaluate evidence.

In England, science education standards are organized based on age-related key stages focused on three basic aims: the development of science knowledge and concepts and scientific inquiry skills (‘working scientifically’) (Department for Education, 2014a). Schools are required to teach students science across all ages. However, mainstream content can often be inaccessible for students with DD (Spooner et al., 2014), where the teaching paradigm is often focused on inquiry or discovery-based learning. These strategies are often successful with neurotypical learners in mainstream settings but can be less effective for disabled students (Rizzo & Taylor, 2016).

Previous research on science education and students with DD

In the present review, we focused on science education for students with ID and/or autism describing these groups of children with the general term developmental disability (DD). “Intellectual Disability (intellectual developmental disorder) is a disorder with onset during the developmental period that includes both intellectual and adaptive functioning deficits in conceptual, social, and practical domains.” (American Psychiatric Association, 2013). Autism is a neurodevelopmental condition characterized by differences in social communication, social interaction, and repetitive behaviours (American Psychiatric Association, 2013). Those two populations were chosen due to similarity of challenges that the learners face and the relatively limited existing research literature and guidelines for professionals. Findings for both ‘diagnoses’ are clearly differentiated in the current review to help practitioners find relevant information in relation to their population of interest.

Students with disabilities or SEN have poor attainment in science. For example, in England, only 43% of students aged 4–7 with SEN achieved the expected standard in science, compared to 90% for students with no SEN (Department for Education, 2020b). According to educational progress data published in the United States by National Assessment of Educational Progress (NAEP), in 2015, disabled students in grade 4 (9–10 years old), grade 8 (13–14 years old), and grade 12 (17–18 years old) achieved scores between 124 and 131 (out of 300) in science in comparison to scores between 153 and 158 for students with no disabilities (The Nation's Report Card, n.d.). Given the cognitive difficulties associated with ID in particular, the science attainment gap is likely to be much larger for children with DD, although specific data on these disability groups are not available at national levels.

Three previous systematic reviews have been published on science education for students with DD. Courtade et al. (2007) focused on research published between 1985 and 2005 on teaching science concepts to students with significant cognitive disabilities. The search strategy was based on seven science standards from NSES and included a systematic literature search of two databases. Eleven studies, all using single-case experimental designs, were identified. The most recent included study was published in 2003. The total of students in all included studies was 58. All interventions used components of systematic instruction—an approach focused on teaching observable and measurable behaviours and promoting generalization (Browder & Spooner, 2011) (see later for definition). Courtade et al. (2007) concluded that students with significant cognitive disabilities can benefit from teaching strategies like time delay, modelling, and errorless learning to acquire science skills and that a strong emphasis should be put on generalization of learning.

Spooner et al. (2011) focused on research literature published between 1985 and 2009 on science education for students with severe DDs. The conceptual framework of science education used in the review was developed after consultations with experts in the field of science education and severe disabilities, and the search strategy was based on eight science standards from NSES. Five databases were searched. Seventeen studies were included in the review, of which 14 were rated as being of adequate or high quality.

Spooner et al. (2011) concluded that systematic instruction is an evidence-based practice for teaching science to students with DDs. Spooner et al. (2011) also emphasized that most recent research suggests that students with severe disabilities can successfully learn science skills based on the general curriculum.

Rizzo and Taylor (2016) analysed literature on inquiry-based instruction for students with various disabilities. Three databases were searched. Twelve studies published between 1992 and 2013 were included, and the authors concluded that students' science achievement improved when inquiry teaching techniques were used; but that, it is not an effective teaching strategy on its own. Rizzo and Taylor (2016) also concluded that disabled students require support to access inquiry-based instruction and that their science gains increase when components of explicit instruction are used.

The most recent systematic review on all components of science education (Spooner et al., 2011) included articles published before 2009. Since then, new articles have been published on teaching science to students with various DDs, thus an updated review is warranted. Moreover, none of the previous reviews focused on the entire population of students with ID and/or autism. Courtade et al. (2007) and Spooner et al. (2011) focused on students with severe ID only (IQ below 55), and Rizzo and Taylor (2016) focused on all disabled students. Spooner at al. (2017) in their summative paper on evidence-based practices for students with severe disabilities reported that at the time of the last comprehensive systematic review on teaching science to students with DD (Spooner et al., 2011), published studies were mainly focused on traditional functional curriculum domains (e.g., safety skills). Since then, more research targeting skills that are part of National Curriculum in the United Kingdom or NSES and the NGSS in the United States have been published. In addition, in the last two decades, a shift in science education has taken place from a more knowledge-based curricula to more creative methods of teaching that encourage deeper understanding (National Research Council, 2013; Sawyer, 2008). This is reflected in the number of studies published in recent years on science education for neurotypical populations, as well as for disabled students. Due to those dynamic changes in the field and the shift in the understanding of science education, a new systematic review is warranted. An additional aim of the present systematic review was to extend the findings of Spooner et al. (2011) by including students' and teachers' experiences of the interventions. These data are crucial to fully understand effectiveness and feasibility of different interventions.

The current review focused on the following questions: What interventions have been developed to teach science skills and knowledge to children with DD? and What are the views and experiences of students with DDs and their teachers on interventions used to teach science?

Method

The protocol for this systematic review was registered on PROSPERO (https://www.crd.york.ac.uk/prospero/ - also available from the corresponding author on request) before any searches started (registration number: CRD42017057323) to enhance transparency and rigor (see Appendix 4). PRIMSA guidelines (Moher et al., 2009) for reporting systematic reviews were used in the current article (see Appendix 1).

Review focus and inclusion criteria

This review focused on research evaluating educational interventions for teaching science to students with DD. The population of interest included children and young people up to 25 years old with an ID and/or autism. Participants had to have one or both diagnoses to meet the inclusion criteria. Science education was defined in line with UK standards as “scientific knowledge and conceptual understanding through the specific disciplines of biology, chemistry and physics” (Department for Education, 2014a, p. 168) and understood as “the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence” (Science Council, n.d., para. 1). The contexts of interest were individual or group settings in schools or further education colleges (including international equivalents). Studies describing interventions delivered in different settings were excluded. Included studies reported outcomes from interventions compared against teaching as usual (typical lessons as per students' timetables) or other interventions. Studies with no comparison but reporting change from baseline measures were also included. Included studies had to report either students' change in science skills and knowledge (review question 1) or students' and teachers' opinions and experiences of the science intervention effectiveness, usefulness, or ease of use (review question 2). For review question 1, any quantitative research with a comparison design was included (e.g., controlled trials, single-group pre-test post-test designs, and single-case experimental designs). For review question 2, any quantitative or qualitative studies reporting data on students' and/or teachers' opinions or experiences of the science intervention were included. Studies could be included with mixed samples of students with different disability diagnoses or no disability as long as the data on students with DD were reported separately.

Search strategy

Six databases were searched in March 2017. Databases were chosen based on their area of focus related to education, psychology, and science. In August 2017, forward and backward reference searches of all included studies (and the Spooner et al., 2011 review) were conducted. Following that, five active researchers in the field of science education for students with DDs whose studies had been identified were contacted to inquire about any relevant unpublished research. Forward and backward searches were completed for any newly identified studies until no new studies were identified.

The search strategy was developed based on the terms related to science education, ID, and autism with a help of a University-based librarian and applied in the following databases: ERIC, Education Research Complete, PsycINFO, Social Science Citation Index, British Education Index, and ASSIA. Search terms were organized into two lists—one containing terms related to ID and autism and the second terms related to science education (see Table 2-1). Due to the nature of science education, the search strategy was deliberately designed to be wide to minimize the chance of potentially relevant studies being missed. Search terms within each list were separated with “OR,” and Lists 1 and 2 were combined with “AND.” All terms were searched in titles, keywords, and abstracts.

The review focused only on research papers published in English and Polish—the languages in which the research team were competent. No restrictions regarding publication date were applied. In addition, database searches were limited to peer review journal articles only.

Table 2-1. *Lists of terms used in the database searches.*

List 1	List 2	
Autis*	Scien*	Fungus
ASD	Physics	Insect*
"Autism Spectrum Disorder*"	Chemistry	Temperature
"Intellectual Disabilit*”	Biology	"Work* scientifically"
ID	Plant*	"Scien* enquiry"
"Mental retardation"	Animal*	"Scien* inquiry"
"Developmental Disabilit*"	"Human bod*"	"Scien* Experiment"
"Down syndrome"	Material*	STEM
"Pervasive developmental disorder"	Force*	"Scien* model* and analog*
PDD	Earth	"Scien* pattern-seek*"
Asperger*	Electricity	"Scien* curriculum"
"Learning Disabilit*"	Acid*	"Scien* intervention"
"Learning Difficult*"	Rocks	"Scien* program*”
"Learning Impairment*"	Soil	"Scien* prediction"
"Intellectual Deficien*"	Magnet*	"Scien* classification"
"Developmental Impairment*"	Space	"Scien* test*"
Handicap*	Chemical	
	Weather	
	Season*	
	Mass	
	Planet*	
	"Solar system*"	
	"Living organism*"	
	Cell*	
	Bodypart*	

Study selection

After the relevant articles were identified in the databases, all results were exported to an electronic data program and scanned for internal and external duplicates. Following that, the first author (MA) scanned the titles, abstracts, and keywords of all the results against the inclusion/exclusion criteria. At this stage, articles were excluded only if they clearly did not meet the review criteria. To examine reliability of this selection, the fifth author (AP) independently scanned 20% of randomly selected results against the inclusion/exclusion criteria. Agreement was calculated by dividing the number of agreements by the number of agreements and disagreements and multiplying by 100%. Reliability for initial study selection was 99.85% (kappa = 0.93). Full-text versions of all studies identified at initial screening were obtained, and a checklist of all inclusion/exclusion criteria was used to establish whether to include papers in the review (see Appendix 5). Agreement for this full-selection stage was 96.62% (kappa = 0.88). Inclusion disagreements were discussed with a third research team member for resolution.

Quality appraisal and data extraction

After all the articles were screened, quality appraisal tools were applied to the included articles by the first author. Appropriate tools were chosen depending on each study's design. The Critical Appraisal Skills Programme (CASP) checklist for RCTs (Critical Appraisal Skills Programme, 2017) was used for studies incorporating RCT designs. This checklist consists of 11 questions and is divided into three sections in relation to results—their validity, their value, and if they can be helpful in practice. The same checklist, excluding the randomization question, was used for the non-randomized controlled studies. For Parts A and C of the checklist, each question is assigned either yes or no answer based on the information provided in the article. For Part B, appropriate information from the results section of the article is provided. For articles using single-case experimental designs, the Quality Indicators tool developed by Horner et al. (2005) was used. This tool consists of 21 indicators within seven main sections: participants and setting, dependent and independent variables, and baseline, internal, external, and social validities. Each indicator is assigned either yes or no answer based on information provided in the article, and a quality appraisal score is derived from the total number of quality indicators present.

Data extraction used a piloted bespoke tool for this review that included the following information: author, year, origin, population characteristics, setting characteristics, study characteristics, intervention characteristics, intervention delivery characteristics, quantitative outcomes, together with data on participants' and teachers' experiences of the intervention. The first author completed the data extraction for all included articles, whereas the fifth author independently completed extraction for 20% of randomly selected articles. Studies included in the systematic review were summarized using narrative synthesis.

Results

Study selection

Figure 2-1 summarizes the study selection process. In total, 27,205 records were identified through initial database searches and 28 through reference searches. No additional studies were identified through contact with active researchers in the field. After removal of 7,233 internal and external duplicates, the initial screening of titles, abstract, and keywords led to the exclusion of 19,817 records. Subsequently, full texts of 183 studies were assessed for eligibility. From these, 151 records were excluded with the main reasons recorded, and full-text copies of two articles could not be obtained. Quality

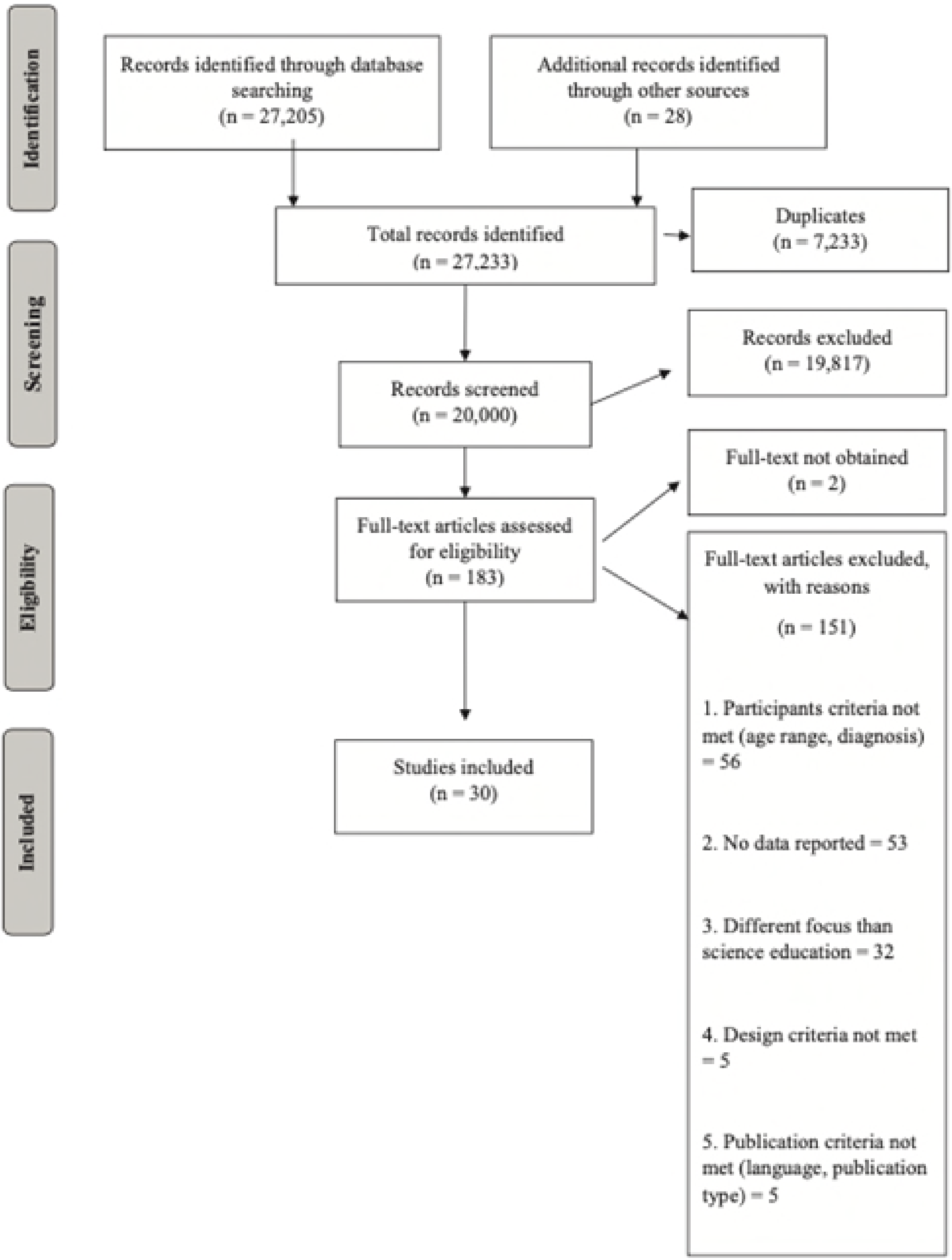


Figure 2-1. A flow diagram illustrating study selection process (adapted from PRISMA Diagram - Moher et al., 2009).

appraisal and data extraction were completed for the remaining 30 articles.

Study characteristics

The included studies were published between 2003 and 2017 with the majority of the studies published in or after 2010 (n = 22). Of the 30 included studies, 29 were from the United States and one from the United Kingdom. All 30 studies included data on students' science-related learning (research question 1). Twelve studies included multiple educational outcomes, but the current review reports only on students with science-related targets. Twenty studies reported students' and teachers' experience and opinions on science interventions (research question 2). Tables 2-2, 2-3 and 2-4 present a summary of 30 studies included in the systematic review.

Participants. The mean number of participants with science targets reported across all included studies was 3.9 (range 1-21), with most of the studies reporting outcomes for three students (n=14). In total, 118 students were involved in the included studies.

Facilitators. Seventeen studies included interventions delivered by school staff - either general or special education teachers or paraprofessionals (e.g., Karl et al., 2013; Knight et al., 2017; Riesen et al., 2003). Seven interventions were implemented by researchers (e.g., McMahon et al., 2016), three by peer tutors (e.g., Hudson et al., 2014), and one by researchers and school staff (Roberts & Joiner, 2007). Two articles did not contain clear descriptions about intervention facilitators (e.g., Miller et al., 2015).

Setting. All 30 studies were conducted in school or college settings. Fifteen interventions were delivered in students' typical classrooms (special education classroom, resource rooms, or self-contained classrooms) (e.g., Miller et al., 2015; Riggs et al., 2013; Smith et al., 2013a). Ten studies included interventions delivered in general education classrooms (e.g., McDonnell et al., 2006). Two interventions were delivered in both special and general education classrooms (e.g., Collins et al., 2007), and another two interventions were in different settings—one in a kitchenette (Miller & Taber Doughty, 2014) and one in a greenhouse (Collins et al., 2017). One study did not provide a detailed description of the setting (Carnahan & Williamson, 2013).

Design. Twenty-eight studies incorporated single-case experimental designs (e.g., Jimenez et al., 2014a; Karl et al., 2013**;** Riggs et al., 2013; Smith et al., 2013b) and two used group designs (Browder et al., 2010; Roberts & Joiner, 2007).

Science targets. The majority of the studies targeted science vocabulary and concepts (n = 18) (e.g., Collins et al., 2007; Knight et al., 2012). Two studies focused on science inquiry skills (e.g., Miller & Taber-Doughty, 2014), and six studies included targets related to both science inquiry and vocabulary (e.g., Jimenez et al., 2009). Two studies focused on textbook comprehension (e.g., Carnahan & Williamson, 2013), whereas the remaining two focused on listening comprehension of science content (Hudson et al., 2014) and chemical and physical properties (Collins et al., 2011).

Interventions. The majority of interventions used components of systematic instruction (see later for definition) (n = 23) (e.g., Browder et al., 2010; Collins et al., 2007; Knight et al., 2013; McDonnell et al., 2006). Five studies used self-directed learning (see later for definition) (e.g., Roberts & Joiner, 2007), and two studies focused on comprehension-based instruction (see later for definition) (e.g., Carnahan & Williamson, 2013). The seven studies where the main intervention components were based on systematic instruction also contained elements of different teaching approaches—peer tutoring (n = 3), technology-based instruction (n = 3), and self-directed learning (n = 1). Three studies that used self-directed learning also incorporated different approaches—task analysis (n = 2) and technology-based instruction (n = 2).

Generalization and maintenance. Fifteen studies assessed generalization of targeted skills beyond the teaching context (e.g., Heinrich et al., 2016; Riggs et al., 2013), and 15 studies did not assess (e.g., Johnson et al., 2004; Knight et al., 2014). Twenty articles included data on maintenance of skills over time (e.g., Riggs et al., 2013; Smith et al., 2013a), and 10 articles did not (e.g., McMahon et al., 2016; Miller & Taber-Doughty, 2014).

Perceptions and experiences of the interventions - participants. The majority of studies that reported data on participants' opinions and experiences of the intervention focused on both students and teachers (n = 5) (e.g., Carnahan et al., 2016; Jimenez et al., 2009) or students only (n = 5) (e.g., McMahon et al., 2016). Five studies reported only perceptions of teachers (e.g., Carnahan & Williamson, 2013) and two of students, peer tutors, and teachers (e.g., Jimenez et al., 2012a). The remaining three studies reported experiences of peer tutors and teachers (n = 2) (Hudson et al., 2014) and parents and teachers (n = 1) (Courtade et al., 2010).

Perceptions and experiences of the interventions – tools. Fifteen studies incorporated a single tool to gather data on experiences and perceptions of the intervention (e.g., Johnson et al., 2004), and five studies used multiple tools (e.g., Jimenez et al., 2012a). Ten studies used questions with rating scales (e.g., Miller & Taber-Doughty, 2014). Seven studies incorporated tools with a mixture of open- and close-ended questions (e.g., McMahon et al., 2016), and six used surveys with closed-ended questions (e.g., Smith et al., 2013a). The remaining four studies used open-ended questions (n = 2) (Agran et al., 2006), focus groups (n = 1) (Jimenez et al., 2012a), and incidental observations reported by school staff (n = 1) (Agran et al., 2006).

Synthesis

Systematic instruction. Systematic instruction is “teaching focused on specific, measurable responses that may either be discrete (singular) or a response chain (e.g., task analysis), and that are established through the use of defined methods of prompting and feedback based on the principles and research of applied behaviour analysis" (Browder, 2001, p. 95). It focuses on five components: socially important skills, operationally defined targets, data collection to monitor progress, stimulus control transfer methods, and generalization (Browder & Spooner, 2011). Spooner and Browder (2015) described systematic instruction as one of three most significant advances for students with severe disabilities. Systematic instruction has been used to teach a range of skills from functional living skills like cooking (Mechling et al., 2008) to navigating around the community (e.g., Taber et al., 2002) and teaching academics (e.g., Knight et al., 2013). Although a range of different systematic instruction teaching methods can be used to teach different skills, educators generally apply four steps to implement the instruction. These steps start with (i) defining target skills, then move to (ii) planning and defining instructional methods, next they (iii) implement the intervention, and later (iv) assess students' progress and modify the methods if needed (Browder & Spooner, 2011).

Twenty-three studies that used systematic instruction to teach students science content were included (see Table 2-2 and Appendix 8). Twenty-two of them used single-case experimental designs, and one used a group design. The interventions used procedures such as task analysis (breaking down a complex task into smaller steps); embedded instruction (providing instruction for target skills during ongoing activities); constant time delay (procedure involving delivery of the prompt after a specific amount of time after the instruction, usually starting at zero seconds and systematically increasing the interval); simultaneous prompting (the prompt is delivered straight after the instruction and then gradually faded out; unprompted trials are conducted before the training to determine if the skills has been acquired); system of least to most prompts (hierarchy of prompts used to help the students, starting from the least intrusive); scripted lessons (an instructional strategy that provides teachers with scripts with exact information on how to teach each target and deliver the instruction); and explicit instruction (an active teaching method involving modelling). Simultaneous prompting procedures and embedded instruction were the two most frequently used teaching approaches. Fourteen interventions were delivered by school staff (either a teacher or paraprofessional), six by researchers, and three by peer tutors. Three studies also used computer-assisted instruction (CAI)—a teaching approach involving the use of different means of technology to deliver the instruction.

In addition, two studies evaluated effectiveness of a science curriculum for students with DD. Jimenez et al. (2014) taught three students with moderate to severe ID and autism science vocabulary and concepts using scripted lessons with and without guided notes. Two students made good progress after the intervention was implemented, and one student made little progress. Smith et al. (2013b) taught three students with severe disabilities science vocabulary and concepts during inquiry-based lessons using systematic instruction. All the students made good progress when the intervention was implemented.

Students in all studies showed increases in dependent variables after the intervention was implemented. However, some students did not reach mastery criterion. For example, Collins et al. (2017) used a simultaneous prompting procedure to teach science content related to photosynthesis embedded in a practical skill (plant care) to four students with ID. The rate of correct responses for all students improved at post-test compared to pre-test. However, none of the students met the mastery criterion before receiving three additional training sessions.

Three students in three of the studies showed no or very little increase in target skills. For example, Fetko et al. (2013) used a simultaneous prompting procedure to teach three autistic students with ID science vocabulary embedded in a leisure activity training (UNO game). The rate of correct responses increased from 0% at pre-test to 100% at post-test for two students, but the third student did not show any progress. There were no

Table 2-2. *Summary table of studies using systematic instruction procedures.*

Source and Origin	**Participants**	**Target skills**	**Intervention**	**Design**	**Science outcomes**	**Students' and teachers' experiences**	**Quality appraisal rating**
Browder et al. 2010 USA	- 21 students (11 with autism and 10 with moderate to severe ID) - 12 males and 9 females - 14-21 years - 7 Caucasian, 1 Hispanic and 13 African American - English was a primary language for all participants - IQ: 33-53 (mean 42.90)	Inquiry skills (task analysis of steps to participate in the inquiry lesson on magnetism) and science vocabulary	Task analyzed inquiry-based instruction	Quasi experimental design	Baseline Students scored mean 41.9% (SD 11.5) of correct answers for the science test with mean 56.5% (SD 15.3) for inquiry subscale and mean 38.3% (SD 13.2) for science vocabulary subscale. Outcomes At post-test students scored mean 57.6% (SD 22.1) at the science test with mean 70.5% (SD 21.7) for inquiry subscale and mean 54.4% (SD 23.0) for science vocabulary subscale. Overall, students showed 15.7% gain at post-test compared to baseline at the science assessment - 14% gain at the inquiry subtest and 16.1% gain at science vocabulary subscale. Maintenance and generalization Not assessed.	Results reported in relation to mathematics and science targets. Teachers' perceptions of the training and interventions were assessed using a survey with a rating scale. They agreed that both interventions (math and science) were beneficial for their students and practical to implement. Teachers indicated that the materials were helpful, and time spent on practice with the researcher was useful.	8/9 (CASP form for randomized controlled trials)
Collins et	- Targets for 1 student were	Functional and core	Compared three	Adapted alternating	Baseline Student's rate of responding was 0%.	Not reported	Overall

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
al. 2007 USA	science related. - 1 male student with ID - 9 years - No ethnic background or primary language reported - IQ: 50	<u>science vocabulary/ sight words</u>	interventions: 1. simultaneous prompting with massed trial instruction in a resource room 2. simultaneous prompting with distributed trial instruction in general education setting 3. embedded instruction in a general education classroom	treatments design replicated across three instructional conditions and four participants (although only one had science related targets)	<u>Outcomes</u> The student reached mastery criterion only for one word set (functional content) in the embedded instruction condition. <u>Maintenance and generalization</u> The student maintained acquired knowledge for functional content in the embedded instruction condition with 100% accuracy only for six (17%) out of 35 maintenance sessions.		20/21 <u>Science targets only</u> 19/21 (Horner et al., 2005)

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
Collins et al. 2011 USA	- 3 students (1 with autism and 1 with Down Syndrome (DS); no diagnosis reported for the third student) - 2 males and one female - 14-15 years - No ethnic background or primary language reported - IQ: 41-55 (mean 47.67)	Chemical and physical properties of elements in the Periodic Table (gases, liquids, and solids)	Constant time delay procedure	Multiple probe design across behaviors (language arts, science, and math) replicated across participants	Baseline Students had between 11.1% and 75% (mean 35.6%) of correct responses for core content and between 33% and 62.9% (mean 51.4%) for functional content. Outcomes After the intervention was implemented students met mastery criterion in four to 69 sessions (mean 28.3) for core content and in four to 32 sessions (mean 13.3) for functional content. Maintenance and generalization Students maintained core content with 44.4% to 100% accuracy (mean 80.8%) and functional with 33.3% to 100% accuracy (mean 77.8%). Students' scores during generalization increased from mean 20.1% to 88.9%.	Not reported	Overall 20/21 Science targets only 20/21 (Horner et al., 2005)
Collins et al. 2017 USA	- 4 students with ID - 2 females and 2 males	Science concepts (Photosynth-esis core content) embedded in	Simultaneous prompting procedure used to embed core content in teaching	Multiple probe across participants design with pre- and post-test measures	Baseline Students answered between one and two (out of six) questions correctly (mean 1.3). Outcomes Responding improved at post-test compared to baseline for all students, but none of the students reached mastery criterion. Students answered between four and five (out of	Results reported in relation to science targets and practical skill training. Students' experiences of the intervention were assessed using a questionnaire. Students reported that they enjoyed the intervention and that	Overall 21/21 Science targets only

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
	- 16-19 years - 3 Hispanic and 1 African American - No primary language reported - GIA: 62-71 (mean 67)	task analysis for plant care	practical skill (plant care)	of the non-target information (science concepts)	six) questions correctly (mean 4.5). Since none of the students reached mastery criterion, students had additional simultaneous prompting procedure training for core content only and reached the mastery criterion within three sessions. Maintenance and generalization All participants maintained acquired knowledge with 100% accuracy over time.	they learned about photosynthesis. Three students indicated that they would use acquired skills in the future and one said they would not.	21/21 (Horner et al., 2005)
Courtade et al. 2010 USA	- 8 students with ID - 4 females and 4 males - 11-15 years - 5 African American, 2 Caucasian and 1 Hispanic - English was a primary language for all	Inquiry skills (task analysis of steps to participate in inquiry lessons) and science vocabulary	Multi-component training in task analyzed inquiry-based instruction for teachers, including: fidelity checklist, training manual, verbal explanation of content, video modelling and feedback from	Multiple probe across participants single subject design	Baseline Students' scores were between one and three correct (out of 12). Outcomes After the intervention was implemented students' scores ranged between three and 12, with majority of scores being nine (75%) or higher. Maintenance and generalization Maintenance probes were conducted with only two students. Their mean score was 10 (range 9-11). One of the teachers reported that her student used new science terms in a context different to the science lesson.	Parents' and teachers' views, and experiences were assessed using surveys with a rating scale and open-ended questions. The parents agreed that it is important for their children to learn science and that they should have science lessons every day. Parents also agreed that it is important that science instruction is recommended by the National Science Education Standards. Parents reported that their children showed interest in science skills. Teachers responding on the validity survey was in the range of 5-6 (6-point rating scale). Teachers responding on the	Overall 21/21 Science targets only 21/21 (Horner et al., 2005)

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
	participants - IQ: 39-54 (mean 44.14 - not reported for one student)		the researchers			feasibility survey was in the range of 3-5 (5-point rating scale).	
Fetko et al. 2013 USA	- 3 students (2 with ID and 1 with autism) - 2 males and 1 female - 12-14 years - No ethnic background or primary language reported - IQ scores not reported	Science vocabulary	Simultaneous prompting procedure with core content (science vocabulary) embedded as non-target information while teaching a leisure skill activity (UNO game)	Multiple probe design across participants with pre- and post-test measures of the non-target information (science vocabulary)	Baseline All three students scored 0% during the baseline probe. Outcomes Two students reached 100% during the post-test probe and one student scored 0%. Maintenance and generalization Not assessed.	Not reported	Overall 19/21 Science targets only 16/21 (Horner et al., 2005)
Heinrich et al. 2016	- Targets for 1 student were science	Science vocabulary and Punnett	Embedded simultaneous prompting	Multiple probe across participants	Baseline The student scored correctly to 0% of probes for both discrete and chained tasks.	Data reported in relation to all participants in the study. Peers' and general education teacher's attitudes	Overall 20/21

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
USA	related - 1 male student with moderate ID - 17 years - No ethnic background or primary language reported - IQ: 53	Square	procedure	design with concurrent demonstration across two skills per student	Outcomes The student reached mastery criterion for science vocabulary (discrete task) in seven sessions and for Punnett Square (chained task) in five sessions. Maintenance and generalization The student maintained acquired content with 100% accuracy after a month and generalized some content to other contexts. He also showed some generalization of acquired skills during the state assessment, scoring mean of 60% of correct responses for discrete tasks and 100% for chained tasks.	towards disabled students were assessed using a survey. Before the intervention out of 17 peers, 12 said that students with ID should attend general education classrooms. After the intervention, the number increased to 15, all peers also indicated that disabled students can learn core content. Before the intervention sixteen students thought that disabled students should be taught core content and after the intervention all seventeen students said that they should. The number of peers agreeing with the following benefits of inclusion also increased after the intervention was implemented: social interactions, academic skills acquisition, communication skills and self-esteem. The general education teacher indicated that she thought that disabled students should attend general education classes, can learn core content, and would benefit from the inclusion. Following the intervention, she also indicated that disabled students can learn core content at a modified pace.	Science targets only 18/21 (Horner et al., 2005)

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
Hudson et al. 2014 USA	- 3 students with ID - 2 females and 1 male - No age range and no IQ scores reported - No ethnic background or primary language reported	Listening comprehens-ion of science content	Peer-delivered system of least prompts with adopted science read-alouds	Multiple probe design across participants	Baseline Students responded correctly to 18-27% of questions correctly (mean 22.7%). Outcomes After the intervention was implemented, students' rate of correct responses increased to 63-79% (mean 71.3%). Maintenance and generalization Rate of responding during generalization probes did not exceed baseline levels for all three students.	Attitude surveys Peer tutors at pre-test indicated that they had limited contact with disabled people and the majority were not sure if they would talk to a student with a disability. At post-test, the majority of peer tutors indicated that they would talk and eat lunch with a student with a disability. Social validity forms (with a rating scale) Teachers either agreed or strongly agreed that disabled students can learn in general education classes, that the peer-delivered instruction is effective in teaching new content to disabled students and that they would use and recommend the intervention. Peer tutors reported that they enjoyed their role, would like to do it again in the future and would recommend the intervention. One peer tutor said that the intervention required a lot of work while the other said it did not.	21/21 (Horner et al., 2005)
Jameson et al. 2007 USA	- Targets for 1 student were science related	Science vocabulary on states of matter	Comparison of two interventions: 1. One-to-one	Single subject alternating treatment design	Baseline The student responded correctly to 0% of probes Outcomes Both interventions were effective in teaching science vocabulary to the participant.	Results reported in relation to all students. Teachers' and paraprofessionals' perceptions of the intervention were assessed using a	Overall 21/21

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
	- 1 male student with DS - 15 years - Caucasian - No primary language reported - IQ: 46	content	embedded instruction 2. One-to-one massed trials instructional format		The student reached mastery criterion in fewer sessions in the one-to-one embedded instruction condition - 255 trials (around 19 sessions) than in the one-to-one massed trials instruction condition - 342 trials (around 27 sessions). Maintenance and generalization Not assessed.	questionnaire with a rating scale. They reported that the embedded instruction was effective and practical. Teachers and paraprofessionals also indicated that the prompting procedure was feasible, useful for the students and helped them with inclusion in general education classrooms.	Science targets only 20/21 (Horner et al., 2005)
Jimenez et al. 2009 USA	- 3 students with ID - 2 females and 1 male - 11-13 years - No ethnic background or primary language reported - IQ: 48-54 (mean 51.3)	Self-directed inquiry (task analysis on using a KWHL chart - What we know?; What we want to know?; How to find out?; What was learned?) and science concepts	Multicompon-ent training package (multiple exemplar training, time delay and KWHL chart)	Multiple probe design across two science concepts with a concurrent between participant replication	Baseline Students were not correct with any steps of the task analysis for both concepts. Outcomes After the intervention was implemented students reached mastery criterion for the first concept in one to five sessions (mean 3.3). Two students exhibited spontaneous generalization across concepts and reached mastery criterion for the second concept before intervention was implemented. The third student reached mastery criterion for the second concept within one session. Maintenance and generalization During maintenance probes students responded correctly to all probes. Students generalized acquired knowledge across materials and the second concept. They also generalized the use	Students' and teachers' views were assessed using the adopted intervention rating profile with a rating scale. The teachers strongly agreed to all statements about intervention's acceptability, procedures and outcomes. The students indicated that they enjoyed the intervention to learn science and liked using KWHL charts. The students reported that the intervention might also be beneficial for other students.	Overall 21/21 (Horner et al., 2005)

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
					of KWHL chart to the general education classroom.		
Jimenez et al. 2012a USA	- 5 students with ID - 2 females and 3 males - 11-14 years - No ethnic background or primary language reported - IQ: 34-55 (mean 46.2)	Science vocabulary and concepts and the use of KWHL chart during inquiry lessons	Peer-mediated embedded instruction with time delay	Multiple probe across three science units with between participant replications	Baseline Students had between one and six correct responses (mean 2.6) for Unit 1, between zero and six (mean 2.3) for Unit 2 and between two and seven (mean 3.4) for Unit 3. Outcomes After the intervention was implemented students had between three and eight correct responses (mean 7.2) for Unit 1, between two and eight (mean 6.4) for Unit 2 and between four and eight (mean 6.57) for Unit 3. Maintenance and generalization Data not clearly reported.	There was an increase in surveys' scores (5-point rating scale) from pre- to post-test. Peer tutors' scores increased from 3.2 to 4.6 and students' scores increased from 3.5 to 4.7. During the focus group peer tutors indicated that they enjoyed the intervention and wanted to continue with it. Peer tutors also indicated that the intervention was beneficial to them. In the feasibility survey the teachers agreed that the intervention was socially important, effective, and practical to implement. Grades of the peer tutors remained the same throughout the intervention.	Overall 21/21 (Horner et al., 2005)
Jimenez et al. 2014 USA	- 3 students with autism and ID - 2 males and 1 female	Three science content units including inquiry skills,	Scripted lessons and scripted lessons with guided notes	Multiple probe across science content units design with replication across	Baseline Students had between zero and seven correct responses (mean 2.6) for Unit 1, between zero and 10 (mean 4.4) for Unit 2 and between zero and 10 (mean 3.9) for Unit 3. Outcomes When scripted lessons were introduced students' rate of correct responses	Teachers' views and experiences of the intervention were assessed using social validity questionnaires. They reported that both interventions were effective in teaching science to the students but that the scripted lesson	Overall 20/21 (Horner et

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
	- 9 years - African American - No primary language reported - IQ: 71-99 (mean 86.67)	science concepts and vocabulary		students	improved to between zero to 10 (mean 5.8) for Unit 1, between one and 10 (mean 6.4) for Unit 2 and between one and 10 (mean 7.5) for Unit 3. Once scripted lessons with guided notes were introduced, students had between zero and 10 correct responses (mean 5.9) for Unit 1, between two and 10 (mean 7.6) for Unit 2 and between three and 10 (mean 8.9) for Unit 3. Maintenance and generalization Students maintained their rate of responding over time apart from Student 3 for one of the units.	condition was preferred. Scripted lessons with guided notes were reported to be more time consuming.	al., 2005)
Johnson et al. 2004 USA	- Targets for 1 student were science related. - Female with DD (exact diagnosis not reported) - 9 years - No ethnic background or primary language	Science concepts	Embedded instruction implemented in general education classroom (constant time delay, error correction and reinforcement)	Multiple baseline across behaviors design	Baseline The student had 0% correct responses at baseline probes for all three units. Outcomes After the intervention was implemented the student reached the mastery criterion for all three units in 4 – 7 sessions. Maintenance and generalization Student's rate of responding was maintained for two units (maintenance data for third unit was not collected) over time.	Results reported in relation to all students. Teachers' and paraprofessionals' views and opinions of the intervention were assessed using questionnaires with a rating scale. They reported that the intervention was effective, it met students' needs and it was not very disruptive to the rest of the class. Staff members indicated that they were likely to use the intervention in the future.	Overall 19/21 Science targets only 19/21 (Horner et al., 2005)

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
	reported - IQ: 59						
Karl et al. 2013 USA	- 4 students with ID - 3 males and 1 female - 15-18 years - No ethnic background or primary language reported - IQ: 41-55 (mean 48)	Science concepts	Simultaneous prompting procedure used to teach core content within a functional activity (cooking)	Multiple probe design across behaviors replicated across participants	Baseline Students had 0% of correct responses. Outcomes Students reached mastery criterion in four to 23 sessions (mean11.5). Maintenance and generalization Three participants maintained acquired knowledge with 100% accuracy after one, three and five weeks (no data reported for one student) and all student generalized target skills with 100% accuracy to different materials.	Not reported	Overall 20/21 Science targets only 20/21 (Horner et al., 2005)
Knight et al. 2012 USA	- 3 students with autism - 3 males - 5-7 years - No ethnic background	Science descriptors	Explicit instruction (model-lead-test strategy)	Multiple probe across behaviors with concurrent replication across participants	Baseline Students correctly responded to between zero and two science descriptors (mean 0.7) for Set 1, between zero and two (mean 1.1) for Set 2 and between zero and three (mean 0.8) for Set 3. Outcomes After the intervention was implemented students reached mastery criterion	Students' and teachers' views and experiences were assessed using questionnaires. Students' impressions of the intervention were positive, and they indicated willingness to participate in the future research. The teacher strongly agreed that targets were socially important to the	Overall 21/21 (Horner et al., 2005)

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
	or primary language reported - IQ: 53 and 62 (not reported for 1 student) (mean 57.5)			design	in 16-22 sessions (mean 18.3) for Set 1, in 10-14 sessions (mean 12.7) for Set 2 and in 12-18 sessions (mean 14.3) for Set 3. Maintenance and generalization Two students maintained high rate of responses over time and all of the students generalized acquired knowledge across different materials.	students and that the intervention was a good use of time. She also indicated she would be interested in taking part in future research. The teacher agreed that acquired targets generalized to other inquiry content but not to other settings and she would use explicit instruction in the future.	
Knight et al. 2013 USA	- 3 students with ID and autism - 1 female and 2 males - 13-14 years - No ethnic background or primary language reported - IQ: 40-55 (mean 46.33)	Science concepts	Treatment package of systematic instruction (constant time delay, examples and non-examples, graphic organizers)	Multiple probe across participants design	Baseline Students had between zero and seven correct responses at the task analysis (mean 2.8). Outcomes After the intervention was implemented students reached mastery criterion in seven to eight sessions (mean 7.7). Maintenance and generalization Data collected only for two students – they maintained high rate of correct responses over time.	Not reported	Overall 21/21 (Horner et al., 2005)
Knight et al. 2014	- 4 students with ID and	Science vocabulary and concepts	Book Builder (BB) - three	Multiple probe across participants	Baseline Students responded correctly to between 8.3% and 33.3% (mean 20.7%) of vocabulary questions, between 16.7% and 40%	Students' and teachers' views and experiences were assessed using surveys. The teachers agreed that the	Overall 20/21

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
USA	autism - 1 female and 3 males - 11-14 years - African American - No primary language reported - IQ: 53-67 (mean 59.5)	comprehen-sion	phases: - BB only - BB and explicit instruction (EI) - BB, EI and referring to definition	with an embedded ABCD design	(mean 28%) of comprehension questions and between 10% and 50% (mean 29.9%) for application questions. Outcomes After the first phase of the intervention (BB only) was implemented students responded correctly to between 22.2% and 44.5% (mean 33.3%) of vocabulary questions, between 25% and 55.6% (mean 43.8%) of comprehension questions and between 0% and 75% (mean 27.1%) of application questions. After the second phase of the intervention (BB and explicit instruction) was introduced students responded correctly to between 16.7% and 66.7% (41.7%) of vocabulary questions, between 50% and 77.8% (mean 62.5%) of comprehension questions and between 0% and 66.67% (mean 45.8%) for comprehension. After the third phased of the intervention (BB, EI and referring to definition) was implemented students responded correctly to between 16.67% and 100% (mean 64.2%) of vocabulary questions, between 50% and 80% (mean 60%) of comprehension questions and between 40% and 100% (mean 67.5%) of application questions. Maintenance and generalization Students' responding during maintenance probes was between four and seven correct (out of seven).	intervention was effective, practical and that they would use it in the future. They also agreed that the intervention might be useful for students in other areas. They reported the most helpful resource to be coaches, limited language, summarizing resources and visual cues. One of the teachers reported that the intervention would be more effective if it could respond to students' errors. Students reported to have enjoyed the intervention. They found coaches and hyperlinks to vocabulary to be most helpful.	(Horner et al., 2005)

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
					Data not collected for two students.		
Knight et al. 2017 USA	- 4 students with ID - 1 female and 3 males - 18-21 years - White - No primary language reported - IQ: 41-55 (mean 47.5)	Science comprehension skills (vocabulary, comprehension and application probes)	Modified Book Builder (embedded animated coaches, examples and non-examples and referrals to the definitions)	Multiple probe across participants research design	Baseline Students had mean of 1.4 correct responses. Outcomes After the intervention was introduced students met mastery criterion on seven to 11 sessions (mean 9.3). Maintenance and generalization Not assessed.	Not reported	Overall 21/21 (Horner et al., 2005)
McDonnell et al. 2006 USA	- Targets for 2 students were science related. - Both students with DD - Males - 13-15 years	Science concepts/ definitions	Comparison of two interventions: 1. One-to-one embedded instruction 2. Small-group spaced-trial instruction	Alternating treatment design	Baseline Students had 0% of correct responses. Outcomes When intervention was implemented students reached mastery criterion for both conditions in 435-585 trials (mean 510). Maintenance and generalization Not assessed.	Not reported	Overall 20/21 Science targets only 20/21 (Horner et

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
	- No ethnic background or primary language reported - IQ: 50 and 55 (mean 52.5)						al., 2005)
Riesen et al. 2003 USA	- Targets for 2 students were science related - 1 autistic student and 1 with multiple disabilities. - Male and female - 13 years - No ethnic background or primary language	Science vocabulary and concepts	Embedded instruction with comparison between constant time delay and simultaneous prompting	Adapted alternating treatment design	Baseline Students had 0% of correct responses. Outcomes Students reached mastery criterion for simultaneous prompting condition in 17-54 trials (mean 35.5). Due to time constraints only one student reached mastery criterion for constant time delay condition (34 trials). Maintenance and generalization Not assessed.	Not reported	Overall 20/21 Science targets only 20/21 (Horner et al., 2005)

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
	reported - IQ: 55 and 66 (mean 60.5)						
Riggs et al. 2013 USA	- 5 students with moderate to severe disability - 3 males and 2 females - 14-18 years - No ethnic background or primary language reported - IQ: 40-76 (mean 50.8)	Science concepts	Constant time delay procedure with examples and non-examples	Multiple probe design replicated across students	Baseline Based on students' responding during baseline probes researchers determined a starting point for all participants. One student started at Level 1, two at Level 2 and two at Level 3. Outcomes Students required between four and 18 sessions to reach mastery criterion (mean 8.6). Maintenance and generalization All students had 100% at 1-week maintenance probes. At 3-week maintenance probes students had between 67% and 100% (mean 93.4%). Students generalized acquired knowledge to novel exemplars.	Not reported	Overall 19/21 (Horner et al., 2005)
Smith et al. 2013a	- 3 students (2 with autism and 1 with autism and	Science vocabulary (terms and	Embedded computer-assisted explicit	Multiple probe across participants	Baseline Students had between one and four (out of 18) correct responses. Outcomes After the intervention was	Students, peer tutors' and teachers' views and opinions were assessed using questionnaires. Students reported that science is important for	Overall 21/21

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
USA	ID) - Males - 11-12 years - 1 Asian/Pacific Islander, 1 mixed ethic background (African American and Caucasian) and 1 Native Hawaiian/Other Pacific - No primary language reported - IQ: 59 and 69 (not reported for 1 student) (mean 64)	applications)	instruction	design	implemented students reached mastery criterion for all three units after six to eight sessions (mean 7). Maintenance and generalization Students had 12-13 correct responses (mean 12.7) at one week maintenance probe. Their responding decreased by one compared to intervention values during generalization probe.	all students. They also indicated that the intervention was effective, and they would like to receive more instruction using iPads. The peer tutors reported that the intervention was effective, and they would like to use iPads in their own classrooms. They indicated that science education is important for all students and they enjoyed supporting disabled students. The teachers reported that the intervention was effective, and it was time well spent. They also expressed their interest of using technology in the classrooms.	(Horner et al., 2005)

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
Smith et al. 2013b USA	- 3 students (1 with ID and 2 with multiple disabilities) - 2 females and 1 male - 6-7 years - 1 African American and 2 Caucasian - No primary language reported - IQ scores not reported.	Science concepts	Task analyzed science inquiry lessons	Multiple probe across behaviors with concurrent replication across participants design	Baseline Students responded correctly to between two and three probes (mean 2.3) for Unit 1, between 0.8 and 2.5 (mean 1.6) for Unit 2, between one and 4.2 (mean 2.6) for Unit 3 and between 1.6 and 2.4 (mean 1.9) for Unit 4. Outcomes Students responded correctly to between 4.8 and 6.5 probes (mean 5.9) for Unit 1, between 5.3 and six (mean 5.6) for Unit 2, between 6.2 and 7.4 (mean 6.7) for Unit 3 and between 5.6 and 6.9 (mean 6.1) for Unit 4. Maintenance and generalization Students responding during maintenance probes remained the same or slightly decreased compared to intervention outcomes.	Students' and teachers' views and experiences were assessed using a questionnaire. The students reported that they enjoyed the intervention and would like to do it again in the future. Two students (out of three) said that the intervention was not helpful during other lessons. The teacher strongly agreed that the intervention was a good use of time and she would like to participate in similar projects in the future. The teacher also agreed that targets were important, and she would use some components in the future. She reported that acquired skills did not generalize to other classes.	Overall 20/21 (Horner et al., 2005)

studies where none of the students showed an increase in the dependent variable when the intervention was implemented, perhaps due to publication bias.

Fourteen studies reported students' and/or teachers' experiences and opinions on the systematic instruction intervention used, four studies also included peer tutors' views, and one study included parents' views. Overall, reported experiences of the interventions were positive with students reporting that the intervention was enjoyable, and they would like to try it again in the future. Teachers reported that the intervention targeted skills important for their students and was effective in improving their science outcomes and feasible to implement. Attitude surveys conducted with peer tutors showed increases in their positive attitudes toward disabled students. Parents indicated that they believed that it was important that their children could access science lessons. They also reported increased interest in science skills of their children.

Out of 23 studies using systematic instruction methodology, only ten reported students' ethnic background and only two reported their primary language (see Table 2-2). Available data suggested a lack of diversity. The majority of the students were African American (n=27), Caucasian/White (n=13) or Hispanic (n=5). Two studies reported students' primary language as English. The remaining 13 studies did not provide any information about ethnic background of the participants.

Table 1 summarizes quality appraisal results for the systematic instruction studies (see Appendix 6 for more details). Ten studies met all 21 indicators and were categorized as high quality; nine met 20 indicators; and the remaining three studies met 19 indicators. The main area of weakness for the single-case experimental design studies was the description of participants (n = 6); although these articles provided a general description of participants, they failed to include detailed information about participant's primary diagnosis. A further area of weakness was the lack of an operational description of the dependent variable (n = 5). Three studies did not meet the magnitude of change criteria as some participants in those studies made no or very little progress after the intervention was implemented. Because 11 studies targeted multiple skills, including other areas of education apart from science, a second quality assessment was conducted using the same tool (Horner et al., 2005) with the focus on science targets only. Seven articles received the same quality score during the revised quality appraisal when only science-related intervention was evaluated. In contrast, four articles received a lower score. Most of those discrepancies were due to design limitations. Overall, the quality appraisal results were relatively unaffected by this sensitivity analysis adjusted to focus on science aspects only.

One RCT study (Browder et al., 2010) was high-quality except for whether participants and staff were blinded to the intervention, although this would not be feasible to achieve in the school context (see Table 2-2 and Appendix 7).

Self-directed learning. Self-directed "strategies allow students to manage, direct, and regulate their own learning and permit students to plan, execute, and evaluate actions based on problem solving and self-directed decision making" (Agran et al., 2006; p. 231). This type of instruction allows students to take control over their learning (Browder & Spooner, 2011).

Five studies used self-directed learning to teach science to students with DD (see Table 2-3 and Appendix 9). Four studies used single-case experimental design, and one used a group design. Some of the interventions included: a self-determined learning model of instruction (instructional model that teaches students to set goals, implement curriculum augmentation strategies, and self-monitor progress; Agran et al., 2006), augmented reality application (digital tool that blends the physical environment with digital content; McMahon et al., 2016), a self-monitoring checklist, and concept mapping (method of constructing visual maps to help establish connections between different concepts; Roberts & Joiner, 2007). One intervention was delivered by school staff, one by the researcher, and one by both, a researcher and teacher. Two articles did not provide detailed descriptions of

Table 2-3. *Summary table of studies using self-directed learning procedures.*

Source and Origin	**Participants**	**Target skills**	**Intervention**	**Design**	**Science outcomes**	**Students' and teachers' experiences**	**Quality appraisal rating**
Agran et al. 2006 USA	- Targets for 2 students were science related. - 1 student with ID and 1 with autism - Male and female - 13-15 years - No ethnic background or primary language reported - IQ scores not reported	Inquiry skills for Student 1 and Science concepts for Student 2	Self-determined learning model of instruction - self-monitoring and goal setting	Multiple baseline across individuals design	Baseline Students had between 0% and 25% of correct responses (mean 8.5%). Outcomes After the intervention was introduced students reached mastery criterion in 10-18 sessions (mean 14). Their performance ranged from 13% to 87% (mean 60%) Maintenance and generalization Students maintained acquired skills with between 75% and 87% (mean 82.5%) (one of the students had only one maintenance session).	Students' views and experiences were assessed using self-evaluation forms. One student made no verbal responses to any of the questions. The other student reported that as a result of the intervention: she was working harder in science class, she appreciated having guidelines, she knew what she wanted to know but she indicted that she did not know what changed with things she did not know before the intervention. Teachers of both students reported improvement in their lesson participation.	Overall 20/21 Science targets only 20/21 (Horner et al., 2005)
McMahon et al. 2016 USA	- 4 students (3 with ID and 1 with autism) - 1 male and 3	Science vocabulary	Augmented Reality application	Multiple-probe across-behaviors/	Baseline Students' average performance for first word list was between 6.7-30%, between 7.5-27.5% for second word list and between 10-20% for the third word list.	Students' views and experiences were assessed using surveys with a rating scale and two open-ended questions. Students reported that the intervention was socially appropriate,	Overall 21/21

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
	females - 19-25 years - No ethnic background or primary language reported - IQ: 48-85 (mean 65.25)			Skills design	Outcomes Students reached mastery criterion for the first word list in four to eight sessions (mean 6.5), for the second word list in five to 11 sessions (mean 9.5) and for the third word list in five to 11 sessions (mean 7.5). Maintenance and generalization Not assessed.	helpful, feasible and they would like to use it in the future with other targets. They also reported that hearing the definitions read aloud was easier than reading them and the intervention was enjoyable.	(Horner et al., 2005)
Miller and Taber-Doughty, 2014 USA	- 3 students with ID - 2 females and 1 male - 12-13 years - 2 Caucasian and 1 Latino - No primary language reported - IQ: 46-64 (mean 55.33)	Inquiry skills (task analyzed)	Self-monitoring checklist and science note-book	Multiple probe design	Baseline Students responded correctly on average to 6.7% steps on the task analysis. Outcomes After the intervention was implemented students' rate of responding improved to 96-100%. Maintenance and generalization Students' responding during generalization probes remained at the same level as during the intervention.	Students' views and experiences were assessed using the social validity interviews revised Treatment Acceptability Rating Form). Students reported that they enjoyed the intervention and wanted to continue and recommend it to others. They reported that the checklist was helpful and that they wanted to use it in the future and that the science notebooks were useful (two students out of three).	Overall 21/21 (Horner et al., 2005)

Source and Origin	Participants	Target skills	Intervention	Design	Science outcomes	Students' and teachers' experiences	Quality appraisal rating
Miller et al. 2015 USA	- 3 students with ID - 2 females and 1 male - 14-19 years - 2 Caucasian and 1 Latino - No primary language reported - IQ scores not reported	Inquiry skills (task analyzed)	Guided science inquiry and self-monitoring checklist	Multiple probe across participants design	Baseline Students had between 23.3% and 49.53% of steps of the task analysis completed correctly (mean 35.1%). Outcomes After the intervention was implemented students' responding increased to 58.5-95.8% (mean 79.2%). Maintenance and generalization During generalization probes students responding remained high – 77.9-96.9% (mean 89.5).	Students' views and opinions were assessed using questionnaires. Students reported to have enjoyed the intervention and would like to continue. Two students (out of three) indicated that the checklist was helpful and would be useful in other classes, but all students reported they would prefer not to use it.	Overall 21/21 (Horner et al., 2005)
Roberts and Joiner, 2007 UK	- 10 students with autism - 9 males and 1 female - 11-14 years - No ethnic background or primary	Science concepts and maps	Comparison of two interventions: 1. Concept mapping (experimental) 2. Conventional teaching	Within-participant crossover experimental design	Baseline Students in the concept mapping group scored mean of 29.6 points (SE 7.8) and students in the conventional teaching group scored mean of 47 points (SE 4.2). Outcomes The Wilcoxon signed-rank test determined that the difference in baseline and post-test measures for science questionnaires (concepts) was significantly bigger for experimental (concept mapping) than control (conventional teaching) conditions (z=2.091;	Not reported	7/8 (CASP form for randomized controlled trials)

Source and Origin	**Participants**	**Target skills**	**Intervention**	**Design**	**Science outcomes**	**Students' and teachers' experiences**	**Quality appraisal rating**
	language reported - IQ: 63-120 (mean 92)		(control)		$p<0.05$; $r=0.66$). This was determined as a large effect size (Cohen's effect size criteria). There was no significant difference between experimental and control conditions for concept maps ($z=1.48$; $p>0.05$; $r=0.47$). Maintenance and generalization Not assessed.		

intervention facilitators. Two interventions used CAI, and three incorporated systematic instruction components: task analyses and exemplar and non-exemplar trainings.

Students in all studies showed increases in the level of the dependent variable after the intervention was implemented. For example, Miller and Taber-Doughty (2014) used a self-monitoring checklist and science notebooks to teach inquiry skills to three students with ID. All students showed a large increase in the rate of correct responses after the intervention was implemented compared to baseline. Moreover, their rate of responding remained high during generalization probes.

Four studies also reported students' experiences and opinions of the interventions. Overall, students expressed positive experiences indicating that they enjoyed the interventions and helped them learn science. None of the studies reported teachers' experiences.

Of five studies using self-directed learning, only two reported students' ethnic background and none reported their primary language (see Table 2-3). Available data suggest that samples were not diverse. The majority of the students were Caucasian (n = 4), and two participants were labelled as Latino. The remaining three studies did not provide any information about ethnic background of the participants.

Table 2-3 summarizes the quality appraisal results for self-directed learning studies (see Appendix 6 for more details). Five articles used single-case experimental designs. Three studies met all 21 Horner et al. (2005) indicators and are categorized as high quality (e.g., Miller & Taber-Doughty, 2014). One article met 20 indicators (Agran et al., 2006), because no information about procedural fidelity was included. Because one study (Agran et al., 2006) targeted multiple skills, including other areas of education apart from science, a second quality assessment was conducted with the focus on science targets only. The article received the same quality score again suggesting that the quality of the study was not affected by including multiple targets.

One study (Roberts & Joiner, 2007) used a within-participant crossover experimental design, and the quality was assessed using the CASP form for RCTs (CASP, 2017) without the randomization question. The results are presented in Table 2-3 (see Appendix 7 for more details). The study was high quality.

Comprehension-based instruction. The “goal for comprehension instruction is for students to learn to transfer skills acquired in reading narrative texts to comprehending the elements in expository texts” (Browder & Spooner, 2011; p. 143). The narrative texts include novels, shorts stories, and similar, whereas expository texts include, for example, textbooks.

Two studies used comprehension-based intervention to teach science to students with DD (see Table 2-4 and Appendix 10). Both used single-case experimental design and the intervention was delivered by the school staff. The interventions included a compare-contrast strategy package (intervention including contrasting and comparing signal words and summarizing information; Carnahan & Williamson, 2013) and multicomponent text structure intervention (intervention pack involving instruction in different types of text patterns; Carnahan et al., 2016). Students in both studies showed increases in the level of the dependent variable after the intervention was implemented. For example, Carnahan and Williamson (2013) used a compare-contrast strategy package to teach science textbook comprehension to three autistic students. The rate of responding of all students was already quite high at baseline, but students made progress when the intervention was implemented and maintained their responding over time.

Both studies also reported students' and teachers' experience and views on the interventions. Students reported that the intervention helped them learn textbook comprehension and they would like to continue using it. The teachers indicated that the

Table 2-4. *Summary of studies using comprehension-based instruction.*

Source and Origin	**Participants**	**Target skills**	**Intervention**	**Design**	**Science outcomes**	**Students' and teachers' experiences**	**Quality appraisal rating**
Carnahan and Williamson, 2013 USA	- 3 students with autistic - Males - 13 years - No ethnic background or primary language reported - No IQ scores were reported.	Science textbook comprehens-ion	Compare-contrast strategy package	Single-subject reversal design	Baseline Students' responding was between 50% and 77% (mean 62.3%). Outcomes After the intervention was implemented students' responding improved to 97%. Maintenance and generalization During maintenance probes students responding remained high at 95-100% (mean 98.3%).	Teacher's views and experiences were assessed using a questionnaire. The Teacher indicated that the intervention targeted important areas for her students, was feasible to implement and increased student's comprehension of science textbooks.	Overall 21/21 (Horner et al., 2005)
Carnahan et al. 2016 USA	- 3 students with autism - Males - 15-16 years - No ethnic background or primary language	Science texts comprehensi-on	Multicomponent text structure intervention (text structure organization and text analysis)	Multiple baseline design	Baseline Students' average rate of responding was 42-54% (mean 49%). Outcomes Students' responding improved to 88-97% (mean 91.7%) when the intervention was implemented. Maintenance and generalization Students' responding during maintenance probes remained high at 95%.	Students' and teachers' views were assessed using questionnaires with a rating scale and open-ended questions. Both students and teachers reported that the intervention was feasible, effective and would likely be continued. Students reported that they would not change the intervention. Teachers felt that the intervention was helpful in learning	Overall 21/21 (Horner et al., 2005)

	reported - IQ: 76 (reported only for one student)	more about their students' skills.

interventions were feasible, targeted skills important for their students and were effective in teaching them new skills. Neither study reported students' ethnic background.

Table 2-4 summarizes quality appraisal results (see Appendix 6). Both studies met all 21 Horner et al. (2005) indicators and were categorized as high quality.

Discussion

The main aims of this review were to identify what methods had been reported in the education literature to teach aspects of science to students with DD, and, for the first time, to report on students' and other stakeholders' perceptions and experiences of these interventions. We begin our discussion by briefly summarizing the main findings from our review. Finally, we discuss our findings within the conceptual framework of the main theories of learning in science education and describe how more systematic approaches to teaching can be used to help teach students with DD to 'work scientifically'.

Spooner et al. (2011) concluded that systematic instruction was an evidence-based practice for teaching science to students with moderate to severe disabilities. Although the current review also found systematic instruction research, we identified additional teaching approaches (self-directed instruction and comprehension-based instruction) that might also be effective in teaching specific science content to students with DD.

Three main teaching approaches were identified in this systematic review. The majority of the studies (n = 23) used systematic instruction. Of 90 participants, only three students did not make progress in their target skills after the intervention was introduced. Although this may represent a reporting bias, these data on progress in outcomes are consistent with Spooner et al.'s (2011) conclusion that systematic instruction is an effective teaching technology for science education for students with DD. In addition, teaching strategies and targeted outcomes were very diverse in the current review such that quantitative synthesis of the studies was not possible. Thus, any conclusion about the effectiveness of systematic instruction should be made with caution. For the first time, we also reported data on stakeholders' experiences, and the 10 studies reported participants' perceptions indicated that systematic instruction interventions were valued and feasible to implement.

Multiple-teaching methods were often combined in one intervention. However, simultaneous prompting procedures and embedded instruction were the two most frequently used teaching approaches. The majority of the interventions were implemented by school staff in the general education classrooms or students' typical classrooms. The students' experiences were positive, and teachers commented that the targeted skills were socially important. In addition, quality appraisal results indicate that the majority of the studies using systematic intervention (n = 19) were of high or acceptable quality with only four studies obtaining a lower rating. One study using a group design was also of adequate quality. Overall, systematic instruction seems to be a promising approach to teach science to students with DD. However, more high-quality research is needed, especially using RCT designs, to establish its effectiveness for students with severe DD. More high-quality single-case experimental design research is also warranted, especially studies sharing procedures and outcomes that can later be synthesized quantitatively.

The second teaching approach identified was self-directed instruction. Five studies that used this method reported positive outcomes for students with DD. All 22 participants made progress in their target skills, and students in four of the studies reported positive experiences of the intervention (no data reported on experiences of students in one study). Teachers' opinions and perceptions were not reported. Quality appraisal results indicate that four studies were of high or adequate quality. One study using a group design was also of acceptable quality. Self-directed instruction seems to be a promising approach to teach science, especially inquiry skills, to students with DD. More high-quality research is needed to establish its effectiveness across a variety of outcome measures. Again, the variability in teaching approaches and outcomes precluded a quantitative synthesis of these studies.

The third identified approach was a comprehension-based instruction that was used in two studies to teach science textbook comprehension to students with DD. Students in both studies made progress in their target skills and reported positive experiences. Students indicated that the interventions helped them acquire new skills, and the teachers reported that the interventions were effective, feasible to implement and that the target skills were socially important. Quality appraisal results indicated that both studies were of high quality. Overall, comprehension-based instruction might be an effective method for teaching science text comprehension to students with DD, but they do not currently have an evidence based for their effectiveness for teaching learners scientific reasoning (or science inquiry skills). These skills are essential to help learners identify and manipulate variables to identify causal influences, including the ability to generate predictions and the use of evidence to evaluate findings. Given the small number of studies, additional research is needed to establish the effectiveness of comprehension-based instruction in supporting the acquisition and understanding of science vocabulary and key concepts.

Ten studies incorporating systematic instruction methodology focused on a population of learners with ID only, one with autism only, and nine with autism and ID. Three studies did not report diagnosis. Two studies using self-directed learning focused on students with ID only, one with autism only, and two with both autism and ID. Both studies focusing on comprehension-based instruction recruited only autistic students. There does not appear to be a pattern in the use of specific teaching procedures using self-directed teaching or systematic instruction on their effectiveness dependent on diagnosis (see Tables 2-2 and 2-3, Appendices 8 and 9). Interventions were successfully implemented with students with autism, ID, and autism and ID. Only autistic students were included in studies using comprehension-based instruction (see Table 2-4 and Appendix 10), and therefore, these approaches need to be examined with children with other labels. There was limited availability of information on participants' cultural and ethnic origin in the studies included in the present systematic review. Thus, the applicability of findings across diverse groups is unknown.

Implications for teaching science to students with DD

Although the dominant perspective in the field of mainstream science education is heavily influenced by teaching methodologies based on a cognitive approach (McGinnis & Kahn, 2014), the majority of studies reported in the present systematic review are consistent with the behavioural approach. Very few studies reported findings from teaching programs designed from a more constructivist perspective. This might be related to the nature of disabled students and their learning but is more likely a direct reflection of the preference of researchers in special education to favour behavioural approaches as their preferred theoretical framework. The dominant view in the special education field, therefore, is that explicit/systematic instruction is the most effective approach to teaching a range of new skills to disabled students (Spooner et al., 2017). The current review suggests teaching methods based on behavioural approaches are likely to be effective strategies for teaching science skills and knowledge to students with DDs.

At this point, it is also important to identify a further limitation of the existing evidence base and thus a further note of caution. A majority of the research on science and DD has emanated from the same extended research group in the United States. This body of work and the commitment of the researchers is commendable, but there is then a need for extensive replication and for more researchers in special education to research science, and also there is a need for more science educators to research science learning and teaching for students with DD.

The opening to this article provided an overview of the aims of science education and the two main approaches to teaching science, including a review of the features of inquiry-based teaching, the most common approach promoted by science educators and policymakers. The main aim of science education is to enable students to understand some of the ‘big ideas’ in science and to equip students with the necessary inquiry skills to enable them to ‘work scientifically’ to answer questions and understand the natural world. These principles apply equally to students with DD. A distinction was also made between the pedagogy of science education and the epistemology of science as a discipline (i.e., a distinction between how pupils learn about science compared to how pupils are able to put their learning into practice by ‘working scientifically’ [Kirschner et al., 2006]). Many science educators believe that students learn science most effectively through first-hand practical experiences of carrying out scientific inquiry work (i.e., pupils learn science by doing science), and this has become the accepted strategy with science researchers and educators. However, despite its widespread acceptance, there is no convincing research evidence to support the superiority of inquiry-based teaching strategies compared to more direct (systematic) instructional approaches (Kirschner et al., 2006; Mayer, 2004; Novak, 1988). Evidence from the current review, together with findings from trails in mainstream school settings (Cobern et al., 2010), indicates that systematic and self-directed (inquiry) modes of instruction can be effective approaches for teaching science to students with DD and that these students are likely to be able to carry out science inquiry work with some degree of independence.

Interestingly, some of the systematic instruction and self-directed (inquiry-based) programs identified during this review (for example, Jimenez et al., 2014) show positive outcomes with respect to teaching students science knowledge and inquiry skills. Teaching strategies such as these are likely to be promising approaches to teaching science to students with DD, including teaching relevant knowledge and inquiry skills to enable learners to ‘work scientifically’ to help them answer testable questions and gather information. It is important to note, however, that disabled students generally require additional support to access inquiry-based instructional tasks and that their science gains increase when components of explicit instruction are used (Rizzo & Taylor, 2016).

Evidence from our review indicates that comprehension-based instruction may be an effective teaching strategy to help students understand science texts. However, none of these comprehension-based studies focused on teaching science inquiry skills to learners. They cannot, therefore, stand alone as instructional strategies and meet the aim of improving the provision for teaching scientific content and skills through more practical scientific experiences without additional provision for teaching inquiry skills. Although this is certainly a practical proposition for science teachers, the utility of combining two methods of instruction to meet one educational goal is low. Systematic instruction and self-directed inquiry may offer a more efficient way forward for teachers.

More recent research from cognitive and developmental psychology has identified a set of core skills in initial science learning that highlights the importance of students' language and observational skills in developing conceptual and procedural understanding (Tolmie et al., 2016). This focus on core skills recognizes the need for the systematic introduction of scientific language to students alongside observations and practical tasks, especially for very young children. The provision of graded tasks, featuring the teaching of specific language and observational tasks, is an important feature of some systematic instructional programs, and it is reasonable to propose, therefore, that teaching approaches based on systematic instruction will support these emergent core skills in science.

Implications for future research

There is limited evidence for the effectiveness of inquiry-based approaches in the literature. This might be due to the difficulty of implementing this type of teaching approach with students with DD, and/or they cannot be successfully operationalized for this population. The research literature in science for students with DD has been dominated by researchers working from a behavioural tradition. More research is now needed to examine the potential of using inquiry-based science teaching for students with DD, including gathering information on teachers' attitudes, practical implications, and social validity.

More research is also needed on the impact of comprehensive science curricula for students with moderate and severe DD throughout primary and secondary education. Two studies included in the current review evaluated the effectiveness of a systematic instruction science curriculum for students with DD (Jimenez et al., 2014; Smith et al., 2013b). More research (including RCTs) is needed to establish the effectiveness of these programs, including the ability of students to generalize inquiry skills across different science topics. Some of the approaches in this review focus on developing basic science inquiry skills (e.g., simple predictions, observations, measuring, and recording skills) across a range of investigational work (e.g., exploration, classifying, and fair tests inquiry tasks [Goldsworthy et al, 2000]). More research is needed to assess the provision for a wider range of science skills and types of investigation contained within science teaching programs for learners with DD.

Due to the extensiveness of science content, some relevant articles may not have been identified during database searches. This is especially true for studies targeting a variety of educational targets where only one or two participants were working on science-related content. Eight studies included in the review were identified from reference lists instead of via the original searches. For example, in Jameson et al. (2007), the word "science" (or any other related search term) was not used in the title, abstract, or keywords, and therefore, it was not recognized during database searches. Although it is possible that some similar studies will have been missed, the systematic review method was designed to identify studies using a range of processes to reduce the risk of omission.

Chapter 3

Teaching science to students with developmental disabilities using the Early Science curriculum[3]

[3] A version of this study has been published in Support for Learning as follows: Apanasionok, M.M., Neil, J., Watkins, R.C., Grindle, C.F. & Hastings, R.P. (2020). Teaching science to students with developmental disabilities using the Early Science curriculum. Support for Learning, 35: 493-505. https:doi.org/10.1111/1467-9604.1232

Introduction

The Department for Education (2014a) defines science education as ‘scientific knowledge and conceptual understanding through the specific disciplines of biology, chemistry, and physics’ (p. 168). It is one of the core subjects in the national curriculum in England that enhances students’ understanding of the natural world, the human body and the fundamental concepts that govern the physical and material world around them. Science education also provides important foundation skills for employment in later life. UK policy, including the Equality Act 2010, mandates schools to provide equal access to education to all school age children, including students with DD (Department for Education, 2014c). Furthermore, the Special Educational Needs and Disability code of practice advocates for practitioners to select teaching methods based on available evidence (Department for Education, 2015b).

In England, 15.5% of school age children have SEN (Department for Education, 2020a). Among those students, two categories of need can be distinguished: students with SEN support (pupils with additional needs that can be met by the school) and students with EHC plan or a statement (pupils with additional needs that cannot be met by the school alone). Speech, language, and communications needs as well as moderate learning difficulties (i.e., mild to moderate ID in the international terminology) are most prevalent among students with SEN support and autism is the most prevalent among students with an EHC plan or a statement. Over recent years, there has been a significant attainment gap in science between students with SEN and students without SEN. In the school year 2018/2019, only 42% of students aged 4–7 years with SEN achieved the expected standard, compared to 90% for students with no SEN (Department for Education, 2020b).

Over the last few decades, there has been a shift in educational practices, from a standard model of schooling promoting a standardised approach to all students, to a more individualised approach that focuses on learners’ needs (Sawyer, 2008). As a consequence, many science practitioners have adopted a more constructivist perspective, focusing on the use of practical science activities to enable pupils to construct their own understanding of key scientific concepts and skills. It is argued that inquiry-based science teaching produces a more secure understanding of science concepts and skills.

However, existing research literature on teaching science to students with DD indicates that a behavioural teaching approach may be effective. Spooner et al. (2017) reviewed evidence-based practices for teaching students with severe disabilities. They identified systematic instruction and a teaching approach based on behavioural principles as effective approaches to teach a range of skills, including academic skills. The majority of published research on teaching students with severe disabilities focuses on literacy and mathematics. There are, however, a number of studies that target science skills.

Four systematic reviews on teaching science to students with DD have been conducted to date. Courtade et al. (2007) focused on teaching science to students with significant cognitive disabilities. Eleven studies published up to 2003 were identified, all using systematic instruction teaching approaches. Courtade et al. (2007) suggested that students with significant cognitive disabilities can especially benefit from teaching procedures like errorless learning and time delay. Spooner et al. (2011) conducted a systematic review on teaching science to students with severe DD. Seventeen studies published up to 2009 were identified. All used systematic instruction teaching methodology, with Spooner et al. (2011) concluding that this is an evidence-based practice for teaching science to students with DD. Rizzo and Taylor (2016) focused on the use of inquiry-based instruction to teach science to students with various disabilities. Twelve studies published up to 2013 were identified. Although the students included in these studies made progress in their science skills after the inquiry-based instruction was introduced, Rizzo, and Taylor (2016) suggested that it is not an effective approach on its own and students perform better when explicit instruction is also used. Apanasionok et al.

(2019 - Chapter 2) conducted a systematic review on teaching science to students with DD. Thirty studies were identified, 20 of which also included teachers' and students' opinions and experiences of the interventions. The majority of studies used systematic instruction methodology, with only a few using self-directed learning (i.e., students regulating and directing their own learning) and comprehension-based instruction (i.e., transfer of skills and knowledge from narrative texts to expository texts). Students and teachers reported positive experiences of using all interventions. Apanasionok et al. (2019 – Chapter 2) concluded that systematic instruction is a particularly promising method to teach science to students with DD.

Early Science curriculum

The Early Science (ES) curriculum (Jimenez et al., 2012b) uses systematic instruction approaches and has been used in several studies included in the existing systematic reviews (Spooner et al., 2011; Apanasionok et al., 2019 – Chapter 2). The ES curriculum covers content that aligns with the science education standards in the USA for elementary age students (5 to 11 years old), and that are similar to the requirements in the UK. The ES curriculum consists of four units: five senses, the rock cycle, earth and space, and the life cycle of plants and animals. Each unit consists of seven lessons. The first six lessons introduce new topics, and the seventh lesson is a repetition of the whole unit. Each lesson consists of seven teaching components:

1. Guided inquiry;
2. Scripts;
3. Wonder Wally storybook (a set of stories with pictures to accompany each lesson of the unit);
4. Science safety (related to practical activities);

5. Explicit instruction (an active teaching method involving time-delay procedure, most-to-least prompting procedure and an example and non-example procedure) of key concepts and vocabulary;
6. task analysis (breaking down a complex task into smaller steps); and
7. special accommodations/ adjustments for the students.

Lessons should be repeated multiple times - but not more than five times. Students' performances are monitored by short quizzes completed at the end of each session. The teacher draws on quiz results to decide how many repetitions of a specific lesson are needed.

Three studies evaluating the effectiveness of the components of the ES curriculum have been conducted. Smith et al. (2013b) taught science skills and knowledge using the ES curriculum to teach three primary school age children with severe DD in the USA. Lessons were delivered by a teacher as a whole class instruction (seven students). However, data were only collected for three pupils that met the study's inclusion criteria. All three participants made progress in their science skills and knowledge after the curriculum was implemented. Students answered more questions correctly during assessments for all four units after the intervention was introduced. Students maintained their scores for most units over time, although with a few participants decreasing or increasing their scores by one or two points. Additionally, mean fidelity for the delivery of the lessons in all four units was 97.5% and the teacher and students reported positive experiences of the use of the ES curriculum.

Jimenez et al. (2014) compared the effectiveness of scripted lessons (from the ES curriculum) alone and with guided notes to teach science to three primary students with ID and autism in the USA. Both intervention conditions were implemented by a special education teacher as a whole class instruction (six students). However, data were only collected for three students. The number of correct responses at unit assessments increased for all participants after the scripted lessons were introduced. Little or no increase in the number of correct responses was observed when the scripted lessons were combined with guided notes. Students maintained their scores over time for most units (with a few students increasing or decreasing their scores slightly). Mean fidelity of delivery for all lessons across three units was 97%. The teacher reported that they preferred the scripted lessons alone but felt that both conditions were effective in teaching science content to her students.

Finally, Knight et al. (2018) conducted a study to compare scripted and unscripted ES curriculum lessons with nine students with ID or autism in the USA. Both intervention conditions were implemented across four different classes by four teachers in a small group setting. Two units from the ES curriculum were targeted. Results indicated that both the scripted and unscripted approaches were effective in teaching science content to the participants. All students reached mastery criterion for all units in the unscripted lessons condition and seven out of eight for the scripted lessons condition. Fidelity of delivery across both conditions ranged between 84% and 100%. Additionally, Knight et al. recorded data on the duration of the lessons and the number of sessions that the students needed to reach the mastery criterion. They concluded that the unscripted task analysed lessons condition was more efficient to implement. Teachers preferred unscripted lessons.

Despite research literature suggesting that systematic instruction is an effective teaching method for science for students with DD (Courtade et al., 2007; Spooner et al., 2011, 2017; Apanasionok et al., 2019 – Chapter 2), there are no available published comprehensive curricula utilising this methodology to teach science to students with DD in the UK. Therefore, the purpose of the current study was to pilot the ES curriculum in a UK special school setting. We were especially interested to see if the curriculum could be effectively implemented with staff ratios typically available in special schools in the UK. We focused on the following questions: (1) Is it feasible to implement the ES curriculum in a special school in the UK? (2) What are educators' perceptions and experiences of the implementation of the ES curriculum?

Setting and students

Ethical approval was obtained from the Humanities and Social Sciences Research Ethics Committee at the University of Warwick (see Appendix 11).

The study took place in a large special school in the UK catering for around 380 children aged 2–19. Students attending the school have diagnoses of autism, ID, and profound and multiple intellectual disabilities (PMID) among others. Nine students (see Table 3-1) from one primary class took part in this project. To ensure students' confidentiality, pseudonyms have been used.

Table 3-1. *Summary of students' characteristics.*

Student	Sex	Chronological age	Primary label	Ethnicity
Tom	Male	8 year 9 months	Autism	Other Asian
Sam	Male	7 years 8 months	Severe ID	Black British
Harry	Male	9 years 9 months	Severe ID	White British
Peter	Male	9 years 3 months	PMID	Other Pakistani
Steve	Male	10 years 0 months	Autism	Other Pakistani
Daniel	Male	10 years 7 months	Severe ID	Yemeni
Larry	Male	9 years 7 months	Severe ID	Other Pakistani
Ben	Male	9 years 7 months	Severe ID	Indian
Ann	Female	9 years 5 months	Severe ID	Bangladeshi

All intervention lessons took place in the school's science classroom that contained a large interactive screen, three large wooden tables with chairs, cupboards with science materials, and a designated sensory area. Students were divided into two groups and were sat at two tables. They were facing a large display placed in the middle of the classroom with the KWHL (What do we know? What do we want to know? How can we find out? and What did we learn?) chart and a science safety rule poster. Four staff members took part. The Head of Science in the school, the second author on the published version of this study (JN), served as a primary implementer (referred to as a science teacher in the rest of this article). The class teacher and two teaching assistants (TAs) were also trained in the implementation of the ES curriculum and supported students during the science lessons, although during most lessons only the two TAs were present in addition to the science teacher.

Students were nominated to take part in the project by the science teacher and the assistant head teacher based on the following criteria: (1) The student has the prerequisite skills to access the ES curriculum (i.e. is able to sit at the table and attend to the lesson for 10–15 minutes at one time; able to comprehend basic science concepts); (2) The student has the prerequisite skills to access the assessment tools (i.e. is able to circle, point or verbalise the chosen answer); (3) The student is able to work for 10–15 minutes in one sitting; (4) The student has no significant challenging behaviours; and (5) The student has no visual or auditory impairments that cannot be corrected by glasses or hearing aids.

The Early Science curriculum

Due to time constraints, only the first unit (The Five Senses) was evaluated in this study. A total of 15 sessions took place with each lesson of the five senses unit being repeated twice and a single trial lesson at the beginning of the intervention.

Multiple materials were used during the science lessons. The science teacher and staff members supporting the groups used lesson scripts and resource materials provided in the ES curriculum pack. Since teaching was delivered by multiple people, the evaluator (MA) colour-coded all scripts to indicate which parts should be delivered by the science teacher and which by the class teacher or TAs. The scripts contained information on specific knowledge and vocabulary to be delivered by the teacher and TAs, the expected responses to be provided by students, and a description of teaching procedures. The science teacher also used a Wonder Wally storybook as required in the script.

Other materials included in the ES curriculum pack were also used. Primarily, picture- word cards, photo cards, KWHL (What do we know? What do we want to know? How can we find out? and What did we learn?) chart, science safety rule poster, statement cards, and science safety rule cards. During the last two lessons, word and picture cards alongside the Wonder Wally game were also used. All resources were laminated before the start of the project to ensure their longevity. Some of the cards also had Velcro attached on the back to make it easier for the staff members to keep them together. Each student had a My Science Log and a set of quizzes implemented after each lesson to assess students' comprehension and retention of key concepts. Each quiz had a prediction part (usually two questions) used during the lesson and a report part (usually around five to six questions) that was completed after the lesson. Most of the questions were multiple-choice with pictures of each answer to help facilitate the response of students who could not read. A progress monitoring form included in the ES curriculum pack was used to monitor the progress of individual students throughout the duration of the intervention.

Each lesson lasted approximately 40 minutes. Students were divided into two groups of four and five based on their science ability and the level of classroom support they required. Each group was paired with at least one member of staff (either the class teacher or TA) with the science teacher delivering whole class instruction. Lessons started with students saying “hello” to Wonder Wally (a fictional character used throughout the curriculum) that was displayed on a poster in the front of the classroom. Then the science teacher introduced the topic of the lesson and proceeded to read one story from the Wonder Wally storybook introducing key vocabulary. During the next part of the lesson, students made predictions and conducted practical experiments (for example building their own instruments). Towards the end of each session, students reviewed the outcomes of their practical work, including a review of the key concepts and the predictions that they made before conducting the inquiry task. The remaining time was spent on students reviewing key concepts targeted during the lesson and completing their My Science Log.

Some adaptations to the general procedure were made during the teaching to meet the needs of different students in the cohort. Small changes were made to the experiments proposed in the ES curriculum to make them more accessible to the students. For example, for the ‘rock candy’ experiment, different ratios of sugar and water were used to allow for more visible sugar formation. Also, different liquids than those described in the ES curriculum manual were used during the smell and taste lesson to make it more suitable for students’ needs (e.g., allergies).

The science teacher also used a number of different resources required for the experiments and practical activities, some of which were included in the ES curriculum pack in addition to non-specialist science equipment.

Before the start of the intervention, the class teacher and the two TAs were trained in the implementation of the ES curriculum by the science teacher and the evaluator (MA). The training lasted around 30 minutes and included the use of:

1. Scripts;
2. The time delay procedure (prompt/help for the student is delivered following a specific amount of time after the instruction);
3. The example and non-example procedure (the student is presented with an example and non-example of a target item while the teacher clearly labels: ‘This is . . . ’ or ‘This is not . . . ’); and
4. The least-to-most prompting procedure (hierarchy of help/prompts starting from the least intrusive).

The trainers first explained all teaching procedures and then briefly modelled their implementation. During the first few lessons, the science teacher provided assistance to the staff members when needed. Once the science teacher and the evaluator were confident the staff members knew how to implement all procedures the support was withdrawn.

Assessments

Two primary assessment tools were used to monitor students’ progress. Students’ knowledge on the senses was assessed with the ES curriculum assessment for unit one (The Five Senses). This tool consists of 12 multiple-choice questions with pictures of each answer to help facilitate the response from students who cannot read. Before the first ES curriculum lesson (on the same day), the evaluator, science teacher, class teacher and TAs assessed students’ knowledge on the senses using the ES curriculum unit assessment. The test was implemented in one-to-one format with staff members sitting down with each student and reading out the questions and possible responses. The students answered by either pointing to the correct response or circling (if their motor skills allowed). The staff members did not provide any prompts to the students apart from reminding them to choose their answers and encouraging them verbally to continue. The ES curriculum assessment was implemented in the same manner after the intervention was finished.

Additionally, after each lesson students were required to complete a short quiz with five to six open-ended questions (with pictures to facilitate responding). This was a part of the My Science Log record of progress. Scores from the quizzes were then used to make decisions about when it was appropriate to move to the next lesson. The quiz was implemented in the same way as the unit assessment.

After the study, the evaluator conducted informal interviews with the science teacher, the class teacher and both TAs to find out their experience and opinions on the ES curriculum implementation.

Evaluation

All nine students made progress in their ES curriculum assessment at post-test compared to pre-test. The pre-test was completed before the first lesson of the intervention. Seven weeks later the ES curriculum assessment was repeated. Students scored a mean of 4.67 (SD = 2.45) points (out of 12) at pre-test and mean of 10.22 (SD = 1.99) points at post-test. Participants' individual scores are presented in Table 3-2.

Table 3-2. *Summary of students' scores at pre- and post-test.*

Student	Baseline (04.2018)	Post-test (05.2018)
Tom	4	10
Sam	6	11
Harry	1	7
Peter	4	12

Steve	8	12
Daniel	5	7
Larry	7	12
Ben	1	10
Ann	6	11
Mean	4.67	10.22
SD	2.45	1.99

All staff members reported a positive attitude towards the ES curriculum and its impact on the standards students achieved. When asked why the school decided to implement the ES curriculum, one staff member noted that it was the only evidence-based science curriculum that is suited to meet the needs of her students, to her knowledge. Other staff members indicated that this teaching approach helped students to understand science due to its very repetitive structure. When asked about the training, two staff members said that it was helpful but that the ES curriculum is generally self-explanatory with the scripts and teaching methods well described. When asked about their general experience of implementing the ES curriculum, staff members indicated that the intervention went well, with one TA noting that a lot of her students had acquired new knowledge about all five senses and engaged well with the curriculum. One staff member said she was 'shocked' with how well the intervention went as she did not expect that her students would be able to benefit from a more knowledge-based curriculum as opposed to the school's usual sensory approach.

Staff feedback identified some elements of the ES curriculum that worked particularly well, including the practical activities/experiments, the Wonder Wally game, pairing symbols with objects, time delay, exemplar and non-exemplar procedures, and the predicable structure of the lessons. When asked which parts of implementing the ES curriculum were more challenging, staff members mentioned time constraints during the lessons and sometimes inadequate staff ratios. The science teacher also identified problems with the unit assessment, noting that sometimes students verbalised the correct answer but then went to point or circle a different response. The class teacher reported students' logs as the most challenging aspect of the ES curriculum implementation, as students required significant support to complete these. All staff members enjoyed using ES curriculum materials. The science teacher noted that some experiments needed to be amended as they did not work well when directions included in the curriculum were followed.

When asked about what they would do differently if they were to implement the curriculum again in the future, staff members identified the need to allow more time for lessons and practical activities. Each lesson in the school is 45 minutes; however, by the time students transitioned to the science classroom and settled in their seats, there was typically only 35–40 minutes remaining to complete the activities. Additionally, as the groups were quite large (five or four students in each) with only one member of staff per group, it was time consuming to implement the teaching procedures with all students and provide individualised support to complete the My Science Log. The class teacher suggested dividing each lesson into two sittings to make it more suitable for larger groups of students. Staff members also identified staff ratios as a challenging feature. Due to staffing issues, only one staff member (apart from the science teacher) was present during two lessons. Additionally, one TA was often called away from his group to support a student who, due to behaviours that challenge, was not able to take part in the project. This placed an additional demand on the science teacher.

When asked about the impact of the ES curriculum on their students, all staff members noted positive changes, with students still remembering key concepts and the function of the five senses a few weeks after the intervention was completed, as well as being more likely to volunteer their knowledge during lessons. The class teacher noted that although some aspects of the curriculum were very challenging for students, they all made very good progress in improving their science skills and knowledge during the intervention period.

Conclusions

We found that it was feasible to implement the ES curriculum in a special education setting in the UK with some minor adjustments. Many science educators believe that students learn science knowledge and skills most effectively through inquiry-based learning (i.e., pupils learn science by doing science), and this has become a commonly accepted approach within science education. However, despite its widespread acceptance, there is no convincing research evidence to support the superiority of inquiry-based teaching strategies compared to more direct (systematic) instructional approaches (Novak, 1988; Mayer, 2004; Kirschner et al., 2006). Evidence from the current pilot study indicates the ES curriculum is a promising approach to teaching science to students with DD, including teaching relevant knowledge and inquiry skills to enable learners to ‘work scientifically’.

Robust research is needed to evaluate the effectiveness of the ES curriculum. Future studies should focus on evaluating the efficacy of the ES curriculum with more students while providing additional information about the feasibility of implementing all four units. The present study also highlighted the need for a standardised science assessment suitable for students with moderate to severe DD to be developed.

Transition – science to numeracy

Science and mathematics are core subjects in England's programmes of study (Department for Education, 2014a) and their influence on students' independence and living skills are well documented in the literature (Staves, 2019; Apanasionok et al., 2019 – Chapter 2). They form the foundation of STEM subjects that are core areas of focus in all mainstream programmes of study in England and internationally. Strong links of STEM subjects are also well documented in relation to further education and employment prospects. Despite that, there is scarcity of research on teaching science and mathematics to students with DD, especially in settings 'typical' for the educational system in the UK. There is also a large gap in attainment between neurodivergent and neurotypical students (Department for Education, 2020b).

This thesis focuses on science and numeracy education for students with DD and explores adaptations that can be made to ensure evidence-based interventions are more accessible and feasible to implement in specials schools in the UK. Chapters 2 and 3 focused on science education for students with DD and the way Systematic Instruction can be used to teach core skills and knowledge. The remaining three core chapters – 4, 5 and 6 – will focus on numeracy education for students with DD.

Chapter 4

Teaching early numeracy to autistic students using a school staff delivery model[4]

[4] A version of this study has been published in *British Journal of Special Education* as follows: Apanasionok, M.M., Alallawi, B., Grindle, C.F., Hastings, R.P., Watkins, R.C., Nicholls, G., Maguire, L. & Staunton, D. (2021). Teaching early numeracy to students with autism using a school staff delivery model. *British Journal of Special Education*. https://doi.org/10.1111/1467-8578.12346

Introduction

Mathematics is one of the core school subjects in the UK and internationally (DfE, 2014b; National Council of Teachers of Mathematics, 2000). It provides students with essential skills that are necessary for more independent living as they move to adulthood, such as money skills and recognising quantities (Department for Education, 2014a and 2014b). Number is one of the core strands in mathematics in the National Curriculum for England (Department for Education, 2014a). It includes skills such as number recognition and comprehension, and operations and computations.

In England, schools are required to teach number strand from the early years and throughout all school key stages (Department for Education, 2014a and 2017). Early number skills in the current study are referred to as ‘numeracy’, because this is the term more widely used in the research literature to represent basic number skills.

In England, Department for Education (2020a) data show that 15.5% of all students have SEN. Autism is the most prevalent (30%) among students in England who have an Education, Health and Care Plan (that is, pupils whose additional needs cannot be met by the school alone) (Department for Education, 2020a). The introduction of the Equality Act 2010 (Department for Education, 2014c) and the Special Education Needs and Disabilities Code of Practice (Department for Education, 2015b) required schools to provide equal access to high-quality education for all learners, including those with disabilities. Schools were mandated to make the necessary adjustments for disabled students and assess the progress of all learners in the core academic areas, including mathematics. Additionally, schools were required to make decisions about education for disabled students based on the best available evidence.

Despite this policy shift, the attainment of autistic students continues to be low and of concern to educators and researchers. According to data from 2019, only 33% of students aged five to seven years old with SEN in England achieved the expected level in mathematics, compared to 84% for learners without SEN (DfE, 2019a). Similarly, only

21% of students aged seven to 11 years old with SEN achieved the expected level in reading, writing and mathematics, compared to 74% of those without SEN (DfE, 2019a). These attainment data include all students with SEN. Attainment levels for autistic students, especially those who also have ID, are likely to be considerably lower.

Grindle et al. (2020) suggests five possible reasons why disabled students (including those with autism) might be underperforming in mathematics: 1. They may not be provided with enough opportunities to learn; 2. There may be a focus on teaching functional mathematical skills (for example, purchasing items in shops) at the expense of teaching broader, structured mathematics skills; 3. Teachers might not feel prepared or confident to teach mathematics to autistic students; 4. Teachers may find it difficult to teach mathematics due to behaviours that challenge or students' inattention during lessons; 5. Teachers may struggle during everyday practice to gather information and apply evidence-based teaching strategies. Further, Lee et al. (2016) suggest that teachers who work with students with a range of different needs require an individualised approach, but that they often do not have the time or necessary training to be able to adapt curricula to suit each student's needs. Subsequently, students' mathematics education is often limited to basic money skills and number recognition, despite a considerable amount of research evidence suggesting that autistic students can acquire some complex mathematical skills and knowledge (Browder & Spooner, 2011; Grindle et al., 2020; Spooner et al., 2019).

Spooner et al. (2019) conducted a review of evidence-based practices in teaching mathematics to students with moderate to severe developmental disabilities, which was an update of an earlier review carried out by Browder et al. (2008). Spooner et al. included 36 studies in their review. All were rated as high or adequate quality. Thirty-two percent of participants in the included studies had a diagnosis of autism. The most frequently used teaching strategy, identified as an evidence-based practice by both Browder et al. and

Spooner et al., was Systematic Instruction – an approach based on the principles of applied behaviour analysis and focused on teaching observable and measurable behaviours and promoting generalisation. Additional evidence-based practices identified by Spooner et al. included technology-aided instruction, graphic organisers (use of visual aids to help with mathematical process understanding and comprehension), manipulatives (use of different objects to support students' learning and comprehension) and explicit instruction (an active teaching method in which tasks are broken down into smaller steps and modelling with frequent feedback is used).

Teaching Early Numeracy to children with Developmental Disabilities (TEN-DD) programme overview

Despite the fact that mathematics is one of the most researched areas of teaching academic skills to disabled students (Spooner et al., 2017), there is a scarcity of evaluations of comprehensive teaching programmes in the research literature (Grindle et al., 2020). Maths Recovery (MR) is a numeracy intervention initially created for low attaining, neurotypical primary school students (Wright et al., 2012). The intervention was developed based on extensive research conducted by the authors on children's typical development of number knowledge. It is an intensive short-term intervention (usually used for up to 12 weeks with a few individualised sessions a week) created to reduce the attainment gap between students struggling with numeracy and their peers (Wright et al., 2012), and is used in mainstream and special schools as an effective catch-up teaching programme.

The systematic nature of the MR programme creates a useful basis for work with students with SEN. However, the intervention might not be accessible to some autistic students due to the complexity and length of the instructions and targets. Available evidence suggests that autistic students can benefit more from teacher-led/direct instruction as opposed to child-led/ inquiry teaching (Apanasionok et al., 2019 – Chapter 2; Grindle et al., 2020). Therefore, the MR programme has been adapted to meet the needs of students with moderate to severe disabilities (Teaching Early Numeracy to children with Developmental Disabilities (TEN-DD); Grindle et al., 2020). Adaptations include reducing the amount of verbal language used in the instructions; inclusion of the Systematic Instruction procedures such as prompting (help provided by the instructor that increases the likelihood that the student will engage in the correct response) and prompt-fading (a systematic process of decreasing the amount of assistance provided by the instructor and increasing the student's independence); task analysis (breaking down complex tasks into smaller, more achievable steps); targeted generalisation of acquired skills; inclusion of visual prompting strategies; a focus on students' motivation; and clearly defined learning goals and targets (Grindle et al., 2020). Adaptations were based on extensive research recommendations on teaching children with moderate to severe disabilities, including incorporating Systematic Instruction procedures which were identified as evidence-based practices by Browder et al. (2008) and Spooner at al. (2019).

A single group pre–post evaluation of TEN-DD with six autistic children (Tzanakaki et al., 2014a) provided initial evidence of the feasibility of the TEN-DD programme. Tzanakaki et al. (2014b) later conducted a small randomised controlled trial in a special school in Wales that provided evidence of the potential efficacy of the programme. Tzanakaki et al. recruited 24 students with severe ID and/or autism and randomised them into two groups, one accessing TEN-DD intervention and the other receiving mathematics teaching as usual. The intervention lasted 12 weeks and was delivered by teaching staff trained in the Systematic Instruction procedures and by the researchers. Results indicated that TEN-DD was more effective in teaching numeracy to students than the school's standard numeracy curriculum.

Purpose of the current study

Previous evaluations of TEN-DD were conducted with teaching staff experienced in using the Systematic Instruction procedures or with researchers delivering the intervention. The purpose of the current study was to explore the feasibility of implementing the TEN-DD programme in a large special school in the UK using typical teaching staff to deliver the intervention through collaborative work with the teachers, teaching assistants (TAs) and the leadership team.

Our study aims were: 1. To set up a system to implement the TEN-DD programme in a large special school in the UK using a school staff delivery model; 2. To evaluate the initial numeracy outcomes for the students; 3. To gather educators' suggestions on improvements to the provided training and implementation of the TEN-DD programme.

Implementing the TEN-DD programme

As with the original MR programme, TEN-DD is divided into five progressive stages of numeracy development – the emergent, perceptual, figurative, counting on and facile stages. It covers numeracy skills that neurotypical children of four to 11 years old would be expected to be able to acquire. Each stage is further divided into key topics (for example, forward and backward number word sequences; counting by 10s and 100s; finger patterns) that include individual skills/teaching procedures. There is a total of 182 teaching units across the whole programme (Grindle et al., 2020; Wright et al., 2012).

Staff training and supervision

Staff training consisted of initial out-of-class training, followed by in-class training. Before the beginning of the school year, the first (MA), second (BA) and third (CG) authors organised a training session for all educators involved in the project, focusing on the theoretical basis of the TEN-DD programme, discrete-trial teaching (for a definition, see 'Teaching sessions' section), and teaching organisation. The training lasted for approximately 2.5 hours and was a combination of a PowerPoint presentation and practice in small groups. A second out-of-class training session was held after a month and covered data collection and the mentoring system offered as part of the study (conducted by MA and BA). The training lasted approximately 45 minutes and, again, was a combination of a PowerPoint presentation and practice in small groups.

The majority of training offered for the TEN-DD programme was delivered in classes as part of the mentoring system. For the first four months of the intervention, each educator had a weekly in-class session with one of the two researchers/trainers (MA or BA). Each session lasted approximately 45 minutes and consisted of the trainer observing the session, offering feedback, and modelling correct delivery of the teaching targets. As educators became more familiar with the programme, the trainers started to reduce their support to promote independence, and adopted more of an observer role, only offering feedback when absolutely necessary during the session.

To determine when educators were ready to move to a less frequent mentoring schedule, a set of criteria was developed:

1. The trainer is not reminding the educator what they should be doing more than once during the session;
2. The educator is completing three sessions a week with each of the students (minimum 15 minutes of work during one session for each student);
3. The targets are being moved on after the mastery criterion is met;
4. The educator is updating the targets on the target list and prepares new data sheets as needed; and
5. The educator indicates that they feel ready to receive less support when asked.

Once the educator met all the criteria, they were then offered an opportunity to move to bi-weekly mentoring sessions.

The bi-weekly visits lasted approximately 30 to 45 minutes and consisted of the trainer observing the session and recording all steps of the TEN-DD programme delivery via a paper record (see Appendix 12). At the end of the session, the trainer provided the educator with feedback on that session based on the completed record and discussed what went well and what could be improved. After the educator and the trainer agreed on an action plan, they both signed the paper record. The bi-weekly visits were carried out by one trainer (MA) to ensure consistency.

Teaching sessions

The duration of the sessions varied across the classes depending on the number of students in each group. However, the general recommendation was that all students in the group should have the opportunity to practice six current targets multiple times at least three times a week. The trainers checked teaching folders and datasheets during weekly and biweekly mentoring visits. If the frequency of the teaching sessions fell below the prescribed level during two consecutive mentoring visits, the issue was raised with the class teacher and an action plan was agreed.

Numeracy skills included in the TEN-DD programme were taught using discrete trial teaching (DTT) methodology. DTT is a teaching method consistent with the Systematic Instruction that focuses on breaking down skills into small, clearly defined steps that are taught to mastery. The teaching procedure involves frequent practice of the target skills, with the teaching staff utilising prompting and error-correction procedures as well as high volumes of reinforcement, to increase the likelihood that the student will engage in the correct response.

The teaching session started with an entry (warm-up) activity. Teaching staff were given a list of 11 sample activities to guide them (for example, a game involving students counting forwards or backwards while jumping; see Appendix 13) and were encouraged to come up with their own ideas before proceeding to deliver the TEN-DD programme.

Following consultation with the teaching staff, the TEN-DD teaching sessions were implemented using a delivery model frequently employed across the school. The students sat at a table in small groups of two or three with the educator who delivered instruction for a few minutes to one student at a time while the remaining students in the group accessed a reward for previously completed work or an independent activity. After a few trials (educator gauged how long to work with individual students), the student receiving the instruction was given a reward to engage with or an independent activity and the educator moved on to the next student. This process was repeated for 45 minutes or until teaching staff decided that all students in the group had received sufficient practice on all six of their current targets.

We have implemented a simple data collection model using cold probes which involves taking data only on the first try of the session for each current target. Teaching staff scored a trial as correct (by putting a tick on a datasheet; see Appendix 14) if the student was independently correct or as incorrect (by putting a cross on the datasheet) if the student made a mistake or required help. If the student was independently correct on their first ever try, the skill was considered mastered. If not, data were collected until the student reached the mastery criterion of three consecutive ticks (three independently correct responses across three consecutive sessions).

Teaching staff were also given response equivalent guidelines for students with limited verbal communication in their teaching packs (folders; see ‘Materials’ section and Appendix 15) that provided examples of adaptations that could be made to facilitate responses of students with limited verbal communication for all six key topics. Further adaptations were made by the teaching staff after consultations with the trainers.

Materials

All educators working on TEN-DD were given a folder with all the necessary information and a resource kit. Folders contained the TEN-DD group teaching framework (see Appendix 16), a suggested session structure (see Appendix 17[5]), the teaching plans (see Appendix 18), suggested response equivalents for students with limited verbal communication (see Appendix 15), a DTT flow chart (see Appendix 19), suggested entry (warm-up) activities (see Appendix 13), a DTT data sheet (to collect individual data for up to three students; see Figure 4-1), a skills tracker (list of all targets covered in the programme to record introduction and mastery dates; see Appendix 20), a copy of a bespoke mentoring checklist (a task analysis of all steps that the teaching staff should do during one TEN-DD session; see Appendix 12), and copies of two research papers conducted on the TEN DD programme (Tzanakaki et al., 2014a; Tzanakaki et al., 2014b). Each kit contained the resources necessary to implement the TEN-DD programme (numeral lines 1–10; numeral cards 1–20; 30 double-sided counters; red and green dot lines; domino cards 1–6; random array dot cards 1–4; and pair pattern dot cards) and some other items that could be used while targeting generalisation of acquired skills.

[5] Please note that the name of the programme was changed during this study from Teaching Early Numeracy to children with Intellectual Disabilities (TEN-ID) to Teaching Early Numeracy to children with Developmental Disabilities (TEN-DD). Some materials included in the Appendices may still contain the old name – TEN-ID.

TEN-DD Data Sheet
Stage: Emergent

Students' names:	Tom	Jane	Joe	Notes
Key topic 1 Verbal counting 1-20	A1.2 Backward Number Sequences e. Counts backward from 5 to 1 by himself	A1.1 Forward Number Sequences f. Counts from 1 to 5 by herself	A1.1 Forward Number Sequences f. Counts from 1 to 5 by himself	Jane - A1.1f correct on the first try - mastered 27/11/2019
Data (√ or ×):	x x √ √	√	x √ x √	
Key topic 2 Written numerals 1-10	A2.2 Numeral Sequences c. "Count forward and backward" number lines 1-10	A2.1 Forward Numeral Sequence c. Counts 1-3 by himself and points	A2.4 Receptive Number Ind. a. "Touch number 2"	Joe – hand over hand prompt used
Data (√ or ×):	x √ x √	x x x √	x x √ √	

Figure 4-1. Sample DTT data sheet.

Integration of TEN-DD within the school's systems

The goal of this study was to implement the TEN-DD programme within the existing organisational system of a special school. We made a number of changes to the initial proposed implementation of the TEN-DD programme as a result of continued collaboration with the school's teaching staff and the leadership team (the sixth, seventh and eighth authors). First, the teaching plans were amended and updated on the basis of teaching staff feedback. For example, the length of the document was reduced, all specialist terminology was removed, a colour-coded system was incorporated to simplify navigation across the whole document and teacher-spoken instructions were highlighted in yellow. A second consideration focused on how the training was delivered. In this study, the initial training before the start of the intervention was reduced in duration and was divided into two separate sessions to ease the one-off time commitment for teaching staff and to allow better fit into the school's annual training schedule. Another change was related to how the teaching sessions were delivered to the students. In previous evaluations of the TEN-DD programme (Tzanakaki et al., 2014a; Tzanakaki et al., 2014b), all teaching sessions were delivered with a one-to-one staff to student ratio. However, after initial consultation with the school's leadership team and the teachers, it became apparent that those staff-to-student ratios would not be possible in the school and that a different delivery system would have to be implemented to ensure feasibility. Therefore, in collaboration with the school's leadership team, we implemented a delivery model frequently employed throughout the school (see 'Teaching sessions' section). Classes were also given an opportunity to decide themselves the frequency and duration of the teaching sessions, as long as all participating students were given at least three opportunities during a week to practise all six current targets (not necessarily in one sitting). A number of smaller adaptations were also made to the teaching procedure based on individual students' needs. These included more frequent breaks, taking students outside the classroom, and using token boards.

Evaluation study

Ethical approval was obtained from the Humanities and Social Sciences Research Ethics Committee at the University of Warwick (see Appendix 21).

Participants

Seventeen students were recruited across five different classes to take part in this study. They were identified by school staff due to their difficulty in acquiring numeracy skills using the school's usual curriculum and teaching methods. All students had been identified as having autism, according to their school records. Four were female and 13 were male. The age range varied from 8 years 11 months to 15 years 4 months, and the ethnic background of the students included Pakistani, Black other, White British, Black African, Bangladeshi and Somali. Sixteen students were enlisted at the end of 2016/2017 school year (before the start of the intervention) and one additional student was recruited during the 2017/2018 school year (during the study). The inclusion criteria for the study were that the student had: the prerequisite skills to access at least the first stage of the TEN-DD programme; the prerequisite skills to access the assessment outcome measure (see 'Outcome measures' section); the ability to work for 10–15 minutes in one sitting; no significant behaviours that challenge that would interfere with learning; and no visual or auditory impairments that could not be corrected by glasses or hearing aids.

Twelve teaching staff (five class teachers and seven TAs) across five classes were trained to deliver the intervention to the recruited students. All 12 educators trained in the TEN-DD programme were approached by the first and second author at the end of the study period and invited to participate in an interview, to outline their opinions and experiences of implementing TEN-DD. They were given an information sheet describing the purpose of the interview, and a consent form (see Appendix 21). Ten teaching staff (six females, four males; five teachers, five TAs) agreed to take part in an interview.

Setting

The study took place in a special school in the UK, catering for around 380 children aged two to 19 years with severe ID. Students attending the school have diagnoses of ID, autism, or PMID, among others. For the purpose of the current study, researchers focused on students from the Autism Department, which provides education for around 80 students.

All teaching sessions were conducted in the students' usual classrooms during time slots allocated to the teaching of mathematics in the school's timetable. Other students from the class were usually present in the classroom during the sessions.

Outcome measures

Students' numeracy skills were assessed using the Test of Early Mathematics Ability – Third Edition (TEMA-3; Ginsburg & Baroody, 2003). This is a standardised assessment designed for students aged three to nine years that measures early numeracy skills and knowledge. The TEMA-3 is not a time limited assessment and testing can last from 10 to 60 minutes depending on the student's skills. TEMA-3 assessments were conducted at two points: once at the end of the 2016/2017 school year (pre-test) and then at the end of the 2017/2018 school year (post-test). All assessments were conducted by the first and second author with the support of class teachers and TAs. Version A of the TEMA-3 was used at pre-test and version B at post-test. Every few minutes during the assessment, reinforcement was delivered contingent on attending only and not for correct responding. Reinforcement was individually determined and was either in the form of verbal praise (for example, 'You're sitting so nicely') or through providing a small edible treat or preferred tangible item to play with.

To help evaluate teaching staff experiences of the two training sessions, we created two bespoke surveys (see Appendices 22 and 23). Both were anonymous and contained a five-point Likert- style rating scale from 'strongly disagree' to 'strongly agree'. The first survey was created for the introductory training session (22 statements), and the second for the data collection training (17 statements). Both surveys included statements that covered key aspects such as the overall training experience, teaching materials, trainers, and learner outcomes.

To gather information about teaching staff perspectives on improving the TEN-DD programme and how it was implemented, interviews were conducted with 10 teaching staff (see Appendix 24). All were completed in a one-to-one setting by the second author. Interviews lasted between 25 and 40 minutes. Recordings from the interviews were fully transcribed verbatim by the second author and later checked by the first author. In the present article, data on the suggestions for programme improvement are included. Qualitative analysis of educators' experiences with TEN-DD is reported in a separate paper (Alallawi et al., in press – Appendix 3).

Design and approach to data analysis

This study employed a pre-test post-test design. A paired-samples t-test was used to analyse TEMA-3 scores. Effect size was calculated using an equation for Cohen's d adapted for repeated measures (Dunlap et al., 1996). Content analysis was used to code data from the interviews in relation to the suggested intervention improvements. This is a flexible research method used to examine various types of text data to gain understanding of a phenomenon (Hsieh & Shannon, 2005).

Results

Students obtained significantly higher TEMA-3 raw scores at post-test (Mdn = 9.06; SD = 7.02) than at baseline (Mdn = 4.24; SD = 5.24), $t(16) = 5.99$, $p < 0.001$, $r = 0.83$, $d = 0.85$, which represents a large effect size (Cohen, 1988). All students improved their raw scores from baseline to post-test, with pre–post change scores ranging from 1 to 13 points (Mdn = 4.82). Thirteen students improved their age equivalent scores and four students' scores remained the same. See Table 4-1 for individual students' outcomes.

Table 4-1. *Summary of students' TEMA-3 scores at pre- and post-test.*

Student number	**Baseline score**		**Post-test score**		**Change in raw score**
	Raw score	**Age equivalent**	**Raw score**	**Age equivalent**	
1	0	<3	2	<3	2
2	0	<3	1	<3	1
3	12	4-3	21	5	9
4	3	3	7	3-9	4
5	0	<3	3	3	3
6	3	3	8	4	5
7	16	4-6	23	5-3	7
8	5	3-6	7	3-9	2
9	0	<3	2	<3	2
10	3	3	8	4	5
11	1	<3	9	4	8
12	3	3	16	4-9	13
13	2	<3	4	3-3	2
14	14	4-3	18	5	4
15	9	4	15	4-6	6
16	0	>3	8	4	8
17	1	<3	2	<3	1
Mean	4.24		9.06		4.82
SD	5.24		7.02		3.32

Teaching staff had a generally positive training experience (see Table 4-2)

Table 4-2. *Summary of survey scores after the introductory training session (rating scale from 1 "strongly disagree" to 5 "strongly agree").*

Category	Statement	Mean
Overall	The training session was well organised.	4.10
	The content of the training session was covered in the time available.	4.00
	Trainers provided all that I needed to complete training tasks.	4.00
Materials	The presentation slides were relevant, clear, and useful.	4.18
	The handouts were relevant, clear, and useful.	4.36
	The example plans were relevant, clear, and useful.	4.18
	The videos were relevant, clear, and helpful.	4.36
Trainers	Trainers presented TEN-ID programme in clear and concise way.	4.00
	Trainers demonstrated practical skills and knowledge.	4.18
	Trainers' feedback was clear and concise.	4.09
Outcomes	I learned a good deal from the presentation.	4.09
	I learned a good deal from the practical activities and role play.	4.00
	I understand this year plan for implementation of the TEN-ID programme.	4.09
	I understand the rationale of using 'TEN-ID' programme.	4.18
	I understand what 'TEN-ID' aims to do.	4.27
	I understand how to use 'TEN-ID' programme to teach numeracy to a small group of pupils.	4.27
	I understand how to read the teaching plans.	4.09
	I will be able to follow the lesson plans available to adapt my teaching to the needs of the individual child.	4.18
	I understand what Discrete Trial Teaching (DTT) is.	4.45
	I will be able to follow trial structure of Discrete Trial Teaching (DTT).	4.36
	I understand what TEN-ID generalisation sessions aims to do.	4.20
	Training in a small group outside the classroom is very useful for learning how to use 'TEN-ID' programme.	4.18
	Mean	**4.17**

Ratings of the data collection training session were also positive (Table 4-3).

Table 4-3. *Summary of survey scores after the training session on data collection.*

Category	Statement	Mean
Overall	The training session was well organised.	4.57
	The content of the training session was covered in the time available.	4.71
	Trainers provided all that I needed to complete training tasks.	4.64
Materials	The presentation slides were relevant, clear, and useful.	4.77
	The handouts were relevant, clear, and useful.	4.79
	The example TEN-ID Weekly data sheet was clear and useful.	4.79
Trainers	Trainers presented data collection procedure in clear and concise way.	4.71
	Trainers demonstrated practical skills and knowledge.	4.71
	Trainers' feedback was clear and concise.	4.71
Outcomes	I learned a good deal from the presentation.	4.77
	I learned a good deal from the practical activities and role play.	4.50
	I understand the rationale of data collection procedure.	4.71
	I understand how to monitor students' progress.	4.62

I understand how to prepare weekly data sheets.	4.57
I understand what the mastery criteria is.	4.77
I will be able to make the decisions about student's targets.	4.64
I understand the process of mentoring visits.	4.71
Overall mean	**4.69**

Changes to the TEN-DD programme suggested by the teaching staff were grouped into three categories following content analysis: training, implementation, and materials. A summary of all suggested changes and improvements is included in Table 4-4.

Table 4-4. *Summary of changes to the TEN-DD curriculum suggested by the staff members.*

Category	Suggested change	Example comment	Number of staff
1. Training	Break down the initial training session into a few separate sessions	"[Mm] possibly make - probably make that first session more practical and then maybe have another session, maybe later in the year or a few weeks down the line when you've had a chance to get to grips with it".	5
	Follow up session after all staff members familiarize themselves with the programme	"Maybe I would have liked some follow up training - so maybe midway through our time delivering TEN-DD. Maybe we could have some follow up training going on bit more in depth and sort of us asking maybe questions".	3
	Less theory behind the TEN-DD programme during the initial training session	"[Mm] I suppose the theory behind [Pause] the theory behind what we are doing was not necessarily useful. I could've still deliver the TEN-DD as well without having the theory that's said I found it interesting".	4
	Only one trainer present in the classroom during the mentoring visits	"Like I said I think to having two people there is too many - I feel it's a bit redundant for both of you, because I think that was a bit waste of space and waste of time for both of you. Having one of you there it would be sufficient. [Mm]".	2
	Move quicker from weekly to bi-weekly mentoring visits	"I think to start with they have to be more frequent, but we could've maybe [pause] the frequency could have dropped sooner because I think we all got into it quite quickly and we all excited to do the TEN-DD and we did it".	3
	More out of class training for the TAs during the school year	"One of my TAs certainly finds - she asked a lot of questions in class - so having her more time with you guys without the kids there would give her more confidence [Mm] so that's something I would change".	1
2. Implementation	Simplify the wording of instructions for the pupils	"Knowing exactly what was expected of you and the wording and obviously with our students words kind of don't mean a lot to them - so it's obviously training them like when we are saying - count forwards and backwards - and I pretty sure they just got to the habit of going - 1,2, 3... 3,2,1. They don't understand the wording of forwards and backwards because they don't understand up and down, never mind forwards and backwards. But that comes with time and obviously doing it a lot - so a lot of the wording is meaningless".	3
	Simplify the wording of the teaching procedure for the staff members	"It's not all the target, it's just some of the targets, understanding exactly what is required... [Mm] maybe some of the interpretation [Mm] [pause] so that's little bit more understandable - understandable [yeah]".	3

	Make targets more realistic/ as they would be done by the general population	"[Mm] maybe some of the targets are unrealistic to special needs kids because I think as a person with no special needs [Mm] I would find that difficult and hard, especially with the finger one - doing things on your left hand or doing things on your non-preferred hand. It's like, realistically [pause] I wouldn't be doing it on my non-preferred hand".	1
	Reduce the amount of paperwork/ recoding that staff members are required to complete	"Again, paperwork isn't – well not all TAs but a lot of TAs don't like paperwork I would say – [Mm] so they find, sometimes struggle with the amount of recording and stuff that they do but that something is happening around the school more often, so it's something they might have to get more use to".	2
	Include prerequisite targets for students that do not have all the necessary skills to access TEN-DD yet	"Could you simplify certain tasks - make them - could you make them easier? No. The tasks - TEN-DD. Because I found from the start it's - TEN-DD is suitable for the child who is already at some kind of academic level - if that make sense? Whereas if you've got children who - there are children in my class that I know would benefit from TEN-DD but because they are not quite at that level to where TEN-DD starts, I think they're missing out.	2
3. Materials	Make the folder more concise and accessible	"[Mm] The folder again is a big folder with a lot of reading which – and [Mm] teachers and TAs don't always have time to read the instructions before - which can lead to them teaching it in a way is not requested if yourself or MA or whoever is supporting aren't there. So like I said, making that a bit more concise would probably help because a teacher can't read or a TA can't read an A4 page of instructions while a child is sitting there so..."	3
	Make different resources for different skills	"If you move from one target to another target within the same section and you're using the same resources, they struggle to differentiate one target from the other - so you might present within new target, but the same resources and they get confused and they try to do the old target. So, it's trying to find a way to differentiate the resources between targets".	1
	Add more structured adjustments for students with limited verbal communication	"I think [pause] from a conversation with [assistant headteacher's name], obviously for non-verbal children this approach doesn't - well for me it would be hard to teach these targets. There're ways of doing it, I know you can change it, but I don't think they necessarily are gaining the same skills as the verbal ones. So, say if you were doing the numeral line 1,2,3 - 3,2,1 somebody who is non-verbal who probably just be pointing, so it's not the same skill. All of mine	3

would point, but then being able to say it it’s much harder, so it’s different skills for the non-verbal students. So, it’s almost like they need a kind of different set of progress, different set of targets”.

Discussion

The primary aim of this study was to set up a system to implement the TEN-DD programme in a large special school in the UK using a school staff delivery model. We worked alongside teaching staff and the school's leadership team to incorporate the intervention into an existing school structure, while maintaining the intensive and individualised character of the programme. TEN-DD was successfully used by teaching staff with no prior experience of the Systematic Instruction or DTT, and in a setting where high staff-to-student ratios are not typical, which is representative of most special schools in the UK.

Implementation considerations

Our primary goal was to ensure optimal fit into an existing school system, so a number of adaptations to the delivery model and teaching materials were made during the study. These included changing the structure and wording of the teaching plans, shortening the initial training, and focusing more on in-class mentoring, as well as adapting the teaching methodology to suit the staff-to-student ratios available in the school. Classes changed the duration and frequency of the teaching sessions to suit students' needs, while still adhering to the recommended weekly amount of practice across all current targets.

This was the first study focusing on teaching staff delivering the TEN-DD programme, but researchers were still involved in implementation. A considerable amount of supervision and mentoring time was still provided that might not be feasible in 'typical' school conditions. Although we shortened training sessions and introduced in-class mentoring, this required the involvement of experts in the intervention. This was mainly due to educators' lack of prior experience with the intervention. However, after the first year of implementation, teaching staff would have been more expert in the intervention and may have been able to establish peer mentoring processes.

During interviews, staff reported that implementing the TEN-DD programme with students with limited verbal communication was challenging at times. We provided a document outlining possible ways of adapting teaching plans to meet the needs of students with limited verbal communication (see Appendix 15), and the trainers helped educators with more individualised changes during the mentoring visits. However, more systematic adaptations/guidelines need to be incorporated into the TEN-DD programme to allow staff members to be more independent and to maximise students' gains from the intervention.

Educators also highlighted the need for an early numeracy programme to be developed that includes prerequisite/learning to learn skills that are necessary to start acquiring numeracy competencies. As part of the mentoring visits, we helped teaching staff implement a range of different short-term supplementary interventions targeting skills such as verbal or physical imitation to help students who struggled with accessing specific parts of the TEN-DD programme. However, a more formal prerequisite programme may be needed to improve the accessibility of the programme across the autistic population in special schools.

Drawing from the experience of implementing TEN-DD in a large special school and educators' feedback, we have identified three key recommendations to allow a better fit into a 'typical' special school setting. First, it appears that our training model – with initial introductory sessions and in-class training and mentoring – was successful and allowed a good fit into the school's annual training schedule. However, based on educators' feedback, the initial sessions should be shorter and focused only on the practical aspects of the programme, omitting the theoretical basis. Educators could also benefit from a short follow-up training session after a few weeks of implementing TEN-DD. Second, more work should go into incorporating the mentoring system into the special school. This could perhaps be achieved by providing more extensive training to one school staff member who would then become a TEN-DD lead/mentor offering bi-weekly and monthly overlap sessions or troubleshooting meetings across the school. Our last recommendation is that further work should be done on the teaching plans (introducing systematic adaptations for students with limited verbal communication, expanding the help section, and further simplifying the wording of the instructions) to increase teaching staff independence in implementing TEN-DD and, as a result, to reduce the need for out-of-class support.

Outcomes evaluation

Data obtained from the TEMA-3 assessment suggested that TEN-DD may help learners improve their early numeracy skills. All participants improved their TEMA-3 raw scores at post-test compared to pre-test (with a large effect size pre–post group difference), and 14 students' age equivalent scores also improved after accessing the TEN-DD programme for one school year.

Feedback obtained from the staff surveys showed that teaching staff were generally satisfied with the training provided.

Future research

To examine the putative effectiveness of TEN-DD in special schools, future research should focus on minimising the involvement and support provided by the research team to better mimic implementation in special school settings. A randomised controlled trial design is also needed, probably using a cluster randomised design (that is, with schools randomised to use TEN-DD or numeracy teaching as usual).

Chapter 5

Teaching Early Numeracy to children with Developmental Disabilities – Readiness: programme development and overview

Introduction

Number is one of the core strands of mathematics (Department for Education, 2014a and 2014b) and it can be especially difficult to learn for students with DD, often requiring a systematic approach (Grindle et al., 2020). TEN-DD is a numeracy programme for students with DD adapted from the widely used Mathematics Recovery programme (Wright et al., 2012). It covers skills that neurotypical students of four to 11 years old would be expected to be able to acquire. The TEN-DD programme is based on extensive research on number knowledge development (Wright et al., 2012), as well as teaching students with DD (Grindle et al., 2020) and utilises Systematic Instruction procedures (for definition see below) found to be evidence-based practice by Spooner et al. (2019). Existing research evaluations found TEN-DD to be feasible to implement by professionals trained in Systematic Instruction (Tzanakaki et al., 2014a; Tzanakaki et al., 2014b), as well as teachers with no previous experience of using this teaching methodology (Apanasionok et al., 2021 - Chapter 4) and provided initial evidence of the programme's efficacy to teach numeracy to students with DD. However, as pointed out by teachers in Apanasionok et al. (2021 - Chapter 4) study, there are students who could benefit from the TEN-DD programme and its teaching methodology but who do not have the necessary prerequisite skills to access it (i.e., are not yet able to attend to task for longer than a few seconds or imitate actions of the teacher).

Development

This has highlighted the scarcity of teaching programmes and research literature on teaching pre-school level numeracy skills to students with DD. After consultations with the educators from the Apanasionok et al. (2021 - Chapter 4) study, we decided to develop a programme that could directly precede TEN-DD. While developing the Teaching Early Numeracy to children with Developmental Disabilities – Readiness (TEN-DD R), the Six

Steps in Quality Intervention Development (6SQuID) - an intervention development model initially created for public health interventions, now used in range of different sectors – was followed. According to Wight, Wimbush, Jepson and Doi (2016), six steps should be taken while developing a new intervention:

1. Define and understand the problem and its causes;
2. Clarify which casual or contextual factors are malleable and have greatest scope for change;
3. Identify how to bring about change: the change mechanism;
4. Identify how to deliver the change mechanism;
5. Test and refine on small scale;
6. Collect sufficient evidence of effectiveness to justify rigorous evaluation/implementation.

1. Define and understand the problem and its causes. The initial idea to develop TEN-DD R emerged when one of the schools using TEN-DD highlighted the need for a preparatory intervention (Apanasionok et al., 2021 - Chapter 4). Some of their students struggled to access TEN-DD or learn some of the target skills due to the lack of more fundamental skills. Prerequisite (also known as readiness) skills include a broad area of learning to learn skills (attending to task, physical and verbal imitation, matching, etc.), as well as more numeracy focused skills. Those skills can contribute to a more successful acquisition of numeracy skills for students with DD and as a result higher levels of attainment. Grindle et al. (2020) suggest that without readiness skills students may struggle to acquire more complex numeracy skills and it may be difficult for educators to help them when they are struggling. For example, if the student finds it difficult to pay attention during teaching or is not able to imitate the actions of others, they may not be able to follow an educator's model of a correct response.

Neurotypical children usually have basic number skills when they start school in their reception year. These are learned through observation, games, number songs and books. In fact, infants as young as 14 months start to develop a basic understanding of quantities (Wang & Feigenson, 2019). For this reason, learning to learn skills and early number skills are not usually given much attention in official programmes of study (Staves, 2019). However, students with DD might struggle with acquiring skills solely through observation and play and often require more systematic intervention targeting readiness skills (Staves, 2019; Grindle et al., 2020). Les Staves (2019) published some advice on teaching mathematics to students with severe DD, such as targeting early and learning to learn skills, utilising different processes of learning (i.e., observation, imitation, play) and developing thinking processes relevant for mathematics. However, to our knowledge there are no teaching programmes that systematically target numeracy readiness skills that are accessible to students with DD. This lack of consideration for different learning needs of students with DD results in many students lacking prerequisite skills to effectively acquire more complex content and as a result lower attainment. Therefore, after consultations with the educators and reviewing available literature, the lack of systematic numeracy readiness teaching to students with DD was identified as the primary issue.

2. Clarify which casual or contextual factors are malleable and have greatest scope for change. Two factors that contribute to this issue and have the scope to bring about a change were identified. First, the educational system in England is not always fully inclusive of different learning needs, especially when it comes to very early mathematic skills. Educators are given little guidance on how to teach readiness skills and too much emphasis is still placed on observational and indirect learning, rather than the systematic teaching of these skills. This results in students with DD struggling to access official programmes of study when they start school (Staves, 2019). Therefore, what is needed, is a wider change to the pre-school education system to address this issue from a young age for students with DD. Secondly, to our knowledge, there are no numeracy readiness catch up interventions (for those who did not acquire those skills in pre-school) that are accessible to students with DD.

While a systematic change is needed to address the root of this issue, we recognise that this will likely to be a gradual process. Therefore, what will have the biggest impact on the numeracy education of students with DD in the current circumstances, is the development of the catch up/ supplementary numeracy readiness intervention.

3. Identify how to bring about change: the change mechanism. Considering the research on teaching academic skills to students with DD and our experience of implementing the TEN-DD programme, it was clear that the effective 'active ingredient' for the new intervention should be Systematic Instruction. This is a teaching approach derived from ABA that focuses on observable and measurable behaviours and on breaking down complex skills into small, achievable steps. Systematic Instruction has been identified as an evidence-based practice to teach a range of academic skills, including mathematics and numeracy, to students with DD (Spooner et al., 2019; see Chapter 1 and 2 for more details). Systematic Instruction has already been successfully used to teach numeracy to students with DD as part of the TEN-DD programme (Tzanakaki et al., 2014a and 2014b; Apanasionok et al., 2021 - Chapter 4) and received positive feedback from educators (Alallawi et al., in press – Appendix 3), so it was clear that the new readiness programme should follow a similar structure and teaching methodology.

4. Identify how to deliver the change mechanism. We have built on the advice of Les Staves (2019), our work on the TEN-DD programme, consultations with educators from a special school in the UK and experts in the field of ABA/ Systematic Instruction to develop the TEN-DD R. The goal was to create a programme that could be used in conjunction with the TEN-DD and one which would cover: (a) pivotal prerequisite skills such as imitation and matching, and (b) very early numeracy skills that directly preceded those included in the first stage (emergent) of the TEN-DD (hereafter, referred to as pre-emergent numeracy targets). The TEN-DD R programme covers skills that neurotypical children usually learn between the ages of two and four years, primarily through observation, exploration, and play. The TEN-DD programme was used as the foundation for the new programme as it was important to keep the structure and the teaching methodology as similar as possible. This way educators already trained in using the TEN-DD programme could, with little guidance, start using the TEN-DD R right away.

Numerous sources, including teaching models, assessment tools and curriculum guides, were used to develop ideas for TEN DD R (both for the pivotal prerequisite skills and the pre-emergent early numeracy targets). The full list of sources is provided below:

1. Assessment of Basic Language and Learning Skills - Revised (ABLLS-R; Partington, 2006) – an assessment of learning and language skills for children with DD;
2. Early years foundation stage statutory framework (EYFS; Department for Education, 2017) – government’s learning and development standards for children up to the age of five in England;
3. Beery-Buktenica Developmental Test of Visual-Motor Integration (6th edition; VMI; Beery et al., 2010) – a visual-motor skills assessment for children and adults.
4. Brigance Early Childhood screens III (Brigance & French, 2013)– early development and school readiness assessment;

5. The Verbal Behavior Milestones Assessment and Placement Program (2nd edition; VB-MAPP; Sundberg, 2014) – verbal behaviour assessment for autistic children;
6. Early Start Denver Model (Rogers & Dawson, 2010) – therapy model for autistic children derived from behaviour analysis;
7. Very Special Maths (Staves, 2019) – guide to teaching mathematics to students with SEN (including DD) in the UK.

For the pre-emergent numeracy targets, key numeracy skills included in the Emergent stage of TEN-DD were also selected and used to create a task analysis (process of breaking down skills into small, achievable steps) to form a list of numeracy skills directly building up to TEN-DD.

In addition, the already existing numeracy curriculum of the school that had requested the readiness programme was consulted for further ideas. Although we did not feel that any elements of their curriculum could be included in TEN-DD R (due to the lack of operationally defined goals and targets), we did continue to work closely with the educators and the leadership team of the school to ensure that the developed programme was both relevant and accessible to their students, as well as being feasible to implement for their educators.

The assumption when creating the TEN-DD R programme, confirmed by the educators, was that the majority of the students accessing it would have limited verbal communication. For targets that required a verbal response, alternations that educators could easily implement to make the programme accessible to their students were included (e.g., using numeral cards or Makaton).

The remainder of this chapter describes the TEN-DD R programme and its proposed implementation in detail. Chapter 6 describes the plans for the last two steps of the 6SQuID model – 5. Test and refine on small scale; and 6. Collect sufficient evidence of effectiveness to justify rigorous evaluation/implementation.

The TEN-DD R structure

The TEN-DD R programme consists of two progressive stages. The first stage focuses on pivotal prerequisite (also known as readiness and learning to learn) skills such as attending, motor and verbal imitation and matching. The second stage focuses on early numeracy skills that are direct prerequisites to targets included in the TEN-DD programme. This includes skills like counting and imitating actions of number songs, one-to-one correspondence, matching numerals one to five, counting forward and backward on numeral lines and so on. The student needs to have all pivotal prerequisite skills before moving on to the numeracy focused part of the programme.

Each stage consists of number of skills that form key topics arranged vertically (i.e., with progressive stages of difficulty) and in a developmental order (see Tables 5-1 and 5-2). This is consistent with the format used for the TEN-DD. The pivotal prerequisite skills stage of the TEN-DD R consists of 23 teaching activities that are arranged in four key topics. These cover a range of learning to learn and readiness skills (see Table 5-1 for details).

Table 5-1. *Teaching activities included in the pivotal prerequisite skills stage.*

Key topic	**Targets/ teaching activities**
Prerequisite and learning to learn skills	1. Engaging with a preferred task for up to 5 minutes. 2. Looking at a single object held at the eye level for 3 seconds. 3. Allowing an object to be placed in hand and holding it for up to 5 seconds.

	4. Allowing up to 10 objects to be counted into hand. 5. Tracking an object as it is moved by an adult for 5 seconds. 6. Reaching for an object and picking it up. 7. Pointing to a specified item when asked. 8. Looking at a number book for 1 minute. 9. Taking turns when playing a familiar game.
Motor imitation	1. Imitate head movements (e.g., shaking, nodding). 2. Imitating actions with objects (e.g., banging a drum, pushing a toy car). 3. Imitating large body movements (e.g., clapping hands, stomping feet). 4. Imitating small body movements (e.g., pointing, tracing a line with a finger).
Verbal imitation	1. Imitating simple sounds (e.g., ‘aaah’, ‘m’). 2. Imitating up to 2 simple sounds in succession (e.g., ‘ma-ma’, ‘da-da’). 3. Imitating initial sound of any word (e.g., ‘bat’, ‘shoe’). 4. Imitating simple words (e.g., ‘pop’, ‘blue’). 5. Imitating number words 1-5.
Matching	1. Matching identical everyday objects in an array of up to 8. 2. Matching identical picture cards in an array of up to 8. 3. Matching picture card to a corresponding 3D object and

	3D object to a corresponding picture card in an array of up to 8. 4. Matching identical colour cards in an array of up to 3. 5. Matching identical shape cards in an array of 4.

The numeracy skills stage consists 35 teaching activities arranged in eight key topics. These cover a range of very early numeracy skills (see Table 5-2 for details).

Table 5-2. *Teaching activities included in the numeracy stage.*

Key topic	**Targets/ teaching activities**
Number songs	1. Imitating actions and touching objects during number songs. 2. Singing number sequences in number songs 1-5 with the teacher.
Beginning skills	1. Taking one object in a familiar situation (e.g., one biscuit out of the container/plate). 2. Demonstrating one-to-one correspondence with objects 1-5 (e.g., putting one peg in the pegboard). 3. Demonstrating one-to-one correspondence in everyday situations with up to 5 objects (e.g., giving cake to teddies).
Counting written numerals	1. Matching identical numeral cards 1-5. 2. Matching non-identical numeral cards 1-5. 3. Identifying numbers 1 to 5 immediately after matching

	numeral cards. 4. Sorting identical numeral cards 1-5.
Counting visible items	1. Matching corresponding numeral cards with numbers on a numeral line 1-5. 2. Pointing to numeral on the numeral line 1-5. 3. Counting 1-5 simultaneously with the teacher. 4. Counting 1-5 while pointing to the corresponding numerals on the numeral line simultaneously with the teacher. 5. Identifying last numeral counted on the numeral line (up to 5) 6. Placing counters on a numeral line 1-5 and counting. 7. Pointing to blocks and counting simultaneously with the teacher. 8. Pulling beads one by one as the teacher counts up to 5.
Spatial patterns (patterns on cards)	1. Matching identical dot configuration cards 1-5. 2. Matching non-identical dot configuration cards 1-5. 3. Matching up to 5 3D objects to corresponding objects on the picture card. 4. Counting objects on picture cards and matching to identical objects (up to 5).
Quantity matching	1. Producing sets of up to 5 counters to match a numeral card. 2. Counting out up to 5 objects and matching to

	corresponding numeral card. 3. Matching quantity cards in various configurations. 4. Matching identical dice configuration cards 1-6. 5. Matching non-identical dice configuration cards 1-6. 6. Matching dot cards up to 5 with numeral cards.
Patterns	1. Imitating set number of rhythmical movements, such as clapping hands. 2. Imitating pattern making 1-5 (e.g., making fist or stamping feet). 3. Building block tower up to 5 and counting. 4. Matching and sorting identical finger pattern cards 1-5. 5. Using fingers to count during number songs. 6. Using fingers to count down during number songs.
Beginning counting skills	1. Adding up to 5 counters to a box. 2. Removing up to 5 counters from a box.

The majority of targets are divided into steps. The more complex the target skill the more steps it consists of. For example, the target ‘Identifying numbers 1 to 5 immediately after matching numeral cards’ from the numeracy stage of TEN-DD R (key topic - counting written numerals) includes the following steps:

1. Matching numeral card 3 out of numeral cards 1-3;
2. Matching numeral card 1 out of numeral cards 1-5;
3. Matching numeral card 2 out of numeral cards 1-5;
4. Matching numeral card 3 out of numeral cards 1-5;
5. Matching numeral card 4 out of numeral cards 1-5;

6. Matching numeral card 5 out of numeral cards 1-5;
7. Finding numeral card 3 out of numeral cards 1-3 immediately after matching numeral cards 3;
8. Finding numeral card 1 out of numeral cards 1-3 immediately after matching numeral cards 3;
9. Finding numeral card 2 out of numeral cards 1-5 immediately after matching numeral cards 3;
10. Finding numeral card 3 out of numeral cards 1-5 immediately after matching numeral cards 3.
11. Finding numeral card 4 out of numeral cards 1-5 immediately after matching numeral cards 3; and
12. Finding numeral card 5 out of numeral cards 1-5 immediately after matching numeral cards 3.

Only when the student reaches mastery criterion for one step, the educator introduces the next step on the list until the whole target is learnt. Skills are always taught in the developmental order (following the order of the programme). Each target is accompanied by a teaching plan (see “Materials” section and Appendix 25 for more details) and assigned teaching resources.

Teaching methodology

Discrete Trial Teaching overview

Discrete Trial Teaching (DTT) is a method that incorporates breaking down complex skills into small, achievable steps. Each step is taught until the student becomes confident with it and reaches the prescribed mastery criterion. Teaching is delivered in short, discrete trials (DT; with a clear start and end) that are conducted at a quick pace. The three main components of the DT are: antecedent, behaviour and consequence (see Figure 5-1).

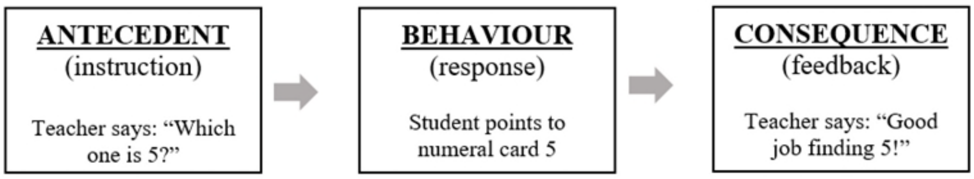


Figure 5-1. Diagram illustrating three main components of DTT.

Each DT starts with an antecedent – an instruction or other teaching cue – such as "Which one is five?" The instruction is short and delivered after establishing the student's attention. The same instruction/phrasing is used until the student masters the skill. The student's response is the behaviour component of the DT – for example, the student pointing to the numeral card five. The target response is operationally defined so that the educator is always clear about what constitutes a correct response. Students are expected to respond within three to five seconds after the instruction; however, this can be longer if the student is known to require more time to process information. The last component of the DT is the consequence or feedback in the form of either positive reinforcement – such as praise "Good job finding five!"; or correction (followed by an error-correction procedure described below) – such as "That's not right, let us try again." The consequence is delivered immediately after the student's response and is unambiguously positive (praise for the correct response) or negative (correction for the incorrect response). Reinforcement is described in more detail below.

Reinforcement and motivation

If students are to receive a positive learning experience and acquire new skills quickly, it is crucial that they are well motivated. In order to maintain student's motivation, educators use positive reinforcement – a consequence that increases the likelihood that the student will engage in the target behaviour (e.g., providing a correct response to a question) in the future. What students find reinforcing is highly subjective, so the form of reinforcement is always individualised based on student's preferences. This is achieved by conducting a preference assessment to identify a list of potential reinforces to use during teaching (Grindle et al., 2020).

The level (strength) of reinforcement also varies depending on the target behaviour, this is known as differential reinforcement. For new or more difficult targets, greater level of reinforcement is used – for example, a very enthusiastic praise comment "Fantastic, you are a star!" presented alongside a preferred tangible object or an edible item. For established skills, reinforcement of lesser level is used – for example, a positive praise comment such as "Well done" that is not delivered in such an exuberant manner.

Prompting and prompt fading

Each DT consists of the three core components descried above – antecedent, behaviour and consequence (see Figure 5-1). However, sometimes an additional component might be needed – the prompt. A prompt or hint/ cue is delivered after an instruction, in the situation where the student needs some help to come up with the correct response. There are different types of prompts depending on the form of the target skill/behaviour - these are:

1. physical - physically guiding the student to engage in the correct response, for example by guiding their hand towards a correct numeral card;

2. modelling - demonstrating the correct response to the student, for example by picking up the correct numeral card;
3. gestural – making a gesture that can indicate the correct response to the student, for example by pointing to the correct numeral card;
4. verbal – demonstrating partially or fully the correct verbal response to the student, for example by saying “th…” when the target response is “three”; and
5. visual – showing the student a visual cue (like picture, text, or video) that can indicate a correct response to the student, for example when the student is asked to say how many ducks are in the picture the educator can flash numeral card four to indicate the correct response.

Educators always use the least amount of help necessary for the student to engage in the correct response. Prompts are used only when necessary and faded (reduced) as soon as the student starts responding independently. This can be achieved by gradually reducing the amount of help provided. For example, if the target response is for the student to say “three”, the educator initially prompts the student by modelling saying “three”, but after a few successful trials this is reduced to “thr...”, then “th…”, then “t…”, until finally the student responds independently. Students are always given a chance to respond independently first before prompting procedures are implemented.

Error-correction procedure

When the student makes a mistake, the educator implements an error-correction procedure. It is an important part of the learning process that ensures that students do not form incorrect habits. By reducing the number of errors (by implementing error-correction procedure) and increasing the number of correct responses followed by a positive reinforcement, the educator also ensures more positive learning experience for the student -

in turn helping to maintain their motivation. The error-correction procedure is illustrated in Figure 5-2. When the student makes a mistake, the educator provides clear feedback in a neutral voice, for example by saying, “No, that is not right”. The educator then repeats the antecedent (instruction) and immediately delivers a prompt as described above. After the student repeats/provides the correct response the educator praises the student in a positive, but not overly enthusiastic voice, for example “Well done”. It is important not to provide high level of reinforcement after a prompted response, so the student can distinguish between being independently correct (high levels of reinforcement) and correct with help (lower levels of reinforcement). This increases the likelihood that the student will engage in the correct response independently in the future. Following a prompted trial, the instruction is repeated, and the student is given time (three to five seconds) to respond independently.

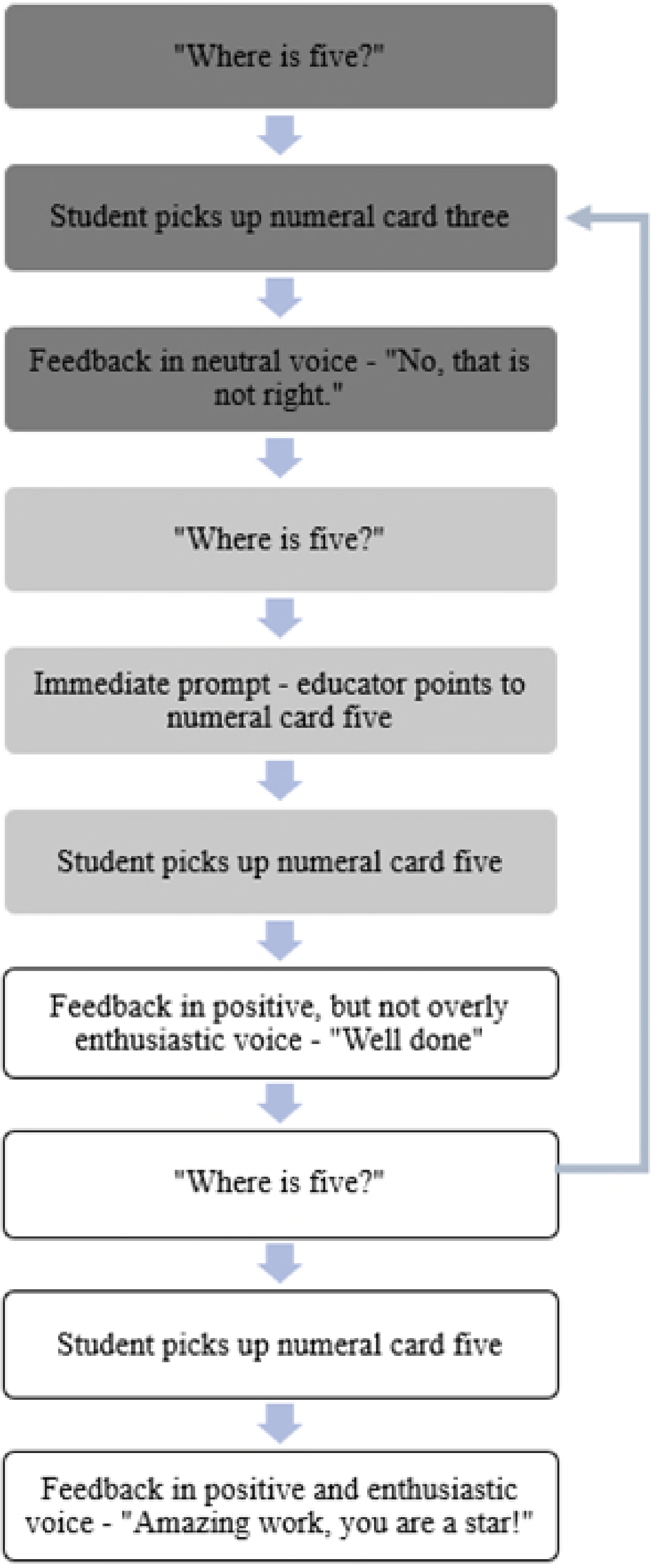


Figure 5-2. Diagram illustrating an error-correction procedure.

Generalisation

Generalisation, an ability to perform a skill learned in one context in a different one, is a crucial part of successful learning (Collins, 2012). The majority of neurotypical students can generalise skills themselves though observation and in-direct teaching. However, students with DD, especially with autism, might not naturally generalise skills learned in one context to another (Grindle, 2020). Therefore, working on the generalisation of acquired targets in a systematic and structured way is an essential (and crucial) part of a successful learning experience for students with DD. To achieve this, targets already mastered by the student are regularly and systematically taught/practiced under four conditions:

1. With different people – The student is asked to perform target skills when the instruction is delivered by a different educator or a peer;
2. In different places – The student is asked to perform the target skills in a different place to that which they originally learnt the skill (for example, this may be at a different table, in a different classroom, etc.);
3. With different instructions – The student is asked to perform the target skills using a different, but functionally equivalent instruction (for example, instead of saying "Find two", educator says "Show me two" or "Where is two?"); and
4. Using different teaching materials – The student is asked to perform the target skills when different, but functionally equivalent teaching materials are presented (for example, instead of using black and white numeral card two, the educator presents a colourful numeral card two or one with a different font, size, etc.).

Maintenance of acquired skills

An important aspect of making sure that learning lasts over time is for teachers to work on maintenance of acquired skills (Collins, 2012). Multiple strategies have been incorporated into the TEN-DD R programme to facilitate and encourage maintenance of targets. These include: (1) teaching skills relevant for the student, (2) teaching across different settings, (3) over-teaching (i.e., continuing teaching for two consecutive sessions after the student meets the mastery criterion) and (4) using differential reinforcement (i.e., delivering higher levels of reinforcement for new skills and lower levels of reinforcement for established targets). Once a target has been mastered, it is crucial that the educator periodically practices/probes the skill to ensure that the student can still perform it over time. It is recommended that about one quarter of the time in each TEN-DD R session is spent on maintenance and generalisation of mastered skills and that educators keep an up-to-date list of mastered targets and regularly check (probe) them. If the student requires help to perform a skill on three consecutive occasions, then the skill is re-introduced as a current acquisition target and is taught to mastery again.

Individual versus group teaching models

Similarly to the TEN-DD programme, TEN-DD R can be delivered using one-to-one teaching scenarios, or using a small group format, depending on available staff to student ratios and students' needs. Where possible and feasible, the group format is recommended as this can boost observational learning (through encouraging students to pay attention to their peers and incorporating choral [unison] responding) and lead to quicker acquisition and improved maintenance of target skills.

One-to-one format. For educational settings with high staff to student ratios or for students with more complex needs, the one-to-one instruction delivery format might be most appropriate. Here, an educator is sat at the table with one student or a small group of students but delivers only individualised instruction. If only one student is present at the table, then the educator works with them for four to five minutes (depending on attention span) before giving them a short break (around a minute). This process is repeated for the duration of the session.

If the educator is supervising more than one student, but group format is not suitable (due to significantly different baseline skills or ability levels), then sequential responding is used. Here, all students are sat at the table at the same time, but individualised instruction is used. The educator delivers the instruction for two or three minutes to one student while the remaining students are accessing an independent numeracy related activity or a reward for previously completed work. After a few minutes, the student receiving the instruction is given a reward or an independent activity and the teacher moves on to the next student. This process is repeated for the duration of the session.

Group format. When high staff to student ratios are not available or students are known to work well with their peers (and have similar baseline skills), a group teaching format is recommended. It is known to boost observational learning and in turn can speed up target acquisition and improve maintenance (Taubman et al., 2001). Small groups of two or three students are optimal to complete recommended number of trials per student in every lesson and maximise the learning gains. In the group format students are seated together at the same table and sequential as well as choral (i.e., unison) responding is used. The educator delivers individualised instruction to one student at a time using principles of sequential responding (see above), but instead of the other students being occupied with another activity (like in one-to-one format), they are encouraged to listen to the instruction and observe peer's responses and subsequent feedback. The teacher delivers a few trials (covering current targets only) individually to all students in the group before moving on to choral responding.

Choral responding is an important part of the group delivery format and can have many benefits for the students' maintenance of acquired skills and generalisation. Only targets already mastered by all students in the group are used for choral responding. The educator delivers the instruction and all students in the group are encouraged to respond in unison. Every four to five minutes – after each student had a chance to practice their individual (current) targets as well as choral responding – students are given a short break. This process is repeated for the duration of the session.

Progress tracking and data collection

Baseline. Before teaching starts, educators establish a baseline for all participating students. This can be achieved by using the probing sheet (see Figure 5-3). Research shows that the skill acquisition of students with DD might not be linear (Grindle, 2020), especially when no comprehensive and systematic teaching is used. Therefore, gaps in some early numeracy skills might not necessarily mean the student has not learnt more complex skills (this is known as a spiky profile which is especially common for autism). The probing sheet helps educators to establish a starting point in the programme for individual students and to identify gaps in their knowledge. By completing a probing baseline assessment, time can potentially be saved in the future by not introducing targets already known to the student. For this reason, we recommend completing the whole probing sheet before teaching starts. The probing assessment is completed by the students' usual educator, who knows the student well, preferably in one-to-one format.

To complete the probe baseline assessment, the educator works progressively through the list of skills included on the probing sheet and trials them one by one with the student. If the student performs the target skill independently on the first attempt, it is considered known. If the student does not perform the target skill or needs help to do so, then the skill is considered not known. Data is collected by putting a tick on a probing sheet (see Figure 5-3) if the student gives a correct and independent response on the first attempt, or a cross for an incorrect response. The targets which were identified as not known to the student during the probing process form the list of current targets to be taught using the procedure described in the teaching plans.

During the probing process student's responding is not reinforced or corrected, however, every few minutes the educator delivers reinforcement (reward) contingent on attending (sitting well, looking at the resources, etc.).

On-going data collection. The suggested on-going (collected every session) data collection method for TEN-DD is cold probes. It involves taking data only on student's first try of the day on a specific target - the target is practiced multiple times a day, but data is only taken once. This method is particularly helpful for TEN-DD as students have multiple current targets they practice during a single session so cold probes reduce the time commitment for the educators when it comes to data collection. However, in TEN-DD R students are working only on one current target at the time, therefore we have decided to utilise trial-by-trial data collection method instead of cold probes, as it allows for more detailed progress tracking. Trial-by-trial method involves the educator taking data after each DT done during one session. Recommended number of DTs per session is 10, however more can be done if it is deemed appropriate by the educator (for example if the student has a good attention span, is enjoying numeracy or is working on targets that can be practiced quickly). Data is collected by putting a tick on a data sheet (see Figure 5-4) when the student gives a correct and independent response, or a cross for an incorrect or prompted (requiring help) response. Other data collection methods, like cold probes, can also be used for TEN-DD R after slight adaptations to the data sheet and mastery criteria.

Mastery criteria. Similarly to TEN-DD, if the student is correct on the first two ever tries of a new target it is deemed as mastered and the educator introduces the next target on the list. If not, trial-by-trial data is collected until the student reaches the mastery criterion of nine out of 10 correct responses for two consecutive days with the same educator.

Ongoing progress tracking. A crucial part of successful programme implementation is ongoing progress tracking. Educators are asked to set up a skill tracker (see Figure 5-5) for each student and record the date when each target is introduced and mastered. By doing this, educators ensure they are introducing targets in the developmental order and can also identify if the student is taking longer than expected to master a particular skill. In this case, the educator can promptly flag this up to the TEN-DD R designated lead who can review student’s progress and decide if any alternations might be needed (for example, by breaking the target down further).

Materials

Lesson plans

A total of 58 lesson plans are included in the TEN-DD R programme. Lesson plans follow the same structure that was used successfully in the TEN-DD programme. Appendix 25 presents an example lesson plan with explanations. The main elements/sections include target number, lesson plan title and purpose, list of required materials, example materials and activities, teaching procedure description (teaching environment arrangements, teaching steps, instructions, and expected students’ responses), generalization plan, help section (including possible amendments) and mastery criteria reminder.

Teaching materials

All teaching materials required in the TEN-DD R programme are either included with the programme or easily accessible in the school environment (e.g., number books, student’s preferred items, simple turn taking games). Information about materials needed to teach a specific skill are always included at the start of a relevant teaching plan (see

Appendix 25). Materials included in the pivotal prerequisite section include animal pairs, 'Your turn' card, colour cards, object cards, and geometrical figures cards. Materials included in the numeracy section include variety of object cards, number song accessories (e.g., frogs and a picture of a pond for the '5 little speckled frogs' song), 1-5 numeral cards, 1-6 domino cards, 1-5 shapes cards, 1-3 and 1-5 numeral lines, 1-5 dot cards, 1-5 finger pattern cards, 'My turn' and 'Your turn' cards.

Data sheets

Three data sheets were created for the educators to use during the implementation of TEN-DD R.

Probing list. The first one is a probe list (see Figure 5-3) that contains all skills included in the programme. There are two separate lists for both stages of the programme – pivotal prerequisite and numeracy. Before starting to teach, educators probe which skills the student might already have and do not need training for. Last two columns are used to record date when probe was completed and the outcome - ticks for targets the student can already preform independently and crosses for targets not yet known to the student.

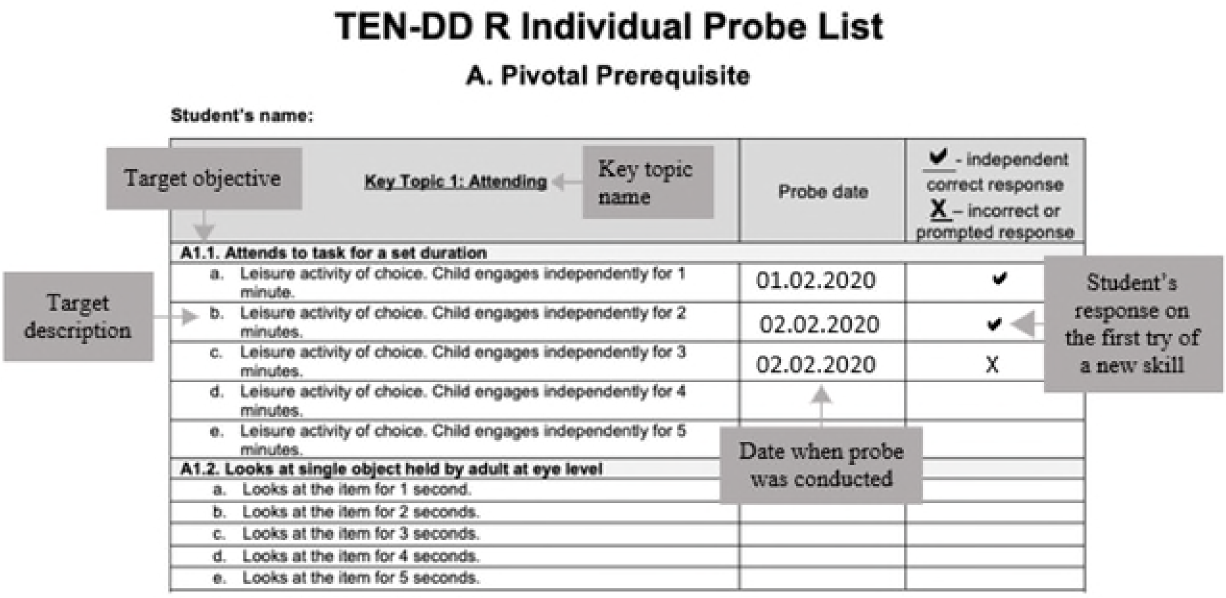


Figure 5-3. Sample probing list for the pivotal prerequisite skills.

DTT data sheet. The second data sheet is a DTT data sheet designed to record trial data from each session. It contains three sections: current target (shown in Figure 5-4), maintenance targets and generalisation targets. The first two columns are used to record the target code and a date of the lesson. Third column is used to record trial-by-trial data as per data collection guidelines (see the previous section). The data sheet also contains column to record summative score after each session and space for notes where educators can record any relevant information such as prompts used or the target mastery date.

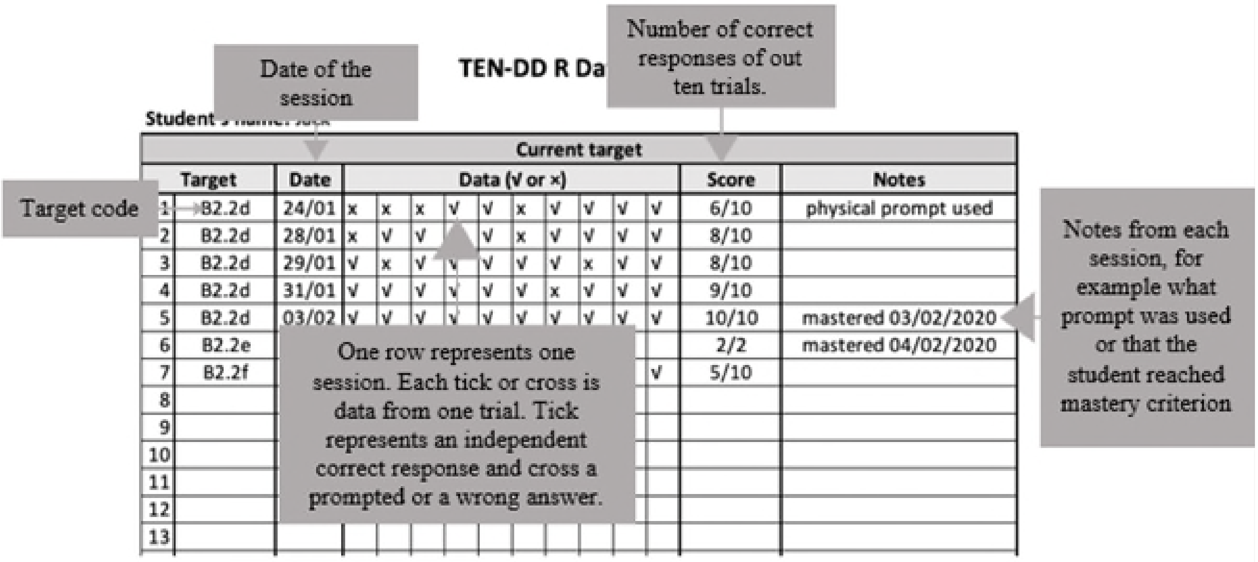
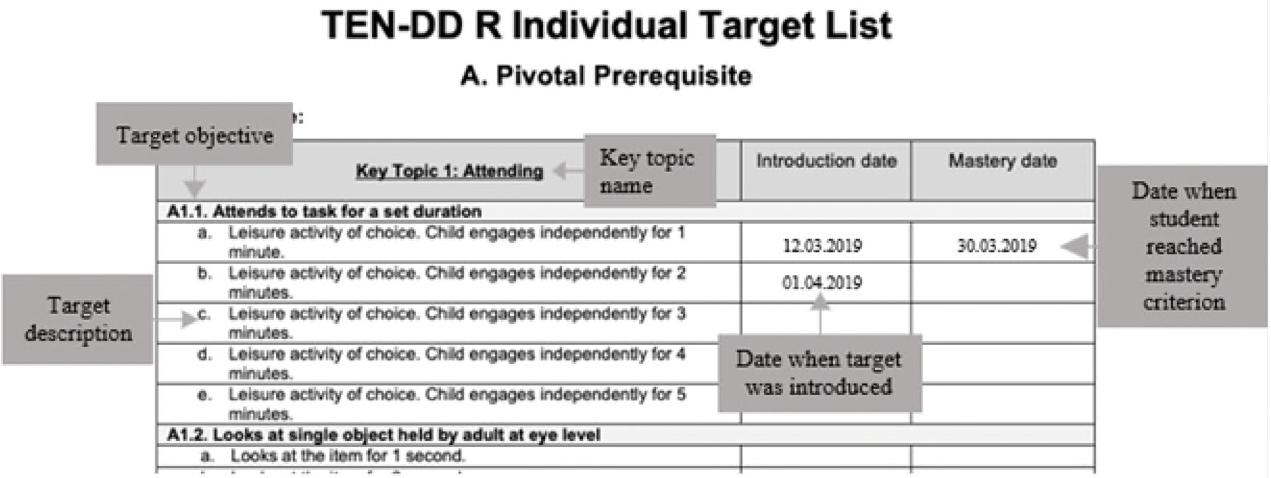


Figure 5-4. Sample current target section of the TEN-DD R session data sheet.

Skills tracker. The third data sheet is a skills tracker (see Figure 5-5). There are two separate list for both stages of the programme – pivotal prerequisite and numeracy. Similarly to the probing list, it contains the list of skills included in the programme. However, it also contains space for the educators to record the date of the target introduction and mastery to effectively track students' progress through the programme.


TEN-DD R Individual Target List

A. Pivotal Prerequisite

Key Topic 1: Attending	Introduction date	Mastery date
A1.1. Attends to task for a set duration		
a. Leisure activity of choice. Child engages independently for 1 minute.	12.03.2019	30.03.2019
b. Leisure activity of choice. Child engages independently for 2 minutes.	01.04.2019	
c. Leisure activity of choice. Child engages independently for 3 minutes.		
d. Leisure activity of choice. Child engages independently for 4 minutes.		
e. Leisure activity of choice. Child engages independently for 5 minutes.		
A1.2. Looks at single object held by adult at eye level		
a. Looks at the item for 1 second.		

Figure 5-5. Sample skill tracker.

Mentoring visit record. We also developed a mentoring visit record (see Appendix 26) which can be used formally or informally by the TEN-DD R designated lead during class visits (for more details see section on staff training and supervision). The document contains a key that defines scoring criteria – 0 means the educator is incorrect for most of the time; 1 means the educator is correct for approximately half of the trials; and 2 means the educator is correct for most of the time – as well as space to record educator's name and date of the class visit.

The first section, which includes implementation and data collection, is a task analysis of target delivery and includes all steps the educator needs to complete when using the TEN-DD R programme. The second section lists actions the educator needs to complete to correctly maintain all student's documents (data sheets and the skill tracker). Each step in both sections is scored by the designated TEN-DD R lead by circling the most appropriate key (0, 1, 2, 'yes' or 'no'). The third section is used by the designated TEN-

DD R lead to summarise what went well during the session and what the educator can improve on. Those points are then used to guide the discussion with the educator and identify possible actions. The fourth section is used to record any concerns raised by the educator and agreed actions. Once the record is completed, the designated TEN-DD R lead and the educator use the space on the bottom to sign the document.

Implementation protocol, guidelines, and visuals

Along with the lesson plans, the educators receive a TEN-DD R implementation protocol (see Appendix 27) containing a summary of guidelines to effectively use the programme. This document contains sections on suggested session frequency and duration, session structure (dividing time between current, maintenance and generalisation targets), DTT overview including a trial visual with an example, prompting and error-correction procedures, mastery criteria summary, maintenance and generalisation targets and overview of data collection procedures.

Educators also receive a detailed guide on motivation and learning, DTT and prompting procedures (accompanied by prompt fading visuals). All three documents are numeracy focused and applicable for the TEN-DD and TEN-DD R programmes. They are written in plain English avoiding specialistic terminology (or providing clear definitions) so the educators can access them independently. The motivation and learning guide is 12 pages long and focuses on principles of ABA, especially the importance of reinforcement. The document contains the description of different types of reinforcement, as well as how to effectively identify potential reinforcers for individual students to maintain their motivation to learn. The DTT guide is 10 pages long and contains information like what is DTT and how to deliver it effectively. It is accompanied by different visuals and written examples illustrating the antecedent – behaviour – consequence sequence. The prompting guide is 13 pages long and focuses on how educators can help the students acquire new skills by using effective prompting methods. The document describes the types of prompts, how to choose the most appropriate type of prompt depending on the form of the target skills and how to implement them effectively to avoid student's reliance on teacher's help. The accompanying prompt fading visual contains three flow chats illustrating how to gradually reduce amount of help provided for the students until they start responding independently. Each flow chat contains a different type of prompt fading procedure, physical, visual, and verbal, depending on the target skill.

Staff training and support

Staff training and ongoing support is crucial to the successful implementation of the TEN-DD R programme.

Train-the-trainer style training

Based on staff feedback collected as part of the research studies on teaching numeracy (Apanasionok et al., 2021 - Chapter 4), as well as our experiences, we suggest setting up a mentoring system in the school with a designated TEN-DD R lead. This person receives an extended training (around two and a half hours) on the programme, including its structure, implementation, and peer support arrangements. They are responsible for implementing and overseeing TEN-DD R in the school. The designated TEN-DD R lead delivers training to all staff members as well as being responsible for ongoing training and support.

Initial staff training

Introductory staff training takes place before the programme is introduced. An hour and a half training session (can be broken down into two shorter slots) is usually sufficient. The length of the introductory training depends on the educators' expertise in DTT. If participating educators did not have any previous experience with DTT, they might benefit from a slightly longer training session to allow more time for practice. The introductory training covers the TEN-DD R structure (including materials), teaching methodology and data collection procedure. Staff feedback collected as part of the previous research studies suggests that educators prefer practice-based training sessions with demonstrations and role play that omits the theory behind the teaching programme. Educators might also benefit from a short follow up training session a few weeks after the programme is introduced. This session can be conducted in the Q&A format where educators ask specific questions on the implementation of the programme.

Ongoing training and support

An important part of the successful implementation of the TEN-DD R programme is ongoing training and mentoring. Following the introductory training session, educators continue their training in classes. This is best achieved by establishing peer mentoring system in the school led by the designated TEN-DD R lead as explained above. Depending on availability, the lead visits each class using the TEN-DD R programme weekly to conduct short observations, answer any questions, model target delivery, and provide feedback. The designated TEN-DD R lead can use the mentoring visit record (see Appendix 26) to guide this process. This is a checklist describing all steps the educator needs to complete to correctly implement TEN-DD R. It gives the designated TEN-DD R lead a chance to score the teaching using included criteria and use it to guide a discussion with the educator about their further training. The mentoring visit record is used bi-weekly or once a month to check on educator's progress and treated as a formal record which, once completed, is signed by the designated TEN-DD R lead and the educator. It can also be used informally by the designated TEN-DD R lead as a guide during the class visits. As educators start becoming more confident with the target delivery and data collection, the frequency of the visits is reduced to bi-weekly and then monthly. Educators might benefit from a termly booster session conducted in a similar format to the follow up training.

Conclusion

This chapter described the development of the TEN-DD R programme following the 6SQuID model (Wight et al., 2016). We have focused on the first four steps – 1. Define and understand the problem and its causes; 2. Clarify which casual or contextual factors are malleable and have greatest scope for change; 3. Identify how to bring about change: the change mechanism; and 4. Identify how to deliver the change mechanism. We have described the current practice of teaching early numeracy and provided reasoning as to why it is important to systematically target learning to learn and numeracy readiness skills with students with DD. We have also identified how to bring about the change and explained why we chose to utilise the same teaching methodology and structure as the TEN-DD programme. Chapter 5 also described in detail the implementation of the TEN-DD R programme. What follows in Chapter 6 is the description of the plans for the last two steps of the 6SQuID model – 5. Test and refine on small scale; and 6. Collect sufficient evidence of effectiveness to justify rigorous evaluation/implementation.

Chapter 6

Teaching Numeracy Readiness to Students with Developmental Disabilities: A Feasibility Randomised Controlled Trial

Introduction

Following the successful implementation of the TEN-DD programme in special schools in the UK (Tzanakaki et al., 2014a; Tzanakaki et al., 2014b; Apanasionok et al., 2020 – Chapter 4), we developed a programme designed to teach numeracy readiness skills for students who need additional training to access TEN-DD. Teaching Early Numeracy Skills to students with Developmental Disabilities – Readiness (TEN-DD R) is described in detail in Chapter 5.

We designed a waiting list randomised controlled trial to explore the feasibility of implementing the TEN-DD R programme in a special school setting for students with DD as a school-led delivery model. Our aim was to work in collaboration with the participating school to create a peer mentoring system and minimise researchers' involvement in the delivery of the intervention. The main research questions for this study were: (1) What is the feasibility of implementing the TEN-DD R programme as a school-led delivery model in a special school in the UK?; and (2) What is the feasibility of teaching numeracy readiness skills to students with DD using the TEN-DD R programme?.

Study protocol

Setting

The study will be conducted in a large special school in the UK catering for around 380 students with severe ID. Following the school's request, we will be focusing on students from the primary and secondary departments (five to 15 years old). All teaching sessions will be conducted in students' usual classrooms and at their usual seating arrangements (where applicable) with other students present in the classroom who are not receiving TEN-DD R.

Design

This study will utilise a waiting list randomised controlled trial design. Half of the recruited students will be randomly assigned to access the TEN-DD R programme and the other half will carry on with the school's numeracy teaching as usual (described below). The study will last from January 2020 until July 2020. After the study has finished, as long as the initial findings about the new programme are positive, students not assigned to TEN-DD R will begin using the new programme in the school year 2020/2021 (see Figure 6-1).

Inclusion and exclusion criteria

The inclusion criteria will be: (1) The student does not have the prerequisite skills to access the school's other numeracy curricula; (2) The student has no or very few gaps in the prerequisite pivotal skills part of the programme (described below) and any existing gaps could reasonably be expected to be taught in a six-week period; (3) The student has no visual or auditory impairments that may impair learning or has an impairment that can be corrected by wearing glasses or a hearing aid. The exclusion criteria will be: (1) The student has multiple gaps in the prerequisite pivotal skills part of the programme that cannot be addressed in six weeks; (2) The student has visual or auditory impairments that may impair learning and these impairments cannot be corrected by wearing glasses or a hearing aid.

Recruitment

We will focus on students who do not yet have any numeracy skills (e.g., counting, recognising numerals) and who cannot access the school's regular numeracy curriculum. The TEN-DD R programme will be introduced to all students in the school's primary and secondary department that meet the inclusion criteria and that are not accessing what are considered (by school staff) to be other more suitable numeracy curricula (such as school's

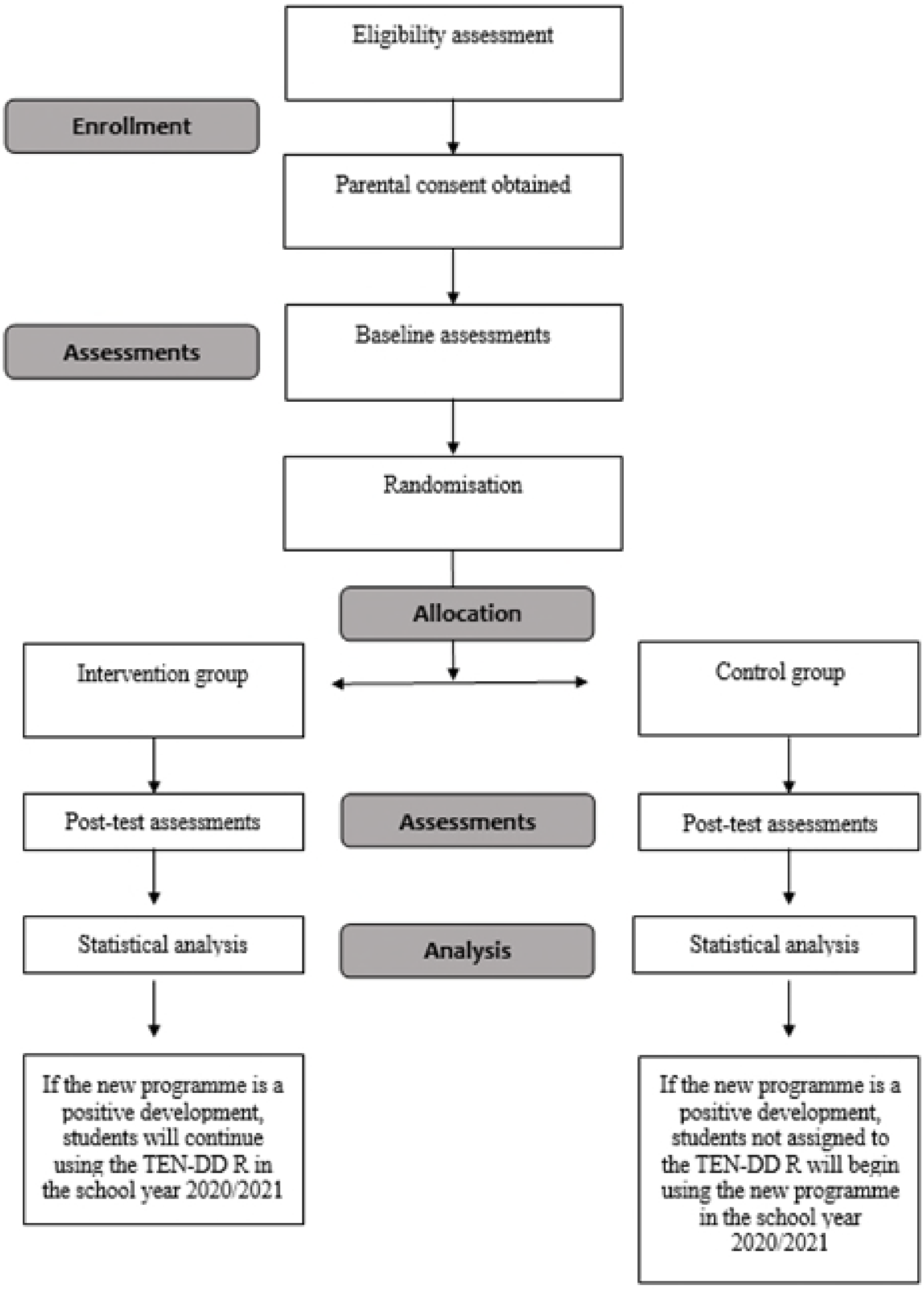


Figure 6-1. Study flow diagram.

regular numeracy curriculum or TEN-DD programme). This is estimated to be approximately 30 students. The list of potential students will be created in collaboration with class teachers and the heads of primary and secondary departments.

In January 2020, parents of the selected students will be sent a study information sheet and consent form to review at home and will be offered an option to come to the school to talk to the school's designated TEN-DD R lead (more detail about this role is provided in the staff training section) and the trainer (MA). If parents do not return the consent form within one week, they will be contacted by telephone by the school's designated TEN-DD R lead and offered the chance to discuss the study and ask questions. A translator from the school will also be available for families for whom English is not the first language. Both the information leaflet and consent form are written in plain English and avoids research jargon. Due to the nature of the needs of the participants, and the fact that no assessments will be conducted directly with the students (all outcome measures with be completed by educators), informed consent will be obtained only from the parents.

Outcome measures

Students' pre-requisite and numeracy skills will be evaluated using two assessment tools. First, sub-tests from the ABLLS-R (Partington, 2006) will be used to assess students' pivotal prerequisite skills such as matching, imitation, and general attending. The ABLLS-R is a tool developed for children with DD to assess their language and learning skills. It consists of 25 skill areas but only domains relevant to the TEN-DD R programme will be used. These will be: (1) visual performance; (2) receptive language; (3) motor imitation; (4) vocal imitation (for students who communicate verbally); (5) intraverbals; (6) group instruction; (7) generalised responding; (8) maths skills; and (9) fine motor skills. There is a total of 243 targets included across all nine skills areas, some comprised of a few smaller steps. We developed a skill tracker (see Appendix 28) which contains all relevant ABLLS-

R skill areas in developmental order with a space to indicate if the student has already acquired the skill and date of acquisition. Using the skill tracker teachers will score each included skill based on their knowledge about the student and observing the student in the classroom. To score, teachers will place a tick next to the skills that the student can already perform independently and a cross next to the ones they cannot perform or need help with completing. The number of ticks will be summarised later to obtain a total score for the ABLLS-R assessment for each student.

Additionally, we will use a TEN-DD R bespoke assessment (see Appendix 29) to determine students' numeracy skills. This tool is a structured interview for teachers we developed based on the content of the numeracy section of the TEN-DD R programme. It is comprised of 17 core skills/items. Each item includes a task description and a question for the educator (see Table 6-1). Included items are based on numeracy skills covered in the numeracy section of the TEN-DD R programme such as attending while the teacher is counting, one-to-one correspondence, copying rhythmical movements, matching number cards one to five or counting with the teacher. The assessment includes a 3-point rating scale where 0 means never, 1 means sometimes (50% of time or with support/prompt) and 2 means usually (without support/prompt). Scores across the 17 items will be summed, and this will form a total score for the students for TEN-DD R bespoke assessment.

Table 6-1. *TEN-DD R bespoke assessment.*

	Skill	Task description	Question
1	Looks at the teacher counting	Watches when teacher counts up to five objects one by one.	What do they do when you count out up to five objects?
2	Attends to, and copies, teacher counting	Copies pointing/touching while the teacher counts up to five objects and points to them.	How about when you count up to five objects while pointing, do they attempt to copy you to touch the objects?
3	One-to-one	Gives out one plate, cup, or	When you give him/her a few

	correspondence in everyday situations	candy to each student in a group of students/teddy at the table, for example.	(up to 5) plates, cups or sweets does he give one to each student or teddy at the table?
4	Attends during singing number songs.	Watches and tries to imitate number words while the teacher is singing a number song.	What do they do when you are singing number songs such as ‘1, 2, 3, 4, 5 Once I caught a fish’ or ‘Five little ducks’ or ‘One, Two, Buckle my shoe’?
5	Counts during singing number songs/reading books.	Attempts to count with the teacher/sing along with familiar number songs.	How about when they hear the song multiple times, do they attempt to sing along or count?
6	Copies rhythmical movements.	Copies teacher doing a single clap/stomp of foot/tap on a table.	What do they do when you clap, stomp your feet or tap the table once?
7	Copies multiple (up to 5) rhythmical movements.	Copies teacher clapping/stomping feet/tapping on the table up to 5 times.	How about when you clap, stomp your feet, or tap the table up to 5 times, do they attempt to imitate you?
8	Takes one from an array of objects in known situations.	Takes one biscuit from a plate/one pen from a pencil holder/one sweet from a bag/one object during number songs.	When you offer him/her a sweet or a biscuit and ask them to take only one, what do they do?
9	Matches numbers 1-5 (identical).	Matches identical numeral cards 1-5.	When you put on a table number cards 1 to 5 and give him/her a second set of number cards 1 to 5 and ask them to match, what do they do?
10	Matches numbers 1-5 (non-identical).	Matches non-identical number cards 1-5.	How about when the number cards from two sets are not identical, e.g., different font, colour?
11	Sorts 3s.	Sorts number card 3 from non-3s in a range 1-5.	When you give them multiple copies of number cards 1 to 5 and ask them to sort threes, do they attempt to separate threes from non-threes?
12	Counts 1-5 with the teacher.	Counts 1-5 simultaneously with the teacher.	When you count 1 to 5, do they attempt to count with you?

13	Counts 1-5 with the teacher while pointing to objects/numbers on the number line.	Counts 1-5 simultaneously with the teacher while pointing to objects or numbers on the number line.	How about when you put five objects in front of them, do they attempt to point to them while counting with you?
14	Produces set of 5 objects with a prompt.	Copies teacher producing a set of 5 objects (e.g., blocks, counters, tokens).	When you take 5 blocks out of a box what do they do?
15	Produces set of 5 objects without a prompt.	Produces a set of 5 objects (e.g., blocks, counters, tokens) when asked	How about when you give him/her box of blocks or other objects and ask them to give you 5 without showing him/her first, what do they do?
16	Matches 3D quantity to 2D quantity 1-5.	Matches number card to a set of objects (e.g., blocks, teddys, counters, pens).	When you put up to 5 blocks or other objects on the table and give him a choice of two number cards (one matching quantity of the objects), what do they do?
17	Counts 1-5 independently.	Counts 1-5 when asked without a prompt.	When you ask them to count to 5, what do they do?

Procedure

Baseline data will be collected before randomisation in January and February 2020, using the ABLLS-R and the TEN-DD R bespoke assessment. The ABLLS-R assessment will be completed by the participants' usual teachers based on their knowledge of the student's existing skills and through their observations. They will have a short (no longer than five minutes) training on the assessment tool and scoring criteria with the trainer on a one-to-one basis and will be given the ABLLS-R skill tracker to complete in a time suitable for them. The teachers will place a tick or a cross next to each listed skill to indicate if the student can perform the task. The trainer will be available to answer any questions during weekly visits to the school or via email.

The TEN-DD R bespoke assessment will be completed by the first author at baseline and by a master's student or a Research Assistant from the University of Warwick at post-test so that assessors remain blind to trial condition. The interviews will be conducted with the class teachers. The interviewer will read out the task description and the question for each of the 17 core skills (see Table 6-1) and the teacher will be asked to rate students' acquisition on the 3-point rating scale described above. Post-test assessments will be completed in July 2020 using the same two tools: the ABLLS-R and the TEN-DD R bespoke assessment.

Staff training and peer support

Following the successful implementation of the TEN-DD programme as a teacher-led model and recognising the importance of establishing a mentoring system in the participating school (Apanasionok et al., 2020 - Chapter 4), we will build a similar model of staff training and support in the present study. The previous research highlighted the need to reduce researcher's involvement in the implementation of the programme, so we will design, in collaboration with the school's staff, a peer support model to aid implementation of TEN-DD R, as well as staff training and supervision.

School's designated TEN-DD R lead. The school's leadership team will nominate a TEN-DD R lead who will be responsible for the implementation of the programme and staff supervision. This person will likely be a staff member already in charge of overseeing mathematics education in the school and who has experience in implementing TEN-DD programme. The researcher (MA), who will act as the trainer/consultant, will deliver the train-the-trainer style training to the school's designated TEN-DD R lead in December 2019. This will involve an in-depth training on the programme and its implementation, as well as peer support arrangements and will last two and a half hours. All decisions about the changes and improvements to the implementation of the programme with be made collaboratively by the research team and the school's designated TEN-DD R lead.

Initial staff training. Two educators (class teacher and a teaching assistant) from each participating class will be trained in the TEN-DD R programme. Most staff members in the primary and secondary departments already have some familiarity with the teaching procedure (i.e., systematic instruction and discrete trial teaching) through the school's curriculum and previous projects. Therefore, the initial training will be short, and more focus will be placed on on-going in-class training and support. The school's designated TEN-DD R lead and the trainer will deliver the initial training session for the class teachers and the teaching assistants. This will include a PowerPoint presentation followed by a short discussion and will last approximately one hour. Table 6-2 describes the structure and content of the initial staff training session.

Table 6-2. Structure of initial staff training session.

TEN-DD R curriculum overview	• Importance of numeracy education and potential challenges with implementing mainstream curricula for children with DD. • TEN-DD programme (including information on the previous studies conducted in the school and staff feedback) and the need for a readiness /preparatory programme for students who do not have the prerequisite skills needed for TEN-DD. • Structure of the TEN-DD R programme – overview of both stages.

Discrete Trial Teaching (DTT) overview	• Introduction – what it is?; how it can be used?; and existing evidence summary • Summary of the elements of DTT– antecedent, prompt (if needed), student’s response, and consequence. • Examples of trials on life skills and numeracy skills. • Detailed overview and how to deliver each element of DTT. • Overview of prompting procedures and error-correction. • Organising the teaching environment.
Teaching organisation	• Overview of the RCT and randomisation process. • Suggested session frequency and duration. • Importance of generalisation and maintenance targets and how to incorporate them into TEN-DD R lessons.
Data collection	• Overview of trial-by-trial data collection method. • Guidelines on how to collect data and criteria for recording a response as correct. • Mastery criteria overview for new and on-going targets. • Brief explanation of a sample data sheet. • Overview of how to introduce and move on targets. • Brief explanation of a sample skills tracker.

How to read lesson plans?	• Sample lesson plan with explanations of each section and how to find required information.
On-going support	• Overview of the on-going in-class training and timeline of phasing that out. • Contact details for the school's designated TEN-DD R lead and the trainer.
Discussion	• Guided discussion around the training content.

Ongoing in-class training and peer support system. The trainer will visit each class on a weekly basis for the first half term of the study (approximately, six weeks). The sessions will last around 15 minutes and involve the trainer observing the teaching sessions and providing feedback, further explanations and modelling target delivery as needed by the educators. After one half term, the trainer will decrease the frequency of in-class training sessions to biweekly and then to once monthly or half-termly to increase staff members' independence. We will place a strong focus on establishing a peer support system in the school to provide staff members with an on-going training and support led by the school's designated TEN-DD R lead. Staff members will be instructed to approach the school's designated TEN-DD R lead with any questions or queries, and that person will be checking on the progress of each class on weekly basis for the duration of the whole study. During the visits, the school's designated TEN-DD R lead will answer any questions, observe TEN-DD R implementation, and suggest any adaptations or improvements.

Randomisation

Students will be randomised to the two arms of the trial on a one-to-one ratio by a Research Fellow from Centre for Educational Development, Appraisal and Research (CEDAR), University of Warwick. Utilising the free to access Minim software, covariate-adaptive randomisation (i.e., minimisation; cf. Hu et al., 2014) will be used to allocate study participants to their respective arms. This 'live' method of allocation is particularly useful when group sizes are small (as in the present study). Student allocation will be balanced on class membership (i.e., the school class children are in) and department (primary or secondary) assignment. Educators will not be informed about group assignment until after they have completed all baseline assessments for each participating student in their class.

Intervention group. Students randomly assigned to the intervention group will be taught numeracy using the new programme – TEN-DD R. Teaching instruction will be delivered in an individual or small group format depending on the class teacher's preference. Teachers will also be able to decide on the frequency and duration of the teaching sessions as long as students will have at least three opportunities to practise their current, maintenance and generalisation targets per week (not necessarily in one sitting). Details of the programme, its origin, content and teaching methodology are described in detail in Chapter 5. Adaptations to the teaching procedure to suit individual students' needs will be made after discussions with the school's designated TEN-DD R lead and/or the trainer. Students' progress will be assessed during every teaching session by establishing data collection system with clearly defined mastery criteria.

Control group. Students randomly assigned to the control group will continue to access the school's usual numeracy teaching. This will depend on individual students needs and skills and might include sensory approaches, play and rhymes and Numicon (numeracy programme that uses colourful number shapes) use. Depending on class and individual needs, students usually have three numeracy lessons per week.

Data analysis

The analysis will compare post-test ABLLS-R and TEN-DD R bespoke assessment scores of students from the intervention and control groups while controlling for baseline scores. We will conduct an ANCOVA analysis provided that the assumptions regarding the independence of the covariate and treatment effect and the homogeneity of regression slopes are met. Effect sizes will be calculated by dividing the difference between mean pre-post-test difference for the intervention and control groups by the pooled standard deviation (Morris, 2008).

Preliminary findings

Ethical approval was obtained from the Humanities and Social Sciences Research Ethics Committee at the University of Warwick (Appendix 30).

Recruited students

Parents of 18 students consented to their participation in the study. Four were attending the school's primary department and 14 the secondary department. Three were females and 15 were males. Students' ages ranged between 9 years 9 months and 16 years 8 months. Fifteen students' primary educational need was recorded as severe learning difficulties (SLD), two profound and multiple learning disabilities (PMLD), and one specific learning difficulties (SpLD).

Randomisation outcome

Nine students were allocated to the intervention group and nine to the control group (see Table 6-3). Each group had two students from the primary department and seven from the secondary. The average age in the intervention group was 155.89 months (12 years and 10 months; SD=23.19) and all participants were males. Eight had educational needs recorded as SLD and one as PMLD. The average age in the control group was 155.55 months (12 years and 10 months; SD=25.66). There were three females and six males, and the educational needs of the participants included SLD (n=7), PMLD (n=1) and SpLD (n=1).

Baseline data

Table 6-3 presents baseline assessment results for intervention and control groups across both assessment tools. The baseline scores for both assessments were reasonably balanced across both groups.

Table 6-3. *Baseline data for ABLLS-R and TEN-DD R bespoke assessment.*

Group	**ABLLS-R assessment**		**TEN-DD R bespoke assessment**	
	Mean	**SD**	**Mean**	**SD**
Intervention	99.9	81.5	12.4	7.4
Control	116.8	91.6	13.3	8.4

Post-test data

The study was cancelled in March 2020 due to the partial closure of schools in England as a result of Covid-19 pandemic. The intervention phase lasted only three weeks and we were not able to collect post-test data.

Reflections on the study process

After completing the initial steps of the study, there is some initial learning about the recruitment process and the assessment of numeracy readiness skills. First of all, despite the fact that 32 students met the inclusion criteria and were selected by the school to participate in the study, we were able to obtain parental consent only for 18 students.

The remaining families either did not return the signed consent form (10) or explicitly refused for their child to participate (four). Most parents who did not return the signed consent form indicated verbally during the follow up telephone calls that they would like their child to participate in the research, but despite that did not provide written consent. We offered the parents an opportunity to come to the school and discuss the study with the designated TEN-DD R lead and the trainer and sign the consent form at the same time (if they wished to do so), but no families attended. In the future, the study information meeting could perhaps be organised on the same day as the termly parental consultations to reduce the number of times the families are asked to come to the school and increase the attendance.

Secondly, we initially planned to complete all baseline assessments within two weeks. However, it took almost four weeks for all the teachers to return the ABLLS-R assessments and complete the bespoke TEN-DD R assessment. The majority of the teachers commented that the ABLLS-R assessment was too long, and they struggled to find time to complete it during their working hours. In the future, fewer skills areas from the ABLLS-R could perhaps be used or the school could nominate a learning mentor in charge of completing the assessments to reduce the time commitment for the teachers. Alternatively, researchers could carry out the testing. However, this would be challenging since it would take some time to observe children during enough tasks to complete an assessment like the ABLLS-R (as it requires certain level of familiarity of the student and their skills).

Lastly, we selected the ABLLS-R and the TEN-DD R bespoke assessment due to the nature of the skills included in the curriculum. We did not find any standardised numeracy assessments that would be accessible to students with DD that covered very early numeracy skills. The TEMA-3 assessment we have used in previous research projects on numeracy skills in students with DD, like the majority of available standardised numeracy assessments, starts at the equivalent of age four for a neurotypical child. The TEN-DD R programme, however, includes skills that could emerge in neurotypical children as early as age two. For this reason, we decided to use the two assessment tools described above as they best covered the skills included in the TEN-DD R programme, despite not being standardised measures. This may, however, impact the robustness of the obtained results.

Chapter 7

Overall Discussion

Overview

Students with DD have the same rights in education as their neurotypical peers. Due to the historical undervaluing of the abilities of disabled students however - as well as a scarcity of research on implementing evidence-based teaching strategies in ‘typical’ special school settings in the UK - there is a large gap in attainment between neurodivergent and neurotypical students (Department for Education, 2020b). This thesis focused on science and numeracy education for students with DD and explored adaptations that can be made to ensure evidence-based interventions are more accessible and feasible to implement in specials schools in the UK. Chapter 1 provided an overview of the literature on teaching academic skills to students with DD, explored how the bioecological model and the MRC complex intervention framework can inform educational research, and provided some considerations on implementing Systematic Instruction interventions in special schools. Chapters 2, 3 and 4 presented three empirical studies on teaching science and numeracy to students with DD. Chapters 5 and 6 described the development of a numeracy readiness programme for students with DD. In this chapter – the overall discussion – I will provide an overview of the findings and their implications, the limitations of this thesis, my own reflections on the thesis, and propose recommendations for future research.

Science

Summary of the findings

Chapter 2. The first study, described in Chapter 2, is a systematic review of the literature on teaching science to students with DD. This review is unique as, apart from reporting students’ science outcomes, it also gathered information on the experiences and perceptions of educators and the learners. The results suggest that Systematic Instruction is likely an effective methodology to teach science to students with DD. Systematic Instruction was utilised in the majority of the studies included in the systematic review (23 out of 30) and was used to teach the largest variety of skills. All but three (out of 90) students in the included studies made progress in their target skills and all educators and students reported positive experiences of using the interventions. Results of the systematic review also suggest that self-directed instruction and comprehension-based instruction might also be a promising approach to teaching science to students with DD; however, more robust research is needed.

Chapter 3. Following on from the findings of the systematic review, Chapter 3 describes the implementation of a science curriculum that utilises Systematic Instruction methodology. The Early Science (ES) curriculum was initially developed in the USA for students with DD. It maps well against science education standards in England. However, previous research on its feasibility and efficacy was conducted only in the USA (Smith et al., 2013b; Jimenez et al., 2014; Knight et al., 2018) and it was unclear if it could be successfully implemented in a different educational system. The study in Chapter 3 is unique as it is the first attempt to use the ES curriculum in the UK special education context. The results suggest that it is feasible to implement the ES curriculum in the UK with staff members who have no or limited previous experience of using the Systematic Instruction methodology. The educators reported positive attitudes towards the curriculum and noticed changes in students' understanding of key science concepts. They also suggested how the ES curriculum could be implemented in the future to ensure better fit into their school's system. This study provided further evidence on the feasibility of using Systematic Instruction methodology to teach science to students with DD. The results also suggest that when systematic teaching methods are used, students can be taught relevant knowledge and skills to enable them to 'work scientifically', a core area of focus in England's science education programmes (Department for Education, 2015a).

Implications

Despite there being a clear gap in attainment between disabled students and their peers (Department for Education, 2020b), science is still one of the least researched disciplines for students with DD (Spooner et al., 2017). This thesis contributes to the existing research literature on using Systematic Instruction methodology to teach science skills and knowledge to students with DD.

Chapter 2. To our knowledge, our systematic review was the first to describe data on the perceptions and experiences of educators and learners in addition to science related outcomes. ABA is sometimes viewed as an exclusive methodology that can only be used in specialist settings where there are sufficient resources to provide detailed training and high staff to student ratios. Those misconceptions can lead to educators avoiding Systematic Instruction interventions, deeming them unsuitable for their setting. In order to address those misconceptions, data on the feasibility and efficacy of interventions should be reported alongside descriptions of the experiences and opinions of educators. This enables practitioners to better understand which methodologies and interventions might be suitable in their settings.

The results from the systematic review also suggest that there might be additional effective teaching strategies to teach science to students with DD than those previously suggested (Spooner et al., 2011). Especially specific science related skills like science text comprehension. Further research is needed to understand how self-directed instruction and comprehension-based instruction can be used to help students acquire science skills and knowledge.

Chapter 3. This study used an evidence-informed curriculum – Early Science – to teach science to students in a special school in the UK. This was the first time this curriculum was implemented outside of the USA. Apart from tracking students' progress, we have also explored the views and experiences of the educators to inform future use of the curriculum in the UK.

One unique feature of the ES curriculum is that it targets skills that enable students to ‘work scientifically’. Many educators still believe that students with DD, especially with moderate to severe needs, cannot engage in inquiry and self-directed learning. For this reason, skills related to ‘working scientifically’ remain neglected when teaching students with DD, despite being a core area of focus in the official programmes of study in England (Department for Education, 2015a). The majority of science teaching for students with DD targets key facts, rather than their practical applications. The ES curriculum focuses on the systematic training of key skills and knowledge to enable students to ‘work scientifically’. The intervention was well received by the educators.

Chapter 3 also illustrated the value of the active involvement of educators in school-based research. A science teacher was involved in all stages of planning and delivering the intervention and is the second author of the corresponding published paper. She provided an in-depth analysis of the science content covered in the ES curriculum, concluding that it is closely aligned with the official programmes of study in England. The science teacher also took an active part in planning the evaluation, providing valuable insight into the school’s system, and was able to select a class that met the inclusion criteria for the feasibility study. She was also involved in planning the implementation of ES, including the frequency, duration, and structure of the lessons. Finally, she took a leading role in training the class teacher and TAs that took part in the study and she facilitated all lessons. The involvement of the science teacher was not only valuable for the study but also gave her a sense of ownership over the project. She later became an advocate for the ES curriculum, and ultimately Systematic Instruction, across other special schools in the UK.

The science teacher also took part in the development of the implementation protocol and suggested a shift of focus from the initial training session to in-class training. This resulted in the curriculum being implemented by the school staff with the researcher acting mainly as an observer, stepping in only when necessary due to staff shortages. The initial training was shortened, and the science teacher provided more support to the educators during the lessons, modelling and correcting the delivery when needed. Feedback from the educators indicated that they preferred this training model. Furthermore, a shorter initial session provided a better fit into the school's busy training schedule.

The study in Chapter 3 also included informal discussions with educators involved in the implementation, providing valuable insight into the acceptability of the ES curriculum and any changes that could be made in the future to allow a better fit into the UK special education context.

Limitations

A potential limitation to consider for the systematic review (Chapter 2) is that some relevant studies might have been missed during the database searches. The search strategy was designed to be broad to reflect the scope of science education; however, some papers, especially reporting on multiple academic subjects, might have been missed. Several papers have been identified via reference searches, including Jameson et al. (2007) which, despite meeting inclusion criteria, did not use the word 'science' in the title, abstract, or keywords and therefore, was missed in the databases search. It is also important to note that the majority of papers included on the use of Systematic Instruction were authored or co-authored by a group of researchers from the USA. This reflects the scarcity of research on teaching science to students with DD, especially outside of the USA.

The most significant limitation for the study reported in Chapter 3 is the lack of standardised science assessment accessible to students with DD. We used the curriculum's built-in assessments for the purpose of this study. This allowed us to assess students' progress on content specific to the curriculum; however, it was not possible to assess their generalised or grade-specific skills. This was not necessary for this study as the aim was to explore feasibility of implementing the ES curriculum; however, if a larger scale study is planned in the future, a suitable assessment needs to be developed first.

It is also important to note that the study on the ES curriculum (Chapter 3) targeted only one unit of the curriculum – Five senses. Due to the time constrains it was not possible to implement the remaining three units. However, since the goal of the study was to explore the acceptability and feasibility of the ES curriculum in the UK special school context, it was deemed sufficient to focus only on the first unit of the curriculum in the initial study. The science teacher involved in the study explored the whole curriculum and checked its correspondence to official programmes of study in England.

Finally, despite the fact that the science teacher played an active role in planning, implementing, and evaluating the study in Chapter 3, the researchers were still involved in the delivery of the lessons. One researcher was present during all lessons to informally assess educators' adherence to the teaching script. During some lessons, mainly due to staff shortages in the school, the researcher had to get involved in the delivery of the intervention by prompting the students or facilitating responses during short quizzes at the end of the lessons. The researcher also had to occasionally prompt the class teacher or TA if they were not following the script and the science teacher was busy. When all involved educators were present (two TAs or one TA and the class teacher) the researcher's help was not necessary as the science teacher was able to lead the lesson and monitor the educators' adherence to the script.

Future research

The research on science education conducted as part of this thesis represents the initial stages of the MRC complex intervention framework (Craig et al., 2008). There is substantial research evidence suggesting that Systematic Instruction can be used to teach science to students with DD. The results from the systematic review (Chapter 2) also suggest other suitable methodologies may be helpful when teaching specific skills, such as science text comprehension. More robust research is needed to evaluate the use of self-directed instruction and comprehension-based instruction with students with DD. More research utilising group design is also needed to assess the effectiveness of Systematic Instruction to teach science to students with DD, including skills related to ‘working scientifically’. Finally, more research is needed on comprehensive science curricula targeting science skills and knowledge that is accessible to students with moderate to severe DD.

Based on our experience of implementing the ES curriculum in the UK special school setting, we believe it can be used independently by school staff. Support from educators that are more experienced with the ES curriculum would be necessary during the initial adjustment period whilst educators familiarise themselves with the scripts and the teaching methodology. This could be achieved by setting up a peer mentoring system in the school. Appropriate staff ratios (that reflect students’ needs) are necessary to implement the curriculum correctly. Some minor adjustments, like breaking down lessons into two sittings, can help facilitate a better fit within schools’ existing systems. Further piloting and feasibility studies should be conducted after making the proposed adjustments – especially on the remaining three units of the ES curriculum – before planning more robust evaluations in line with the MRC complex intervention framework (Craig et al., 2008).

Finally, before planning any further research studies on teaching science to students with DD, it is necessary to develop an appropriate assessment tool. This should be accessible to students with a range of needs, including those with limited verbal communication. Furthermore, it should incorporate both science skills and knowledge that is in line with the UK science education standards.

Numeracy

Summary of the findings

Chapter 4. This study described the implementation of the TEN-DD programme with autistic students. The programme was previously used with students with DD in a special school in Wales and was found to be feasible to implement with some initial evidence on its efficacy (Tzanakaki et al., 2014a and 2014b). However, the studies were conducted in a setting where high staff to student ratios were usually available and with educators with previous experience with Systematic Instruction methodology. The study described in Chapter 4 is unique as it focused on implementing the programme in a more ‘typical’ UK special school setting – with educators with no or little previous experience with Systematic Instruction and where one-to-one teaching is not usually possible. The results indicate that it is feasible to implement the programme using a teaching staff delivery model. We set up a mentoring system that allowed for continued in-class training while maintaining the individualised and intensive nature of TEN-DD. This study added to the limited literature on the use of Systematic Instruction by educators with no or little previous experience with this teaching methodology. Students who took part in the study improved their TEMA-3 scores from baseline to post-test. The difference was statistically significant and represented a large effect size. This suggests that even when the TEN-DD programme is implemented by school staff and in a setting where one-to-one ratios are not typically available, it can still help learners improve their early numeracy skills. Results from staff surveys suggested that educators were generally content with the training programme. By including educators' feedback, the study also helps us to understand how TEN-DD can be implemented in the future to ensure that the programme is accessible to educators with diverse teaching backgrounds. Given that the majority of special schools in the UK do not have high staff to student ratios, the study reinforces the importance of working collaboratively with schools to find the most suitable delivery model. When time is taken to consider a school's structure and to set up a training and mentoring system, the TEN-DD programme can be implemented by school staff.

Chapters 5 and 6. Chapter 5 describes the development of a numeracy readiness programme – TEN-DD R – which targets learning to learn and very early numeracy skills. The 6SQuID model was used to guide the development process. We have identified the lack of numeracy readiness catch up interventions accessible to students with DD as a factor that contributes to poor attainment in mathematics for this population and has the biggest scope to bring about the change. Considering the successful implementation of TEN-DD in special schools in the UK (Tzanakaki et al., 2014a and 2014b; Apanasionok et al., 2021 – Chapter 4), the same structure and teaching methodology was used for the new programme. The second half of Chapter 5 contains a detailed implementation guide for TEN-DD R.

Chapter 6 is a study protocol for a feasibility randomised controlled trial designed to explore the feasibility of implementing the TEN-DD R programme in a special school in the UK. The planned study was unique as it utilised an updated school-led delivery model which significantly reduces the required input from the research team by setting up a peer-mentoring system and nominating a designated TEN-DD R lead. We completed the initial steps of the study – setting up the peer mentoring system, educators' training, recruitment of the participants, randomisation, and baseline assessments. Unfortunately, due to the

Covid-19 pandemic, all schools in England closed to students (apart from a few eligible groups) in March 2020 and the study was cancelled three weeks after the intervention was introduced. Results obtained from this study would have enhanced scientific knowledge about numeracy readiness and numeracy education for children with DD. More specifically, this study would have addressed questions about the feasibility of using the TEN-DD R programme to teach numeracy to students with DD, as well as the feasibility of implementing it as a school-led model with minimal input from the research team. Through completing the initial steps of the study, we were able to reflect on the recruitment process and baseline assessments and make some recommendations for future research, especially in relation to setting up a RCT in an applied setting.

Implications

Chapter 4. Systematic Instruction was found to be evidence-based practice for teaching mathematics to students with moderate to severe DD (Spooner et al., 2019). Results obtained from this study provided further evidence on the feasibility and potential efficacy of using Systematic Instruction methodology to teach numeracy to autistic students. All participants made progress in their numeracy skills at post-test compared to baseline. The programme was generally received positively by the educators, as described by Alallawi et al. (in press) (Appendix 3).

This thesis attempted to address questions about accessibility of Systematic Instruction interventions to teach numeracy in special schools in the UK. Specifically focusing on settings more ‘typical’ for the UK - schools with low staff to student ratios and educators with no or little previous experience with the behavioural teaching methodology. We worked on developing a delivery system led by school staff that required minimal input from the research team while still staying true to the individualised and intensive character of Systematic Instruction. The development process was completed collaboratively with staff from a large special school. We focused on getting to know the school's existing system and teaching methods as well as discussing possible solutions with the leadership team and the teaching staff. Our delivery model consisted of three main adaptations: 1. Development of a peer support system with a designated lead responsible for training and supervision; 2. Making changes to the training protocol to consider time restrictions and the experience of educators; and 3. Adapting the teaching materials to be accessible to educators with limited knowledge about the Systematic Instruction methodology and who are working under significant time constrains. Three school staff members, who co-authored the published paper on which Chapter 4 is based, not only contributed to developing the described school staff delivery model, but also assisted in updating the TEN-DD teaching plans and recommended very well-received changes. We found that by including school staff in the decision-making process, they were more engaged in the implementation and expressed a willingness to continue using the programme after the study was finished (Alallawi et al., 2021). The TEN-DD programme continues to be used independently by the participating school two years after the study was concluded.

Detailed staff interviews were also conducted as part of this study to gather information on further improvements that could be applied to TEN-DD. These recommendations will be used to inform future research on the programme.

Chapters 5 and 6. Despite the consensus that students who have the prerequisite/readiness skills are much more likely to successfully engage with subject-specific teaching (Staves, 2019; Grindle et al., 2020), the majority of the research literature on teaching numeracy to students with DD focuses on pupils who already have a basic understanding of numbers and some emerging numeracy skills. This thesis contributes to the area of numeracy education for students with DD by describing the development of

TEN-DD R. To our knowledge, this is the first programme that targets learning-to-learn and very early numeracy skills that is accessible to students with moderate to severe DD, including learners with minimal verbal communication. The TEN-DD R programme can be used to prepare students to access TEN-DD or as a stand-alone intervention. It covers skills that neurotypical students usually acquire in pre-school through observation and play. This thesis also provides a protocol for a feasibility RCT study exploring the implementation of TEN-DD R with minimal input from the research team.

Limitations

The most important limitation of the studies conducted on numeracy seems to be the lack of appropriate assessments. The TEMA-3 was used to assess students' numeracy skills in the study described in Chapter 4. This is a standardised assessment focusing on early numeracy skills. However, the TEMA-3 is not fully accessible to students with DD due to the complex language and long instructions. Also, some questions require a verbal response so the assessment is not suitable for students with limited verbal communication. It was not possible to calculate standardised scores for the TEMA-3 as most participating students exceeded the age range for this assessment. Additionally, no comprehensive assessments that could be used to evaluate learning-to-learn and numeracy readiness skills targeted in the TEN-DD R programme were identified. Instead, two measures were combined – sub-tests of ABLLS-R and the TEN-DD R bespoke assessment which we have developed. Both assessments are completed by educators so their objectivity cannot be guaranteed.

Furthermore, teachers in the study described in Chapter 4 pointed out that the TEN-DD programme is not yet fully adapted to be used with students with limited verbal communication. A document outlining changes that can be made for each key stage was provided with the teaching plans, however more structured adaptations for students with limited verbal communication are needed.

A few teachers in Chapter 4 also mentioned that they found some teaching plans difficult to understand and needed to ask the mentors or colleagues for clarification. Our aim for the TEN-DD programme is that it is fully accessible to educators from diverse backgrounds and with no experience with Systematic Instruction methodology. The teaching plans have been significantly modified in preparation for this study. However, further simplifications of the format and content should be considered.

This thesis focused on exploring the ways in which Systematic Instruction interventions can be implemented with reduced input from the researchers. We did it by familiarising ourselves with a teaching system of a large special school, consulting with the senior leadership team and the teaching staff, as well as trialling different solutions. This required significant time investment that might not be possible outside of a research context. Chapter 4 described an implementation of the TEN-DD programme using a school staff delivery model. The intervention was delivered solely by educators with no or little previous experience with Systematic Instruction. However, it is important to note that the research staff were still significantly involved in the intervention through providing regular in-class training and supervision. We hoped to address this in a study described in Chapter 6 which contains a description of a further developed school staff delivery model. We have created a peer mentoring system and nominated a TEN-DD R designated lead to ensure the participating school is as independent as possible. The research team was only involved in training (initial and in-class) and was planned to be available for periodical check-in sessions.

Future research

The research on numeracy education conducted as part of this thesis represents the initial stages of the MRC complex intervention framework (Craig et al., 2008) – development, piloting, and feasibility.

Before further research is planned on the TEN-DD and TEN-DD R programmes it is advisable to consider developing robust numeracy and numeracy readiness assessments that are accessible to students with moderate to severe DD. The TEMA-3 can be used to assess students' progress in relation to the TEN-DD, however it is not optimal due to the reasons described in the previous section.

Chapter 4 contains recommendations for changes made by the educators after a full school year of using the TEN-DD programme. The suggestions were grouped into three main categories: training, implementation, and materials. Most frequently, educators suggested that it would be helpful to reduce the amount of theory described during the initial training session, to divide the training into several shorter sessions, or to offer follow up training during the school year. Many educators also suggested that they would have preferred the wording of instructions and the teaching procedures to be simplified. Educators also often mentioned the need for more structured and systematic changes to the teaching plans to accommodate the needs of students with limited verbal communication. This feedback was used to inform the development of the TEN-DD R programme. It is vital that those suggestions for changes are also considered and implemented where appropriate in the TEN-DD programme before further research is conducted. Once the suggestions for changes are implemented, further piloting of the amended programme should take place, including measures to gather educators' feedback. Incorporating a comparison group (possibly with randomisation) could also be beneficial at this stage. If the results are positive, a larger scale RCT study is advised.

The TEN-DD R programme should also undergo a piloting process in line with the MRC complex intervention framework (Craig et al., 2008). Chapter 6 contains a protocol for a feasibility RCT study. This should also involve interviews with educators to explore their experiences and perceptions on the programme and to gather their suggestions for changes. Focus groups could also be beneficial at this stage. If the programme is found to be feasible to implement and to teach the numeracy readiness skills, then a larger study involving a comparison group and randomisation would be warranted.

Following on from Chapter 6, further work should also be carried out on the development of the teaching staff delivery model. It is vital that Systematic Instruction interventions are accessible to all schools and educators with diverse backgrounds. Ideally, involvement of external specialists in the implementation of the TEN-DD and TEN-DD R programmes should be minimised and focus should be placed on providing training to the designated lead in the school.

Personal statement

Completing this thesis has been a very enriching experience and extreme privilege. My ultimate goal was always to contribute to making positive changes in the lives of people with DD. As an ABA practitioner I could clearly see the difference a carefully planned use of behavioural science can make to the lives of autistic individuals as well as those with ID. However, it was also clear to me that the use of behavioural interventions is largely limited to highly specialist settings which represent a minority of educational provisions in the UK (Department for Education, 2020b). This thesis focused on applications of Systematic Instruction in a special education context that is more ‘typical’ for the UK, and with educators with no or little previous experience with this methodology. The overarching aim was to contribute to building an evidence base of the use of behavioural interventions in a range of settings and to contribute to the development of improved numeracy and science education practices for people with DD.

This process involved multiple steps. Perhaps the most important was familiarising myself with a school's existing system - the teaching organisation, the needs of the students, the time that educators are able and willing to spend on lesson preparation and data collection, and the availability of training time and resources. This also involved an exploration of educators' current knowledge about Systematic Instruction and any concerns they may have regarding its use. This was made possible by building a rapport with educators and having informal discussions with a variety of school staff – from the school leadership team to subject leaders, class teachers and the TAs. I also spent a significant amount of time observing numeracy and science lessons across the school and consulting with educators on the use of a variety of implementation models and resources. This step was crucial in helping to inform the later use of the interventions, including the training, and monitoring arrangements.

While planning and conducting the studies described in this thesis, we collaborated with the school leadership team and teaching staff. Our aim was to utilise their teaching expertise and knowledge about students as much as possible. Subject leaders and the school's leadership team also played an important role in helping us to select the interventions and plan implementation. In addition, teaching staff were frequently consulted about the suitability of the teaching materials and data collection systems.

We gathered information on the acceptability of interventions included in the systematic review (Chapter 2) to ensure that the methodology selected for Chapter 3 has been positively evaluated by educators. Both empirical studies in this thesis (Chapters 3 and 4) included formal or informal feedback from the educators, exploring their perceptions and experiences of using the interventions. The same was planned for the evaluation described in Chapter 6. Gathered feedback will inform implementation of the interventions in the future as well as the use of Systematic Instruction methodology in special education settings in the UK more generally.

Although our results are encouraging and teaching programmes used in this thesis (ES curriculum and TEN-DD programme) were accepted by the teachers, there were several issues we had to overcome along the way. Initially, educators' perceptions of the Systematic Instruction were negative and were potentially a significant barrier to the implementation of any behavioural interventions in the school. The educators were concerned that Systematic Instruction interventions are repetitive and too prescriptive and that they do not encourage students' natural curiosity and inquiry skills. The science teacher also suggested that behavioural teaching methods might discourage deeper understanding and focus only on teaching facts. This in turn meant that she did not think that behavioural interventions would enable students to be able to acquire the skills necessary to be able to 'work scientifically', one of the core areas in the English science standards. Some class teachers also mentioned that Systematic Instruction should only be used by TAs who might lack any formal teaching qualification and that it should not be used by teachers as it detracts from their competencies and skills. Other initial barriers included low staff to student ratios available in the school and very limited training time that could be used for any potential interventions.

Overcoming the latter barriers of low staff ratios, and limited training time, was possible by working in collaboration with the school and considering their existing system and strategies. However, addressing educators' reluctance to the use of Systematic Instruction was much more complex. It is worth noting that we were in a privileged position, having been contracted, and as a result supported, by the senior leadership team to implement evidence-based interventions, which according to the research literature were clearly of behavioural origin. However, it was still important that educators working on delivering the interventions were comfortable with the teaching methodology. I was able to spend some time building a rapport with the involved educators and subject leads, presenting them with evidence on using Systematic Instruction to teach academic content to students with DD, modelling the delivery, collaborating on creating implementation systems they would find useful, and feasible as well as addressing individual concerns. I do acknowledge that this might not be possible in larger evaluations or outside of the research context. However, time invested in working with the educators and addressing their concerns meant that the group of educators involved in the studies then became advocates for the interventions, and Systematic Instruction more broadly, among other school staff. The TEN-DD programme is still used in the school and the training and implementation is overseen solely by the subject lead and teachers that participated in the study described in Chapter 4. They invite other class teachers and TAs to observe their numeracy lessons to encourage them to try the programme. The science teacher who was initially very apprehensive about Systematic Instruction is now an advocate for the ES curriculum among other special schools and science education leaders in the UK.

Conclusions

This thesis focused on science and numeracy - STEM subjects that are core areas of focus in mainstream programmes of study in England and internationally. We decided to concentrate on those subjects as despite their importance, they are still under researched when it comes to the education of students with DD (Spooner et al., 2017; Grindle et al., 2020; Apanasionok et al., 2019 - Chapter 2). The attainment of disabled students in science and mathematics is also poor and of concern to educators and researchers (Department for Education, 2020b). This thesis started with a systematic review to explore what interventions exist to teach science to this population and what are the views and experiences of the educators and students using them. Systematic Instruction was the most frequently used teaching approach in the included studies, so the following chapter described a feasibility study on using a science curriculum that utilised behavioural teaching methods. The second half of this thesis focused on numeracy. Chapter 4 described the implementation of the TEN-DD programme with autistic students using a school staff delivery model. It described a training and mentoring system that enabled teaching staff with no or little previous experience with Systematic Instruction to implement the programme. The remaining two chapters described the development of the TEN-DD R programme which focuses on learning-to-learn and numeracy readiness skills and provided a protocol for a feasibility RCT.

More work needs to be carried out to improve the interventions used in this thesis and to pilot their use in different special schools in the UK to ensure their generalisability across multiple settings. Following that, more robust research is needed to establish an evidence base in line with the MRC complex intervention framework (Craig et al., 2008).

References

Alallawi, B., Denne, L., Apanasionok, M. M., Grindle, C. F., & Hastings, R. P. (in press). Special Educators' Experiences of a Numeracy Intervention for Students with Autism Spectrum Disorder.

American Psychiatric Association. (2013*). Diagnostic and statistical manual of mental disorders (5th ed.).* American Psychiatric Publishing.

Apanasionok, M. M., Hastings, R. P., Grindle, C. F., Watkins, R. C., & Paris, A. (2019). Teaching science skills and knowledge to students with developmental disabilities: A systematic review. *Journal of Research in Science Teaching*, 56(7), 847-880. https://doi.org/10.1002/tea.21531

Apanasionok, M. M., Neil, J., Watkins, R. C., Grindle, C. F., & Hastings, R. P. (2020). Teaching Science to Students with Developmental Disabilities Using the Early Science Curriculum. *Support for Learning.*

Apanasionok, M. M., Alallawi, B., Grindle, C. F., Hastings, R. P., Watkins, R. C., Nicholls, G., Maguire, L., & Staunton, D. (2021). Teaching early numeracy to students with autism using a teacher delivery model. *British Journal of Special Education*.

Agran, M., Cavin, M., Wehmeyer, M., & Palmer, S. (2006). Participation of students with Moderate to severe disabilities in the general curriculum: The effects of the self-determined learning model of instruction. *Research & Practice for Persons with Severe Disabilities,* 31(3), 230-241.

Beery K. E., Buktenica N. A., & Beery N. A. (2010). *The Beery–Buktenica Developmental Test of Visual–Motor Integration: Administration, scoring, and teaching manual* (6th ed.). Pearson.

Brigance, A., H., & French, B., F. (2013). *Brigance Inventory for Early Development III*. Curriculum Associates.

Bronfenbrenner, U., & Morris, P. A. (2006). The Bioecological Model of Human Development. In R. M. Lerner & W. Damon (Eds.), *Handbook of child psychology: Theoretical models of human development* (p. 793–828). John Wiley & Sons Inc.

Browder, D. M. (2001). *Curriculum and assessment for students with moderate and severe disabilities*. Guildford Press.

Browder, D. M., Spooner, F., Ahlgrim-Delzell, L., Harris, A., & Wakeman, S. (2008). A meta-analysis on teaching mathematics to students with significant cognitive disabilities. *Exceptional Children*, 74, 407-432. https://doi.org/10.1177/001440290807400401

Browder, D. M., Trela, K., Courtade, G. R., Jimenez, B. A., Knight, V., & Flowers, C. (2010). Teaching mathematics and science standards to students with moderate and severe developmental disabilities. *The Journal of Special Education,* 20(10), 1-10. https://doi.org/10.1177/0022466910369942.

Browder, D. M., & Spooner, F. (2011). *Teaching students with moderate and severe disabilities.* The Guilford Press.

Cage, E., Di Monaco, J., & Newell, V. (2018). Experiences of autism acceptance and mental health in autistic adults. *Journal of Autism and Developmental Disorders, 48,* 473-484.

Carnahan, C. R., & Williamson, P. S. (2013). Does compare-contrast text structure help students with autism spectrum disorder comprehend science text? *Council for Exceptional Children*, 79(3), 347-363.

Carnahan, C. R., Williamson, P., Birri, N., Swoboda, C., & Snyder, K. K. (2016). Increasing comprehension of expository science text for students with autism spectrum disorder. *Focus on Autism and Other Developmental Disabilities*, 31(3), 208-220. https://doi.org/10.1177/1088357615610539.

Cobern, W., Schuster, D., Adams, B., Appelgate, B., Skjold, B., Undrieu, A., Loving, C. C., & Gobert, J. D. (2010). Experimental comparison of inquiry and direct instruction in science. *Research in Science & Technological Education*, 28(1), 81-96.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences* (2nd ed.). Academic Press.

Collins, B. C., Evans, A., Creech-Galloway, C., Karl, J., & Miller, A. (2007). Comparison of the acquisition and maintenance of teaching functional and core content sight words in special and general education settings. *Focus on Autism and Other Developmental Disabilities*, 22(4), 220-235.

Collins, B. C., Hager, K. L., & Creech-Galloway, C. (2011). Addition of functional content during core content instruction with students with moderate disabilities. *Education and Training in Autism and Developmental Disabilities*, 46(1), 22-39.

Collins, B. C. (2012). *Systematic instruction for students with moderate to severe disabilities.* Paul H. Brookes Publishing Co.

Collins, B. C., Terrell, M., & Test, D. W. (2017). Using a simultaneous prompting procedure to embed core content when teaching a potential employment skill. *Career Development and Transition for Exceptional Individuals*, 40(1), 36-44. https://doi.org/10.1177/2165143416680347.

Courtade, G. R., Spooner, F., & Browder, D. M. (2007). Review of studies with students with significant cognitive disabilities which link to science standards. *Research & Practice for Persons with Severe Disabilities*, 32(1), 43-49.

Courtade, G. R., Browder, D. M., Spooner, F., & DiBiase, W. (2010). Training teachers to use an inquiry-based task analysis to teach science to students with moderate and severe disabilities. *Education and Training in Autism and Developmental Disabilities*, 45(3), 378-399.

Craig P., Dieppe P., Macintyre S., Michie S., Nazareth I., & Petticrew M. (2008). Developing and evaluating complex interventions: the new Medical Research Council guidance. BMJ, 337.

Critical Appraisal Skills Programme. (2017). CASP (Randomised Controlled Trial) Checklist. http://www.casp-uk.net/casp-tools-checklists

Cullen, M. A., Lindsay, G., Hastings, R., Denne, L., Stanford, C., Beqiraq, L., Elahi, F., Gemegah, E., Hayden, N., Kander, I., Lykomitrou F., & Zander, J. (2020). *Special Educational Needs in Mainstream Schools: Evidence Review*. Education Endowment Foundation.

Department for Education, 2014a. National curriculum in England: framework for key stages 1 to 4. https://www.gov.uk/government/publications/national-curriculum-in-england-framework-for-key-stages-1-to-4/the-national-curriculum-in-england-framework-for-key-stages-1-to-4

Department for Education, 2014b. National curriculum in England: mathematics programmes of study. https://www.gov.uk/government/publications/national-curriculum-in-england-mathematics-programmes-of-study/national-curriculum-in-england-mathematics-programmes-of-study

Department for Education. 2014c. The Equality Act and Schools. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/315587/Equality_Act_Advice_Final.pdf

Department for Education, 2015a. National curriculum in England: science programmes of study. https://www.gov.uk/government/publications/national-curriculum-in-england-science-programmes-of-study/national-curriculum-in-england-science-programmes-of-study

Department for Education. 2015b. Special Educational Needs and Disability Code of Practice: 0 to 25 years. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/398815/SEND_Code_of_Practice_January_2015.pdf

Department for Education. (2017). Statutory framework for the early years foundation stage. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/596629/EYFS_STATUTORY_FRAMEWORK_2017.pdf

Department for Education. (2020a). Special educational needs in England: January 2020. https://www.gov.uk/government/statistics/special-educational-needs-in-england-january-2020

Department for Education. (2020b). Special educational needs: an analysis and summary of data sources. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/882802/Special_educational_needs_and_disability_-_an_analysis_and_summary_of_data_sources.pdf

Department for Education. (2020c). Level 2 and 3 attainment in England: attainment by the age 19 in 2019. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/881199/Level_2_and_3_attainment_by_19_2019_statistical_commentary.pdf

Dunlap, W. P., Cortina, J. M., Vaslow, J. B., & Burke, M. J. (1996). Meta-analysis of experiments with matched groups or repeated measures designs. *Psychological Methods*, 1(2), 170-177.

Every Student Succeeds Act, Pub.L. No. 114-95, § 1177 Stat. (2015).

Fetko, E. E., Collins, B. C., Hager, K. D., & Spriggs, A. D. (2013). Embedding science facts in leisure skill instruction conducted by peer tutors. *Education and Training in Autism and Developmental Disabilities*, 48(3), 400-411.

Goldsworthy, A., Watson, R., & Wood-Robinson, V. (2000) *Investigations: Developing understanding*. The Association for Science Education.

Grindle, C. F, Hastings, P. R., & Wright, R. J. (2020). *Teaching early numeracy to children with developmental disabilities.* SAGE Publications Ltd.

Harlen, W. (2015). *Working with Big Ideas of Science Education.* Global Network of Science Academies (IAP) Science Education Programme.

Heinrich, S., Collins, B. C., Knight, V., & Spriggs, A. D. (2016). Embedded simultaneous prompting procedure to teach STEM content to high school students with moderate disabilities in an inclusive setting. *Education and Training in Autism and Developmental Disabilities*, 51(1), 41-54.

Heward, W. L. (2003). Ten faulty notions about teaching and learning that hinder the effectiveness of special education. *The Journal of Special Education*, 36(4), 186-205.

Horner, R. H., Carr, E. G., Halle, J., McGee, G., Odom, S., & Wolery, M. (2005). The use of single-subject research to identify evidence-based practice in special education. *Council for Exceptional Children*, 71(2), 165-179.

Hsieh, H. F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, 15(9), 1277-1288. https://doi.org/10.1177/1049732305276687

Hu, F., Hu, Y., Ma, Z., & Rosenberger, W. F. (2014). *Adaptive randomization for balancing over covariates.* Wiley Interdisciplinary Reviews: Computational Statistics, 6(4), 288-303.

Hudson, M. E., Browder, D. M., & Jimenez, B. A. (2014). Effects of a peer-delivered system of least prompts intervention and adapted science read-alouds on listening comprehension for participants with moderate intellectual disability. *Education and Training in Autism and Developmental Disabilities*, 49(1), 60-77.

Jameson, J. M., McDonnell, J., Johnson, J. W., Riesen, T., & Polychronis, S. (2007). A comparison of one-to-one embedded instruction in the general education classroom and one-to-one massed practice instruction in the special education classroom. *Education and Treatment of Children*, 30(1), 23-44.

Jimenez, B. A., Browder, D. M., & Courtade, G. R. (2009). An exploratory study of self-directed science concept learning by students with moderate intellectual disability. *Research & Practice for Persons with Severe Disabilities*, 34(2), 33-46.

Jimenez, B. A., Browder, D. M., Spooner, F., & DiBiase, W. (2012a). Inclusive inquiry science using peer-mediated embedded instruction for students with moderate intellectual disability. *Council for Exceptional Children*, 78(3), 301-317.

Jimenez, B., Knight, V., & Browder, D. (2012b). *Early science curriculum*. Attainment Company.

Jimenez, B. A., Lo, Y., & Saunders, A. (2014). The additive effects of scripted lessons plus guided notes on science quiz scores of students with intellectual disabilities and autism. *Journal of Special Education*, 47(4), 231-244. https://doi.org/10.1177/0022466912437937.

Johnson, J. W., McDonnell, J., Holzwarth, V. N. & Hunter, K. (2004). The efficacy of embedded instruction for students with developmental disabilities enrolled in general education classes. *Journal of Positive Behavior Interventions*, 6(4), 214-227.

Karl, J., Collins, B. C., Hager, K. D., & Jones Ault, M. (2013). Teaching core content embedded in a functional activity to students with moderate intellectual disability using a simultaneous prompting procedure. *Education and Training in Autism and Developmental Disabilities*, 48(3), 363-378.

Kirschner, P. A., Sweller, J., & Clarke, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, 41(1), 75–86.

Knight, V. F., Smith, B. R., Spooner, F., & Browder, D. (2012). Using explicit instruction to teach science descriptors to students with autism spectrum disorder. *Journal of Autism and Developmental Disorders*. 42(3), 378-389. https://doi.org/10.1007/s10803-011-1258-1.

Knight, V. F., Spooner, F., Browder, D. M., Smith, B. R. & Wood, C. L. (2013). Using systematic instruction and graphic organizers to teach science concepts to students with autism spectrum disorders and intellectual disability. *Focus on Autism and Other Developmental Disabilities*, 28(2), 115-126. https://doi.org/10.1 177/108835761247530 I.

Knight, V. F., Wood, C. L., Spooner, F., Browder, D. M., & O'Brien, C. P. (2014). An exploratory study using science eTexts with students with autism spectrum disorder. *Focus on Autism and Other Developmental Disorders*, 1-14. https://doi.org/10.1177/1088357614559214.

Knight, V. F., Creech-Galloway, C. E., Karl, J. M., & Collins, B. C. (2017). Evaluating supported eText to teach science to high school students with moderate intellectual disability. *Focus on Autism and Other Developmental Disabilities*, 1-10. https://doi.org/10.1177/1088357617696273.

Knight, V. F., Collins, B., Spriggs, A. D., Sartini, E., & McDonald, M. J. (2018). Scripted and unscripted science lessons for children with autism and intellectual disability. *Journal of Autism and Developmental Disorders*, 48, 2542-2557.

Lee, A., Browder, D. M., Flowers, C., & Wakeman, S. (2016). Teacher evaluation of resources designed for adapting mathematics for student with significant cognitive disabilities. *Research and Practice for Persons with Severe Disabilities*, 41(2), 132-137. https://doi.org/10.1177/1540796916634099.

Mayer, R. (2004). Should there be a three-strikes rule against pure discovery learning? The case for guided methods of instruction. *American Psychologist*, 59, 14-19.

McConkey, R., Slater, P., Smith, A., Dubois, L., & Shellard, A. (2020). Perceptions of the rights and capabilities of people with intellectual disability in the United States. *Journal of Applied Research in Intellectual Disabilities.*

McDonnell, J., Johnson, J. W., Polychronis, S., Riesen, T., Jameson, M., & Kercher, K. (2006). Comparison of one-to-one embedded instruction in general education classes with small group instruction in special education classes. *Education and Training in Developmental Disabilities*, 41(2), 125-138.

McGill, O., & Robinson, A. (2020). “Recalling hidden harm”: autistic experiences of childhood applied behaviour analysis (ABA). *Advances in Autism.*

McGinnis, J. R., & Kahn, S. (2014). Special needs and talents in science learning. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (Vol. II, pp. 223–245). Routledge.

McMahon, D. D., Cihak, D. F., Wright, R. E., & Bell, S. M. (2016). Augmented reality for teaching science vocabulary to postsecondary education students with intellectual disabilities and autism. *Journal of Research on Technology in Education*, 48(1), 1-19. https://doi.org/10.1080/15391523.2015.1103149.

Mechling, L. C., Gast, D. L., & Fields, E. A. (2008). Evaluation of a portable DVD player and system of least prompts to self-prompt cooking task completion by young adults with moderate intellectual disabilities. *The Journal of Special Education*, 42(3), 179-190. https://doi.org/10.1177/0022466907313348.

Miller, B., & Taber-Doughty, T. (2014). Self-monitoring checklists for inquiry problem-solving: functional problem-solving methods for students with intellectual disability. *Education and Training in Autism and Developmental Disabilities*, 49(4), 555-567.

Miller, B., Doughty, T., & Krockover, G. (2015). Using science inquiry methods to promote self-determination and problem-solving skills for students with moderate intellectual disability. *Education and Training in Autism and Developmental Disabilities*, 50(3), 356-368.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLoS Medicine, 6(7), 1–6. https://doi.org/10.1371/journal.pmed.1000097

Morris, S. B. (2008). Estimating effect sizes from pretest-posttest-control group designs. *Organizational Research Methods*, 11, 364–386. https://doi.org/10.1177/1094428106291059.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.

National Research Council. (1996). *National Science Education Standards*. The National Academies Press.

National Research Council. (2013). *Next Generation Science Standards: For States, By States.* The National Academies Press.

No Child Left Behind Act of 2001. Pub. L. No.' 107-110, 115 Stat. 1425 (2002).

Novak, J. D. (1988). Learning science and the science of learning. *Studies in Science Education*, 15, 77-101.

Partington, J. W. (2006). *The assessment of basic language and learning skills-revised (the ABLLS-R)*. Behavior Analysts.

Piaget, J. (1959). *The language and thought of the child.* Routledge & Kegan Paul.

Riesen, T., McDonnell, J., Johnson, J. W., Polychronis, S., & Jameson, M. (2003). A comparison of constant time delay and simultaneous prompting within embedded instruction in general education classed with students with moderate to severe disabilities. *Journal of Behavioral Education*, 12(4), 241-259.

Riggs, L., Collins, B. C., Kleinert, H., & Knight, V. F. (2013). Teaching principles of heredity to high school students with moderate and severe disabilities. *Research & Practice for Persons with Severe Disabilities*, 38(1), 30-43.

Rizzo, K. L., & Taylor, J. C. (2016). Effects of inquiry-based instruction on science achievement for students with disabilities: An analysis of the literature. *Journal of Science Education for Students with Disabilities*, 19(1), 1-16.

Roberts, V., & Joiner, R. (2007). Investigating the efficacy of concept mapping with pupils with autistic spectrum disorder. *British Journal of Special Education*, 34(3), 127-135.

Rogers, S. J., & Dawson, G. (2010). *Early Start Denver Model for young children with autism: Promoting language, learning, and engagement*. Guilford Press.

Sawyer, R. K. (2008). *Optimising learning: implications of learning sciences research*. In Innovating to Learn, Learning to Innovate, OECD Publishing. https://doi.org/10.1787/9789264047983-4-en.

Science Council. (n.d.). Our definition of science. http://sciencecouncil.org/about-science/our-definition-of-science/

Smith, B. R., Spooner, F., & Wood, C. L. (2013a). Using embedded computer-assisted explicit instruction to teach science to students with autism spectrum disorder. *Research in Autism Spectrum Disorder*, 7(3), 433-443. https://doi.org/10.1016/j.rasd.2012.10.010.

Smith, B. R., Spooner, F., Jimenez, B. A., & Browder, D. (2013b). Using an early science curriculum to teach science vocabulary and concepts to students with severe developmental disabilities. *Education and Treatment of Children*, 36(1), 1-31.

Snyder, T. D., de Brey, C., & Dillow, S. A. (2018). *Digest of Education Statistics*, 2016 (NCES 2017-094). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education.

Spooner, F., Knight, V., Browder, D., Jimenez, B., & DiBiase, W. (2011). Evaluating evidence-based practice in teaching science content to students with severe developmental disabilities. *Research & Practice for Persons with Severe Disabilities*, 36(1-2), 62-75.

Spooner, F., McKissick, B. R., Knight, V., & Walker, R. (2014). *Teaching Science Concepts*. In Browder, D., & Spooner, F. (Ed.), More Language Arts, Math, and Science for Students with Severe Disabilities. (pp. 215-236). Paul H. Brookes Publishing Co.

Spooner, F., & Browder, D. M. (2015). Raising the bar: significant advances and future needs for promoting learning for students with severe disabilities. *Remedial and Special Education*, 36 (1), 28-32. https://doi.org/10.1177/0741932514555022

Spooner, F., McKissick, B. R., & Knight, V. F. (2017). Establishing the state of affairs for evidence-based practices in students with severe disabilities. *Research and Practice for Persons with Severe Disabilities*, 42(1), 8-18. https://doi.org/10.1177/1540796916684896

Spooner, F., Root, J. R., Saunders, A. F., & Browder, D. M. (2019). An updated evidence-based practice review on teaching mathematics to students with moderate to severe developmental disabilities. *Remedial and Special Education*, 40(3), 150-165. https://doi.org/10.1177/0741932517751055

Staves, L. (2019). *Very special maths: Developing thinking and maths skills for pupils with severe or complex learning difficulties*. Routledge.

Steffe, L., & Gale, J. (Eds.). (1995). Constructivism in education. Lawrence Erlbaum Associates, Inc.

Sundberg, M. L. (2014). *The verbal behavior milestones assessment and placement program: The VB-MAPP (2nd ed.).* AVB Press.

Taber, T. A., Alberto, P. A., Hughes, M., & Seltzer, A. (2002). A strategy for students with moderate disabilities when lost in the community. *Research & Practice for Persons with Severe Disabilities*, 27(2), 141-152.

Taubman, M., Brierley, S., Wisher, J., Baker, D., McEachin, J., & Leaf, R. B. (2001). The effectiveness of a group discrete trial instructional approach for pre-schoolers with developmental disabilities. *Research in Developmental Disabilities*, 22, 205-219.

The Nation's Report Card. (n.d.). *2015 Science Assessment*. https://www.nationsreportcard.gov/science_2015/#?grade=4

Tolmie, A. K., Ghazali, Z. & Morris, S. (2016). Children's science learning: A core skills approach. *British Journal of Educational Psychology*, 86, 481-497

Tzanakaki, P., Grindle, C. F., Saville, M., Hastings, R. P., Hughes, J. C., & Huxley, K. (2014a). An individualised curriculum to teach numeracy skills to children with autism: programme description and pilot data. *Support for Learning*, 29(4), 319-338. https://doi.org/10.1111/1467-9604.12069

Tzanakaki, P., Hastings, R. P., Grindle, C. F., Hughes, J. C., & Hoare, Z. (2014b). An individualized numeracy curriculum for children with intellectual disabilities: a single blind pilot randomized controlled trial. *Journal of Developmental & Physical Disabilities*, 26, 615-632. https://doi.org/10.1007/s10882-014-9387-z

United Nations Educational, Scientific and Cultural Organization (UNESCO). (2017). *A guide for ensuring inclusion and equity in education*. UNESCO.

Wang, J., & Feigenson, L. (2019). Infants recognize counting as numerically relevant. *Developmental Science*, 22(6), pp. 1-10. https://doi.org/10.1111/desc.12805

Watkins, R. M., Apanasionok, M. M., & Neil, J. (2020). Teaching science to pupils with SEND: using an evidence-based approach. *Primary Science*, 165

Wight, D., Wimbush, E., Jepson, R., & Doi, L. (2016). Six steps in quality intervention development (6SQuID). *Journal of Epidemiology & Community Health*, 70, 520-525.

Wright, R. J., Ellemor-Collins, D., & Tabor, P. D. (2012). Developing number knowledge: Assessment, teaching & intervention with 7-11-years-olds. SAGE Publications Ltd.

Appendices

Appendix 1. PRISMA 2009 checklist from Moher et al. (2009) completed for Chapter 2.

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	40
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	41
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	48-49
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	49
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	49
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	49-50
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	50-51
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	50-52
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	53-54

Section/topic	#	Checklist item	Reported on page #
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	54
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	54
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	53-54
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	54
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	54
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	53-54
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	n/a
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	54-56
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	56-58 61-78 81-84 87-88
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Appendix 6

			Appendix 7
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	61-78 81-84 87-88
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	58-89
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	53-54
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	89-96
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	92-96
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	95-96
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	40

Appendix 2. Summary of study on feasibility of ES curriculum (Chapter 3) published in teacher journal.

Research

Richard Watkins, Magdalena Apanasionok and **Julie Neil** explain how they used systematic instruction to teach science enquiry skills and conceptual understanding in a special school

Learning the concept of taste by filling out the concept statement card for the lesson on smell and taste

Teaching science to pupils with SEND: using an evidence-based approach

In their recent review of special educational needs in schools, the Education Endowment Foundation (EEF, 2020) highlights the fact that teaching strategies that we know work well for mainstream learners are also likely to be effective for pupils with special educational needs and disabilities (SEND). These strategies include:

- **flexible grouping;**
- **cognitive and metacognitive strategies;**
- **explicit instruction;**
- **using technology;**
- **scaffolding.**

Over recent years there have been a number of accessible and useful research summaries for teachers, often highlighting the effectiveness of general teaching strategies such as explicit instruction, scaffolding and task-specific feedback (Spooner, McKissick and Knight, 2017; Apanasionok *et al*., 2019; Knight *et al*., 2019), but very little research has been turned into practical classroom materials to help teachers improve the provision of science.

There is also a need to support the teaching of science to improve outcomes for pupils with SEND. In England, 14.9% of school-age children are identified as having SEND (DfE, 2019). In 2019, 42% of pupils with special educational needs (SEN) achieved the expected standard in science at the end of key stage 1 (age 7) compared to 90% of pupils with no SEN (DfE, 2020). In the same year, 22% of pupils with SEN reached the expected standard in reading, writing and maths at the end of key stage 2 (age 11) compared with 74% of their peers, and this attainment gap has remained stable since 2017 (DfE, 2020). In this article we describe how we used an evidence-based science programme called the Early Science curriculum to teach science to pupils in a special school, in particular learners with intellectual disability and/or autism spectrum disorder.

Teaching science to pupils with SEND

Over the last few decades many teachers in mainstream and special

Key words: SEND Systematic instruction

schools have favoured cognitive (constructivist) teaching approaches that enable pupils to build their understanding of scientific ideas by undertaking practical scientific inquiry tasks (often called inquiry-based learning). Examples of this style of teaching are common in this journal and also feature prominently in many practical guides to teaching science in primary schools (Serret and Earle, 2018).

In England, the science programme of study for key stages 1 and 2 (ages 5–11) is centred around three main aims: to help pupils develop scientific knowledge and conceptual understanding; to develop an understanding of the nature, processes and methods of science (known as 'working scientifically'); and to ensure pupils can understand the uses and implications of science (DfE, 2015). Teaching this content to pupils with SEND using inquiry or discovery-based teaching strategies can be challenging. These strategies are often successful with typically developing learners in mainstream settings, but can be less effective for less-able pupils and pupils with disabilities (Rizzo and Taylor, 2016).

Our research, focused on the existing research literature on teaching science to pupils with SEND, has indicated that science programmes using behavioural teaching strategies (e.g. systematic instruction – a teaching method focused on breaking down complex skills into smaller steps and promoting generalisation) may be an effective way to improve science outcomes (Apanasionok *et al.*, 2019).

The Early Science curriculum

The Early Science curriculum (Jimenez, Knight and Browder, 2012) uses systematic instruction approaches to teach pupils science knowledge and skills through a series of structured lessons and practical enquiry activities. It has been identified as a promising programme in several studies (Smith *et al.*, 2013; Jimenez, Lo and Saunders, 2014; Knight *et al.*, 2018; Apanasionok *et al.*, 2020) and in a systematic review (a systematic review is a higher-order literature search that critically appraises all relevant research in a given field; Apanasionok *et al.*, 2019).

The scientific content in the Early Science curriculum aligns with the elementary school science education standards in the USA (National Research Council, 2000). The curriculum consists of four units: *The five senses*, *The rock cycle*, *Earth and sky* and *The life cycle*, and we found this content aligned well with most primary science curricula in the United Kingdom. In particular, *The five senses* and *The life cycle* units fall within the key stage 1 (ages 5–7) science programme of study in England, including knowledge and conceptual understanding and scientific methods and processes (DfE, 2015). Each unit consists of seven lessons: the first six lessons introduce new topics and the seventh consolidates the content in each unit. Each lesson is repeated multiple times (at least twice) until all pupils in the class become confident with the key skills and vocabulary. Lessons consist of seven main teaching components:

- **guided inquiry;**
- **teacher scripts;**
- **a *Wonder Wally* storybook (stories with pictures to support each lesson);**
- **science safety information;**
- **explicit instruction;**
- **task analysis;**
- **special accommodations/ adjustments for the pupils, e.g. amending some of the practical tasks.**

Box 1 describes some key features of the curriculum.

Using the Early Science curriculum

We decided to work with a class of nine pupils from a primary department in a large special school to evaluate whether we could use the Early Science curriculum in a UK school setting. The learners in our study had diagnoses of autism spectrum disorder (ASD), intellectual disability (ID) and profound and multiple intellectual disabilities (PMID). The class teacher and two teaching assistants were trained in the implementation and delivery of the Early Science curriculum and supported pupils during the science lessons.

Due to time limitations, we focused only on the first unit of the curriculum: *The five senses*. We used materials included in the Early Science curriculum pack, including picture-word cards, lesson scripts, photo cards, a KWHL (What do we **K**now?, What do we **W**ant to know?, **H**ow can we find out? and What did we **L**earn?) chart, and science safety cards/resources. We gave each pupil a *My Science Log* (a set of multiple-choice quizzes implemented after each lesson to assess understanding), and the progress monitoring form included in the curriculum pack was used to monitor the progress of individual pupils.

We found we could deliver most sessions in the 40-minute time slot allocated to teaching science in the school's timetable. Each lesson started with pupils greeting a fictional *Wonder Wally* character displayed on a poster in the front of the classroom. The science teacher then introduced the main focus of the lesson and read

Box 1 Key features of the Early Science curriculum

Guided inquiry	A process of explicitly teaching inquiry skills, described by Jimenez *et al.* (2012) as teaching the learners '*how to learn about their natural world*'. It comprises five steps related to critical inquiry skills: engage, investigate, describe, explain and report.
Explicit instruction	This is an active teaching method involving time-delay procedure (prompt/help for the pupil is delivered following a specific amount of time after the instruction), most-to-least prompting procedure and an example and non-example procedure (where the pupil is presented with an example and non-example of an item which the teacher clearly labels: '*This is …*' or '*This is not …*').
Task analysis	This is a strategy whereby teachers break down a complex task into a number of smaller, more achievable steps.
Scripted lessons	Each lesson is scripted and colour-coded to increase accessibility and reduce teacher preparation time. The scripts also include expected responses from the pupils, descriptions of the practical activities and key vocabulary to be targeted for that specific lesson.

Learning the concept and key vocabulary for the lesson on touch by describing the feel and texture of a duckling and identifying the correct vocabulary card

one story from the *Wonder Wally* storybook, emphasising the key scientific vocabulary we needed to introduce. All the lessons followed the same teaching steps and focused on simple exploration tasks that allowed pupils to make simple predictions and record observations. At the end of the session, we made sure pupils were able to review their observations and discuss ideas in the context of their initial predictions. The remaining time at the end of a lesson was spent on a review of key concepts and the completion of their *My Science Logs*.

Staff and pupil feedback

We found that nearly all pupils engaged very well with the Early Science curriculum lessons. Many pupils were able to remember some of the key concepts several weeks after the lessons, something that was not typically the case with this cohort of pupils; for example, nearly all the pupils were able to recall the five senses and explain what they are. Although pupils did find some aspects of the curriculum very challenging, they all made very good progress in improving their science skills and knowledge during the course of the study (as recorded in the *My Science Logs* and unit assessment; for more information and results see Apanasionok *et al*., 2020).

We enjoyed using the Early Science curriculum as a teaching resource. The scripted lessons and the guided instruction helped learners understand new scientific knowledge and concepts and use simple enquiry skills, such as making predictions, recording observations and evaluating outcomes. Many of the teaching assistants were familiar with science sessions based on less structured enquiry and/or more sensory-approaches, so they were surprised that the pupils were clearly able to benefit from a more guided and explicit approach with a greater focus on specific science content and associated vocabulary. Teachers and teaching assistants identified the following key features as being helpful:

- **challenging pupils to pair symbols with objects;**
- **using time-delay strategy;**
- **using exemplar and non-exemplar procedures;**
- **the predictable structure of the lessons.**

Does the Early Science curriculum fit into a UK school setting?

Although this curriculum was designed in the United States and referenced to their elementary science standards (National Research Council, 2000), we did not find any significant problems adapting it for use in a UK

Box 2 Issues arising and solutions

Aspect to improve	How could it be improved?
Time	Allow more time for lessons and practical activities. Although each lesson in the school was 45 minutes, by the time the pupils arrived in the science classroom there was only 35–40 minutes remaining. This could perhaps be achieved by delivering each lesson in two sittings/sessions.
Staffing ratios	The class was divided into two groups of pupils, with each assigned a teaching assistant. It was important to retain these two teaching assistants alongside the science teacher to help deliver individualised instruction and prompts.
Supporting pupils to record findings	At times it was a challenge to ensure that all pupils received support and guidance to help them complete their *My Science Log*. The science teacher made every effort to ensure there were two members of staff present during most sessions to support individual pupils.
Practical tasks	At times it was necessary to amend or change the nature of the practical tasks in the lesson plans (because of the lack of resources or other practical limitations). We found it was always possible to substitute a similar task to achieve the learning outcomes.

Pupils filling out *My Student Log* at the end of the lesson to summarise what they have learned

special school. The only issues we noted were time limitations and lack of staff to support some of the more challenging pupils during practical sessions, assisting them to complete their science logs and unit assessments (needed because of difficulties in communicating their ideas and observations), and the need to adjust the nature of some of the practical tasks (Box 2). However, none of these issues prevented us from successfully using the Early Science curriculum.

Conclusions

The pupils in our study enjoyed learning science using the Early Science curriculum. We found that it was possible to use the lesson plans and resources in a UK special school setting, and the teaching units and lessons were well matched to the science programme of study in England. Along with the vast majority of teachers in the UK, staff in this special school had previously employed enquiry- and/or sensory-based strategies to teach science. The evidence and feedback from this study is that programmes built around more explicit/systematic instructional approaches are likely to offer a more promising approach to teaching science to pupils with SEND, including successfully teaching relevant scientific knowledge and inquiry skills to enable learners to work scientifically.

Acknowledgement

This study was carried out as a part of a Doctoral dissertation funded in collaboration by the University of Warwick and Calthorpe Academy.

References and further reading

Apanasionok, M. M., Hastings, R. P., Grindle, C. F., Watkins, R. C. and Paris, A. (2019) Teaching science skills and knowledge to students with developmental disabilities: a systematic review. *Journal of Research in Science Teaching*, **56**(7), 847–880.

Apanasionok, M. M., Neil, J., Watkins, R. C., Grindle, C. F. and Hastings, R. P. (2020) Teaching science to students with developmental disabilities using the Early Science curriculum. *Support for Learning*. DOI: 10.1111/1467-9604.12329.

DfE (2015) *National Curriculum in England: Science programmes of study: key stages 1 and 2*. London: Department for Education. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/425618/PRIMARY_national_curriculum_-_Science.pdf

DfE (2019) *Special educational needs in England: January 2019*. London: Department for Education. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/814244/SEN_2019_Text.docx.pdf

DfE (2020) *Special educational needs and disability: an analysis and summary of data sources*. London: Department for Education. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/882802/Special_educational_needs_and_disability_-_an_analysis_and_summary_of_data_sources.pdf

EEF (2020) *Special educational needs in mainstream schools: five recommendations on special education needs in mainstream schools*. London: Education Endowment Foundation. Available at: https://educationendowmentfoundation.org.uk/tools/guidance-reports/special-educational-needs-disabilities

Jimenez, B., Knight, V. and Browder, D. (2012) *Early Science curriculum*. Verona, WI: Attainment Company.

Jimenez, B. A., Lo, Y. and Saunders, A. (2014) The additive effects of scripted lessons plus guided notes on science quiz scores of students with intellectual disability and autism. *Journal of Special Education*, **47**(4), 231–244.

Knight, V. F., Collins, B., Spriggs, A. D., Sartini, E. and MacDonald, M. J. (2018) Scripted and unscripted science lessons for children with autism and intellectual disability. *Journal of Autism and Developmental Disorders*, **48**(7), 2542–2557.

Knight, V. F., Wood, L., McKissick, B. R. and Kuntz, E. M. (2019) Teaching science content and practices to students with intellectual disability and autism. *Remedial and Special Education*, 1-14. DOI: 10.1177/0741932519843998

National Research Council (2000) *Inquiry and the National Science Education Standards: a guide for teaching and learning*. Washington, DC: National Academies Press.

Rizzo, K. L. and Taylor, J. C. (2016) Effects of inquiry-based instruction on science achievement for students with disabilities: an analysis of the literature. *Journal of Science Education for Students with Disabilities*, **19**(1), 1–16.

Serret, N. and Earle, S. (2018) *ASE guide to primary science education*. 4th edn. Hatfield: Association for Science Education.

Smith, B. R., Spooner, F., Jimenez, B. A. and Browder, D. (2013) Using an Early Science curriculum to teach science vocabulary and concepts to students with severe developmental disabilities. *Education and Treatment of Children*, **36**(1), 1–31.

Spooner, F., McKissick, B. R. and Knight, V. F. (2017) Establishing the state of affairs for evidence-based practices in students with severe disabilities. *Research and Practice for Persons with Severe Disabilities*, **42**(1), 8–18.

Richard C. Watkins and **Magdalena M. Apanasionok** both work at the Centre for Educational Development, Appraisal and Research (CEDAR), University of Warwick, Coventry, UK. Richard also works for the Regional School Effectiveness and Improvement Service for North Wales. At the time of the study **Julie Neil** was at Calthorpe Academy, Birmingham; she is now at Brays School, Birmingham.
Email: M.Apanasionok@warwick.ac.uk

Appendix 3. A paper by Alallawi et al. (in press) on educators' experiences of using the TEN-DD programme.

Special Educators' Experiences of a Numeracy Intervention for Students with Autism Spectrum Disorder

Authors Information:
Barah Alallawi[1] B.Alallawi@warwick.ac.uk
Louise Denne[1] L.Denne@warwick.ac.uk
Magdalena M. Apanasionok[1] M.Apanasionok@warwick.ac.uk
Corinna F. Grindle[1] C.Grindle@warwick.ac.uk
Richard P. Hastings[1, 2] R.Hastings@warwick.ac.uk

[1]Centre for Educational Development, Appraisal and Research (CEDAR). University of Warwick. Coventry. United Kingdom. CV4 8UW.
[2]Centre for Developmental Psychiatry and Psychology, Department of Psychiatry, School of Clinical Sciences at Monash Health, Monash University, Australia.

Acknowledgments: This research was funded by Mutah University, Al Karak- Jordan in the form of a PhD scholarship to Barah Alallawi.

Conflict of interest: The authors declare that they have no conflict of interest.

Correspondence concerning this article should be addressed to Barah Alallawi, Centre for Educational Development, Appraisal and Research (CEDAR), University of Warwick, Coventry, CV4 8UW, UK. Email: B.Alallawi@warwick.ac.uk

Abstract

Very little qualitative research has been carried out about the experiences and perceptions of educators who deliver evidence-based teaching programs to students with autism. Using a semi-structured format, we interviewed ten educators who had been delivering the Teaching Early Numeracy to Children with Developmental Disabilities (TEN-DD) program for eight months with students with autism in a special school setting. Thematic analysis findings indicated that taking part in the numeracy intervention was a valuable experience for both the educators and their students. There was initial scepticism about the intervention, but this was transformed to conviction during the implementation period. Educators reported an increased sense of competence in their teaching skills, which was evident in greater satisfaction and increased self-efficacy. Furthermore, there was a strong interest in continuing to use the numeracy intervention with students. There were also implementation challenges with TEN-DD, including students' challenging behaviour. The implications of these findings for more effective implementation of TEN-DD, and other evidence-based interventions in special education settings are discussed.

Keywords: numeracy intervention, special educators, autism, experiences, interviews

Numeracy is one of the key domains of mathematics (National Council of Teachers of Mathematics, 2000). Numeracy includes the ability to understand and represent numbers, relationships amongst numbers (for example place value, and number operations such as addition, subtraction, multiplication, and division), and using these concepts to form mathematical judgements and conduct complicated problem solving (Mclntosh et al., 1992). There is an increasing awareness that mathematical ability is key to many of the skills required to function in the 21st century (Kilpatrick, 2001) and that it is important that all students leave school with this ability. Counting, telling the time, making payments, measuring, and weighing, recognizing basic graphics and schemes, and carrying out number operations are examples of mathematical skills used in daily life (Baglama et al., 2017) that can also contribute to independent functioning (Su, 2003).

Mayes and Calhoun (2006) argued that mathematics is a domain of academic concern for students with Autism Spectrum Disorder (ASD). Nearly 25% of students with ASD have been found to have a mathematics learning disability (Mayes & Calhoun, 2006), compared with 3% to 14% of other students (Gregoire & Desoete, 2009). Chiang and Lin (2007) examined the mathematical profile of students with Asperger Syndrome and high-functioning autism and found that the majority performed at a similar level to other students. However, the mean arithmetic scores of these students were significantly lower than their mean IQ scores, indicating a moderate mathematical weakness (Chiang & Lin, 2007). The difficulties students with ASD confront in mathematics may derive from differences in executive functioning involving planning, organisation, working memory, mental flexibility, attention, self-monitoring, and impulse control (Alloway et al., 2009; Burney, 2015; Donaldson & Zager, 2010; Happe et al., 2006). Furthermore, differences in language ability that correlate with ASD may also cause mathematics difficulties across several domains such as number-word sequencing, calculation, fact retrieval, and problem solving (Burney, 2015; Donlan, 2007; Zentall, 2007). Other researchers have found that students with ASD demonstrate a highly variable mathematics attainment profile (King et al., 2016). In Wei et al. (2015)'s longitudinal analysis of children with ASD between the ages of six and nine years, distinct profiles of mathematical achievement were identified, with 39% of children demonstrating average attainment across academic areas, and 20% demonstrating average or above the national average skill in mathematics, while scoring below the national average for children in the general population on other tests of achievement.

Spooner et al. (2019) conducted a systematic review to examine evidence-based practices for teaching mathematics to students with moderate and severe developmental disabilities, including ASD. This review was an update of an earlier review conducted by Browder et al. (2008). Spooner et al. (2019) included 36 studies in their review. All studies were rated as of high or adequate quality. Both Browder et al. and Spooner et al. found that systematic instruction strategies can be used effectively to teach mathematics skills for this population. Systematic instruction is an approach that is based on principles of Applied Behaviour Analysis and focused on teaching observable and measurable behaviours and promoting generalization (Browder et al., 2008 & Spooner et al., 2019).

Teaching Early Numeracy to children with Developmental Disabilities (TEN-DD) program overview

Despite the fact that mathematics is one of the most researched areas of teaching academic skills to students with disabilities (Spooner et al., 2017), information is scarce in terms of structured and comprehensive curricula suitable for these students that would help practitioners teach all numeracy domains (Tzanakaki et al., 2014b). TEN-DD was adapted from an existing mainstream numeracy intervention, the Maths Recovery program (Tzanakaki et al., 2014a; Tzanakaki et al., 2014b). Maths Recovery is a numeracy intervention that was developed in Australia in the 1990s and designed for students in mainstream classrooms who were not meeting age-related expectations for numeracy (Wright et al., 2012). Maths Recovery was designed based on extensive research carried out on number knowledge of school students generally. The intervention is an intensive short-term intervention, usually used for up to 12 weeks with a few individualized sessions a week, developed to decrease the achievement gap between students struggling with numeracy and their peers (Wright et al., 2012).

The Maths Recovery programme has been adapted to meet the needs of students with developmental disabilities (Grindle et al., 2020). Adaptations include shorter instructions, prompting procedures, use of task analyses (breaking down complex tasks into smaller, more achievable steps), targeted generalization of acquired skills, clearly defined learning goals and targets, and frequent use of reinforcement (Grindle et al., 2020). Adaptations were based on systematic instruction procedures that were found to be evidence-based practice by Browder et al. (2008) and Spooner at al. (2019). A small pre-post evaluation with six students with ASD (Tzanakaki et al., 2014a), and a pilot Randomized Controlled Trial (Tzanakaki et al., 2014b) offered preliminary evidence of the effectiveness of TEN-DD.

One drawback to these studies, however, was that the intervention was only delivered by staff members already experienced in using systematic instruction strategies or with researchers delivering the intervention. It was still unclear whether TEN-DD would be effective when delivered in ‘typical’ school settings with class teachers or paraprofessionals being responsible for implementation. Apanasionok et al. (2021) aimed to address this issue by training school staff who had no prior experience of using systematic instruction, to deliver TEN-DD. Apanasionok et al. recruited 17 students with autism across five different classes in the school. Twelve special educators (five class teachers and seven paraprofessionals) were trained to deliver the intervention to the recruited students. Results indicated that not only it was feasible for the TEN-DD program to be implemented in a special school using this teacher delivery model but also that the intervention remained effective.

Purpose of the present study

It is crucial to understand the experiences and perceptions of students, educators and parents about instructional methods and interventions since these may affect uptake of interventions in practice. Such perceptions also represent ‘social validity’: that the methods used to teach pupils with ASD mathematics skills (for example) are considered appropriate by key stakeholders including students with ASD, parents, and educators. However, there has been very little research addressing educators’ perceptions of mathematics interventions for students with ASD (Root et al., 2017; O’Malley et al., 2013; Kasap & Ergenekon, 2017), and these studies have mainly focused on quantitative outcomes. For example, O’Malley et al. (2013) conducted a survey with teachers who used an iPad as an instructional tool to enhance basic mathematics fluency of ten students with ASD or multiple disabilities. The survey included six items on a 5-point Likert scale to explore teachers’ perspectives on the intervention’s acceptability and effectiveness for classroom instruction. Findings revealed that teachers were satisfied with the outcomes and had recognized the intervention to be a success.

Using qualitative methods in intervention studies can provide fundamental data about how and why interventions do or do not work, how participants feel about interventions, and what factors might affect the success of interventions (Brantlinger et al., 2005; McDuffie & Scruggs, 2008; Pugach, 2001). Greenwood and Abbott (2001) indicated that teachers might be less likely to adopt and continue using interventions over time when they do not find interventions to be feasible, adequate, or related to their work. Thus, it is valuable to identify and understand the experiences of special educators who use mathematics interventions with students with ASD. In the current study, special educators who had implemented the TEN-

DD intervention with their students with ASD were interviewed to explore their experiences of using the intervention.

Method

Participants

Ten special educators (3 male; 5 female) working across five different classrooms in an autism department in a special school were interviewed. All had used the TEN-DD intervention with 17 of their students for eight months. Five were teachers and five were paraprofessionals (see Table 1). Participants had been trained in the use of the TEN-DD intervention prior to its use in the classroom and prior to the start of this study. All names have been changed to protect the identity of the participants.

Table 1

Study Participants

Participant's name	Participant's gender	Participant's role
Sarah*	Female	Paraprofessional
Jacob	Male	Teacher
Layla	Female	Paraprofessional
Kate	Female	Paraprofessional
Harry	Male	Teacher
Isla	Female	Teacher
Emily	Female	Teacher
Noah	Male	Paraprofessional
Jack	Male	Paraprofessional
Mary	Female	Teacher

*Pseudonyms have been used

Recruitment procedure. Approval was sought and obtained from the Humanities and Social Sciences Research Ethics Committee at the {removed for blind review}. Twelve special educators (five class teachers and seven paraprofessionals) were invited personally, through an initial conversation one-to-one by the first author to participate in the study and were given an information sheet outlining the purpose of the study. The special educators were interviewed after implementing the TEN-DD intervention for eight months.

Ten of the twelve special educators agreed to participate in the current study. When the signed consent forms were received, a suitable time was arranged with the participants to conduct the interview. All ten participants were interviewed during working hours by the first author, face-to-face in a meeting room at the school. In addition to written consent, verbal consent to audio record the interview was obtained just before the interview commenced. Nine agreed to be recorded. For the remaining participant, detailed notes were taken during the interview. The interviews lasted from 25 to 40 minutes, with an average time of 33.27 minutes. The first author introduced the interview to the participants by saying "I am interested in your experience of using the TEN-ID intervention in your day-to-day work at the school over the school year 2017/18. I would like to find out what you thought about the TEN-DD intervention - what went well and what could be improved if you were to use TEN-DD intervention again".

Research Approach

A qualitative approach using semi-structured interviews was used in the present study. Interviews were analysed using thematic analysis. Thematic analysis is "a method for identifying, analysing and reporting patterns within data" (Braun & Clarke, 2006, p.79). It was selected for its flexibility, capability for searching across a large body of data, and identifying similarities and differences across a data set. In addition, thematic analysis can produce unexpected insights (Braun & Clarke, 2006). A reflective diary was kept during data collection. After each interview, the first author reported her own thoughts and reactions as well as her perceptions of the participants' feelings based on their hesitations and the language they used. This helped in the interpretation of the underlying meaning of participants' reports, as well as highlighting instances where the first interviewer's own perceptions may have influenced that interpretation. As is often the case with qualitative research, the first author played an active role in both data collection and analysis, and her own experiences and biases will have influenced the wording to questions, the use of probes, and how answers were followed up. The first and third authors were known to the participants as they had trained them in using the TEN-DD intervention and had provided mentoring visits during the intervention implementation.

Interview structure. An interview protocol was developed by the authors. Its aim was to explore special educators' subjective experiences of being part of the TEN-DD implementation. Data were gathered with regard to the educators' perspectives on using the TEN-DD intervention with their students, how supported they felt during TEN-DD implementation, relevance to their students and to the wider intervention, what they thought of TEN-DD outcomes, how they felt about taking part in the TEN-DD research project, and what they thought about wider implications of TEN-DD. Open ended questions were used (e.g., Tell me about your experience of implementing the TEN-DD intervention with your students?). To obtain more information from the educators, probe questions were also used. A copy of the full interview protocol is available on request from the first author.

Data Analysis

The recorded interviews were fully transcribed verbatim by the first author. To make sure that no data had been missed, the third author listened to the recordings and went through all the transcripts to check. The method of analysis used was informed by Braun and Clarke's description of thematic analysis (2006): a) reading and re-reading the data, noting down initial ideas for coding (summaries of meaning or points of specific importance) on the transcript in the left-hand margin; b) generating initial codes and assigning data relevant to each code; c) sorting codes into potential themes; and d) creating a thematic map that illustrates the relationship between codes, themes, and different levels of themes (main themes and sub-themes).

When conducting data analysis, the researcher becomes the instrument for analysis, making judgments about coding and theming the data (Starks & Trinidad, 2007). Each qualitative research approach has specific techniques for conducting, reporting, and evaluating data analysis processes, but it is the individual researcher's responsibility to assure rigor and trustworthiness (Nowell et al., 2017). According to Braun and Clarke (2006) a rigorous thematic analysis can produce trustworthy and insightful findings. However, there is no clear agreement about how researchers can rigorously apply the method. Examining the overall trustworthiness of a qualitative study can be facilitated by, for example, keeping a reflective commentary and obtaining a peer examination/check and feedback over the duration of the study (Shenton, 2004; Nowell et al., 2017). Consequently, the first author recorded her initial impressions of each interview along with patterns appearing to emerge from the data collected. A peer examination/check of the emerging themes was obtained to increase the objectivity of data analysis. Master themes and the thematic map were checked by the third author and revised in discussion with the research team, until the first author was confident that all themes and related sub-themes had been identified. In addition, the interpretations of themes were collaboratively discussed with the research team throughout the period of analysis and during write-up of the research study.

Results

Four master themes emerged from the thematic analysis (see thematic map Figure 1): a) initial scepticism to conviction, b) increased sense of competence, c) recognition of the potential of TEN-DD, and d) students' challenging behaviour as a potential barrier to TEN-DD implementation.

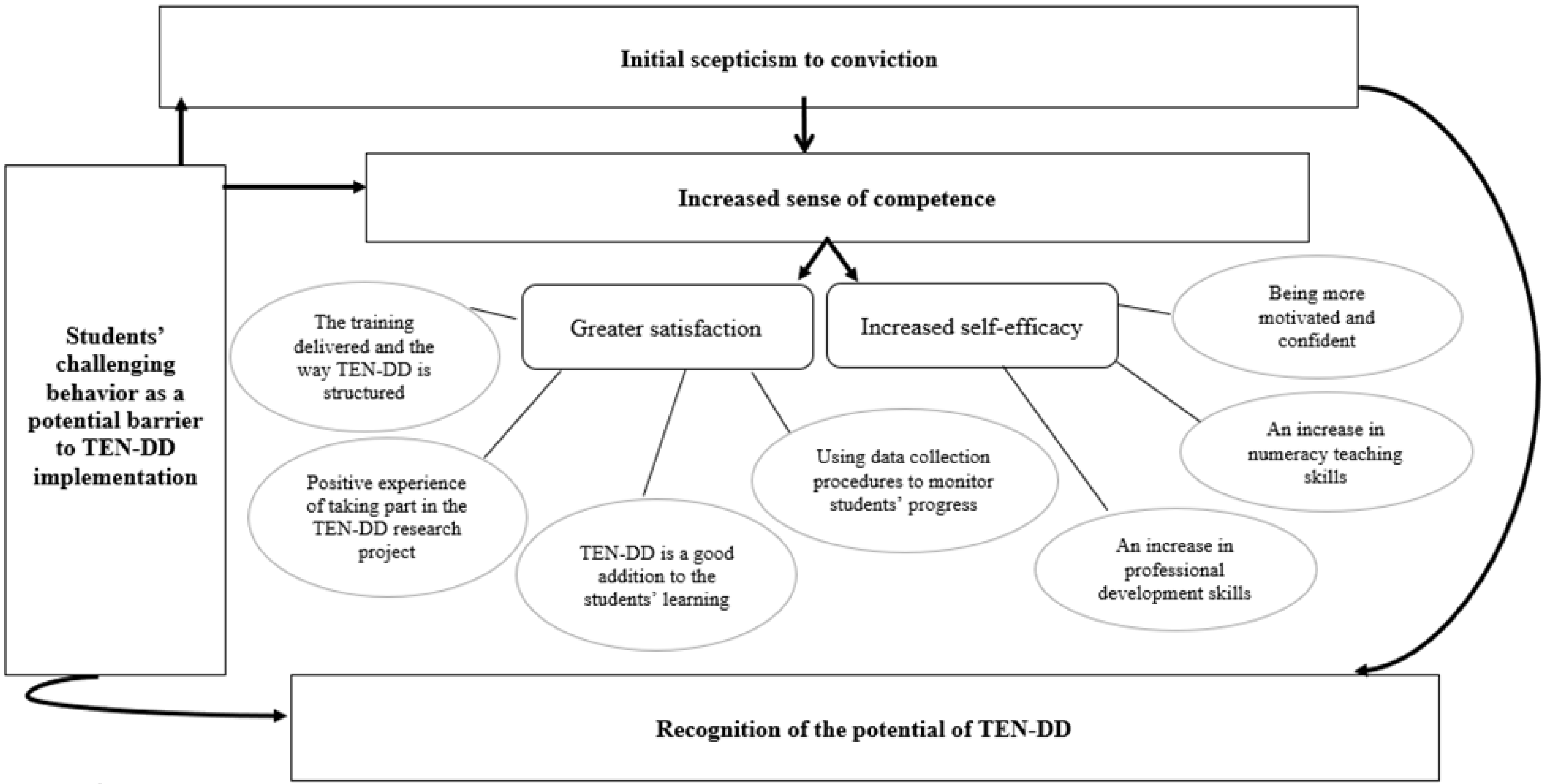


Figure **1**

Thematic Map

Theme 1. Initial Scepticism to Conviction: "I was like-oh my God, I don't know what to do but when we do it and do it it's fine"

Six of the special educators stated that, at first, they were sceptical about the TEN-DD intervention. Reasons for this varied. Three were sceptical because TEN-DD was a new teaching approach to them: "Oh yeah, I was skeptical first, I am with most new things" (Emily) and it required a lot of preparatory work "okay. So, initially [Mm] I was a bit unsure because it is a lot of paperwork, a lot of targets, a lot of getting set up" (Mary). A teacher also reported that the concept of TEN-DD and its subsequent implementation with students was initially daunting "Yeah, [Mm] quite daunting at first kind of understand, trying to understand everything put together" (Jacob).

There were doubts about whether students could gain mathematical skills using this new teaching approach and had the ability to achieve TEN-DD's targets "How you would see a target, think-oh this is impossible [Mm] yeah, some of the skills I didn't think they are able to achieve-they are doing, they are understanding" (Mary). Recording all required data was reported as a concern at first and that this might affect the teacher's time with the pupils "So, in the beginning I was concerned that all the recording, even though it actually was not that much recording, it appeared to be. So, in the beginning I was worried all recording will take over the time that we have the pupils and that has not happened" (Emily). Some initially saw TEN-DD as a dull and repetitive approach, although this view changed after implementing it with students: "I've worked with two different sets of staff with doing this kind of approach of teaching [Mm] initially all of them were a bit like-uh, it's boring, repetitive but all of them now prefer it, because they see the difference that it makes" (Mary).

The initial skepticism about the TEN-DD intervention dissipated over time "but when you start actually sitting down and actually doing it, it all makes sense" (Jacob). Similarly, Mary reported that “when you actually see the difference it makes and the progress the pupil [student] can make with this kind of approach- it changes your opinions”. Mary and Layla were impressed with how much their students had progressed, having initially thought that their students did not have the abilities to learn new numeracy skills and, consequently, not having tried to teach them “when they know how to count, and they recognize numbers, I was amazed to see- my God like- they are able to do it and we didn’t give them the chance to do that” (Layla), “like the domino cards with the air, doing pattern- it’s almost there but that we never thought they’ll be able to do” (Mary).

Theme 2. Increased Sense of Competence: “I know what I want to do with teaching math to special needs children”

With increasing conviction, the educators reported an increased sense of competence. Educators’ sense of competence was evident in the following sub-themes: greater satisfaction and increased self-efficacy.

2.1 Satisfaction from taking part in the TEN-DD intervention: “I am a big thumbs- up with TEN-DD”. All the educators indicated their satisfaction from taking part in the TEN-DD intervention. Satisfaction was evident in the following elements: a) satisfaction from the training delivered and the way TEN-DD is structured, b) satisfaction in using data collection procedures to monitor students’ progress, c) satisfaction that TEN-DD is a good addition to the students’ learning, and d) satisfaction from taking part in the TEN-DD research project.

Satisfaction from the training delivered and the way TEN-DD is structured. The educators indicated that training on the TEN-DD intervention was clear and provided pertinent information. Jack reported that “it was very well delivered, and it was well constructed”. He also mentioned that “the training has been very [Mm] concentrated on us delivering it and what we need to do. There was good explanation why we are doing stuff, why we are doing these things and the theory behind it” (Jack). Sarah reported that being told and therefore understanding the reasons behind implementing the TEN-DD intervention with students was motivating for her as they are not always given that level of understanding with other interventions used in the school: “we understood why we are doing it, which we’re not always told but it certainly gives us motivation to actually – okay, this is what we’re doing it for”. There was also a satisfaction about the practical element of the training. The educators stated that doing some activities during the training on the delivery of TEN-DD’s targets and viewing videos showing good practice gave them a clear idea of how exactly TEN-DD is meant to work: “Yeah showed us activities. Exactly how we should do it with the pupils [students], that was really good because gave me a clear idea of what I need to do” (Layla).

The structure of the TEN-DD intervention was described as a positive aspect. The educators appreciated having structured teaching which involved all targets and associated teaching resources, as well as a step-by-step process for teaching those targets and rewarding correct student responses “I find easy [Mm] having more work-based targets in a folder. I find easy knowing- right there is work, we have all equipment that we need for each target in our boxes and literally rewards, [pause] our resources and the documents all together. So, it is literally straight into work, there is no faffing, no get in this, no get in that, folding things – it is work and it’s straight, it’s done for the kids as well” (Mary). In addition, educators stated that their students enjoyed the way that the TEN-DD sessions are delivered, using ‘reward’-based learning: “they respond really really well to the structure of task-token-task-token and then reward at the end” (Sarah) and the way that this structure made the students more motivated and engaged to learn numeracy: “she knows she gets an iPad… at the end of it, she knows what she’s got to do, so that’s been really really good in a way of getting her” (Sarah).

The support received with the mentoring visits provided by the first and third authors during TEN-DD implementation was also praised. Isla said “The mentoring visits are very useful because you guys were able to give ideas how to implement the targets, able to give ideas how to adapt some targets. For example, you gave me ideas how to help [pupil's name] on doing chopping target [counting by chopping motion with the hand], especially he has problem with his motor skills during the day". Being observed by the researchers during the mentoring visits did not impact the educators negatively: "I've never found under any pressure when I was being observed" (Jack). However, one paraprofessional reported that being observed was daunting at first as he did not want to deliver TEN-DD incorrectly, but said that over the time the mentoring visits made him more confident in delivering TEN-DD : "But you guys being there was daunting as first, I felt really nervous because I didn't want to do it wrong because-but no it's good, it's really-having you ladies there made, gave me a bit more confidence over the time–you know–when I first started I was a little nervous but yeah no it's good" (Noah).

Feedback from the researchers during the mentoring visits was reported as helpful, constructive, collaborative, and encouraging "it's always useful to know [Mm] whether you're doing good or bad. It is always useful to know [yeah] and it's always useful when it's a regular update to just make sure you're going on the right path, because when you teach somebody you don't want to teach something that's wrong-so, it's always useful. And it's always encouraging as well" (Kate). Sarah also reported that "it's always - it's not just like you doing this wrong and you doing that wrong, it's always like - this isn't quite to script, this is what you can do instead or this isn't working, how about this. It's not just negative, it's very much collaborative and constructive or this is working really well we gonna incorporate that or carry on with that, it's fine". Moreover, feedback during the mentoring visits positively affected educators' confidence in delivering TEN-DD "I found the feedback useful as helps me follow and deliver targets. You are able to tell me what to do-do this and do that-do what it might be worked with pupils [students]. So, this helps me to build my confidence over time" (Isla).

Satisfaction in using data collection procedures to monitor students' progress. The educators reported their satisfaction from making the data collection process clear: "I really enjoy the way that you lay out the evidence, makes progress very clear" (Jack). Similarly, Mary stated that "in obviously mainstream children there's kind of a pattern but with our kids it is very different, so you're not actually told where to start and what the progression is, so, with this [raising a TEN-DD document] that gives you that information, that's what I've enjoyed" and Sarah reported that "you know where you're going and what you're doing". Due to making the process of data collection clear, the educators reported that they were able to recognize their students' progress through the TEN-DD intervention "I love being able to see the progress, which is I've missed this year with our new curriculum" (Sarah) "it's nice to feel that you're making progress with-you know-to recognize kids' progress as well" (Harry).

The students' numeracy skills were significantly improved, as noted by all the educators. For example, Jacob said that "I think they are doing fantastic, I've seen a massive difference. Even looking last week, I was looking at a video of one of the pupils [students] in October and then compare it to now". Isla reported that "I have seen an improvement yeah. They have made progress. They learn new math skills like counting from thumb" and Mary stated that "Yeah, he's flying through targets all the time". Harry reported that his students enjoyed making progress "It's great to see the kids making progress and enjoying progress".

Satisfaction that TEN-DD is a good addition to the students' learning. The educators' responses suggested that TEN-DD provided them with a skills based approach to teaching numeracy that is a good fit with the students' learning "but it's very effective teaching basic math skills- like very basic math skills, and I think it gives them the opportunity to teach skills that you might not think of when trying to teach math and therefore we sometimes skip to try and teach them things that they might not understand without having done TEN-DD first" (Harry). Kate said that "I think it's a very good input into the curriculum for the child that I work with anyway". Also, Mary stated that "TEN-DD comes under the cognition and learning and obviously we have a lot of time in a curriculum for cognition and learning, so it filled in there".

Educators were particularly satisfied to see that students were able to generalize the skills they learnt with TEN-DD. Sarah noted that "they've been able to count out money [Mm]-you know- identify numbers on a clock, which they couldn't do before and because we've done numbers in TEN-DD", while Isla reported that "Yes, I did notice generalization of the skills they have learned. I remember that we were doing some counting with them and [student's name] started to count from thumb like we do in TEN-DD".

In addition, the educators believed that the TEN-DD intervention had a positive impact on the students' speech, sitting ability, attitude to learning and concentration during school work "I found that actually, by-product of TEN-DD is actually some of the kids' speech has actually improved, especially with one of the girls whose speech has come a lot more since we adopted the TEN-DD, has been noticed by parents as well" (Jacob), while Harry said that "he's spending more time at the desk". Emily reported the benefit of the TEN-DD intervention on her student's attitude towards learning "so, in the beginning she would -as you know [laugh]-do all of the tasks but squeal the answers loudly almost in protest and now she smiles when she finishes the tasks".

Satisfaction from taking part in the TEN-DD research project. Taking part in the TEN-DD research project was reported as a positive experience by the educators. Four teachers and five paraprofessionals enjoyed taking part in the TEN-DD research project. "I've enjoyed being a part of it. I've enjoyed, [Mm] and I liked what I've read and seen, I do enjoy teaching the TEN-DD" (Kate). Only one teacher reported that taking part in TEN-DD research project was frustrating: "very interesting question. Well, it is frustrating at times. Sometimes my timetable has to be changed as a staff member maybe absent, I have safeguarding [responsibilities to attend to students' safety] issues [Mm] so sometimes I cannot do TEN-DD and stick to the mentoring visits" (Isla).

Moreover, the educators mentioned that with TEN-DD being a part of a research project that this did not affect their day-to-day use of it "but yeah in terms of it, we never felt any pressure that because it's a research project" (Sarah). In addition to this, Jack and Jacob demonstrated that they felt part of the project and welcomed the opportunity to give their opinions, for example regarding the teaching plans and during the mentoring visits: "but, it's been really nice because sometimes people do research and they just go away and just create themselves but by yourselves actually getting teachers and TAs [paraprofessionals] involved" (Jacob).

Furthermore, the educators were positive about the support provided and feedback during the research project. They also reported that the researchers were accessible, flexible and patient during the TEN-DD research project: "there is never a time when you feel like you're stuck, and you have to go to seek - you or MA [researcher name] out, because you're always available, you're always there, which has always been helpful" (Mary); "we are all colleagues working on this together - you know - we know what we're doing with TEN-DD , you guys know what you're doing with the kids, so it's kind of like - we both know what we're doing, coming from different angles but we meet in the middle and make it work" (Sarah).

2.2 Increased self-efficacy: "I have learned different strategies for teaching numeracy to special needs children." Not only were the special educators satisfied from taking part in the TEN-DD intervention, they reported that using TEN-DD in their classes was beneficial for them because it taught them more about numeracy as well as giving them new strategies for teaching numeracy skills to their students: "I learned more about math. I never had a strong suit with math [laugh] [Mm] in terms of teaching it before… but with the TEN-DD I feel like I have more solid understanding of what they could be" (Sarah). Isla said that "TEN-DD gives me different ways of thinking and having an alternative strategy to use". In a similar vein, Mary stated that "I've definitely learned different ways of starting to teach math". Layla found that "teach them one-to-one, it's really good it gives -you know- makes me see how a child is able to take, how can I like take so much from a child one-to-one".

Implementing TEN-DD also had a positive impact on educators' professional development skills. It had a positive impact on educators' self-reflection: "and over the time we've learned not to get frustrated when thing aren't working, which is good" (Jacob) and increased organizational skills "I think I know the importance of having the teaching materials close and to hand and organized…. so, it's highlighted to me how important it is to have things organized and to hand and then you can deliver more confidently" (Jack). In addition to this, TEN-DD implementation helped educators to be consistent in delivering tasks to their students "we've got into a way all four of us are working, of a very similar way and we can swap groups. I can go and work with two other pupils and they are familiar with how I am delivering the teaching because it is very similar" (Jack). Interestingly, Kate mentioned that using TEN-DD taught her different ways and techniques of how to get students interested in learning. A paraprofessional also mentioned that using TEN-DD made him think how he is delivering other areas of the school's learning as it helped him to think about how to deliver a task in a way that students would understand "it's got me to think outside the box" (Jack). Moreover, Noah observed that "doing TEN-DD taught me to make sure you realize how much help you might unknowingly give to the pupils [students] and how much prompts you might unknowingly give".

The educators also noted that they applied what they learnt from TEN-DD in teaching other academic domains: "TEN-DD's taught me and my colleagues new approaches on how to teach other things, so generalization not just for the pupils [students] but for us we can take the skills we have learned from TEN-DD and apply them in other areas of our curriculum and in other parts of our day" (Jack). Furthermore, Sarah stated that she used the new teaching strategies that she learned from TEN-DD in teaching communication skills to one of her students who was not doing TEN-DD: "it has helped in terms of trying to engage him in different ways, like I said, I've learned new ways of teaching math, so that helped in ways of engaging him or even using that method to teach him something else like communication".

As well as commenting on an improvement in numeracy teaching skills and professional development skills, the educators noted that they were more motivated and excited about teaching: "taught me other ways to teach and it's also kind of got me excited a little bit about teaching… I'm like -yeah let's do something, a bit more enthusiastic about - okay let's think of different ways we can do this" (Sarah); "it was encouraging as well and motivating when a child is achieving something" (Kate). Furthermore, the educators believed that TEN-DD had a positive impact on their confidence in teaching numeracy skills to their students "it's certainly giving me more confidence teaching math. I struggle with math, I had to work hard in school so, yes, it's good and its certainly simplified things that are worrying for a teacher" (Harry); and "it did impact on my confidence in doing Discrete Trial Teaching" (Isla). It is notable that a paraprofessional mentioned that TEN-DD increased his confidence because of not having to be directed by the class teacher "when you are a TA [paraprofessional] and you're being directed from the teacher to do this and -you know- you haven't any impact in your teaching but then TEN-DD I found [pause] it was just– it, I felt differently, it wasn't necessarily being directed by the teacher…. but then that confidence went through the whole day to day" (Noah).

Theme 3. Recognition of the potential of TEN-DD: "I would fight for them to have it"

As mentioned earlier, all educators reported that their students benefited from using TEN-DD as there was not only an improvement in their numeracy skills but also an improvement in other domains of their life, for example their speech and sitting ability. Accordingly, they recognized the potential of TEN-DD and strongly wanted it to continue to be used with their students: “they have to continue with it to see the progress and the difference it makes to them” (Layla); “it would be really beneficial for them, even the ones are moving to 6th form… I think it’s proving that they are still learning, it’s proving that they’re still making progress which I know is very important, especially when they go into adult services. If they can prove they’re still learning, they’re more likely to get a place and TEN-DD has really shown, even for the lower ability -yeah, they can learn this, perfectly fine, perfectly capable with it [Mm] yeah, I think it would be a real shame if we got rid of it” (Sarah). Harry also mentioned that he had students in his class who did not have the required numeracy abilities to do TEN-DD, thus, it would be important to try to make TEN-DD accessible for them “I think it would be important to try and access the learners who are pre- emergent [the first developmental phase of TEN-DD] too, so it’s consistent and whatever age group they should be learning and starting to learn it, I think that would be important too” (Harry). In addition, the educators would like to see TEN-DD being used in other departments in the school as it is beneficial: “I don’t see why it wouldn’t roll out, I think it is great” (Jack). Most of them mentioned that TEN-DD would work with students in primary and secondary age departments in the school as they are perfectly capable of accessing it, therefore, they will have the benefits that the students in the autism department had: “I think it would work for primary and secondary… I think the pupils [students] are perfectly capable of accessing it and enjoying the benefit from the structure and all the benefits we’ve had in autism” (Sarah). Similarly, Isla stated that “yes, maybe with primary and secondary. I think they are more able at the number level, so they would appreciate it more. Also, their math skills can be improved”. Jacob and Emily reported that TEN-DD would work in other departments in the school as an intervention to help students who struggle with a particular area of numeracy. On the other hand, Harry believed that students with severe intellectual disabilities would benefit from TEN-DD. He recalled a discussion with a parent of an 18-year-old student with severe intellectual disabilities that he used to teach him when he was 13 or 14 years old: “I spoke to a parent of a child I used to teach… and he still hasn’t learned how to count or still -and he can’t do the course that they want in a college because he can’t count, whereas if he had something like this and he doesn’t like to count now because he thinks he can’t do it-so if he had that intervention earlier then I think it would have benefited him”.

Theme 4. Students’ challenging behaviour as a potential barrier to TEN-DD implementation: “The only issue with some of them was their behaviours”

Students’ challenging behaviour was reported by four of the educators as the only real barrier to TEN-DD implementation. Challenges were experienced in facilitating the students to complete all targets: “she made it hard, refusing to do it or finishing it halfway a through and then not wanting to continue in the afternoon to finish it” (Noah) and doing TEN-DD consistently “there were some weeks when she would do it and some weeks she wouldn’t’ (Emily). Moreover, Sarah reported difficulties with “not being in a very good mood, not wanting to work or just being very distracted”.

In addition, some of the educators reported that using TEN-DD with their students helped in decreasing students’ challenging behaviour “from when we first started she would sit at the table and she would do the work, but it was smaller amounts and after a while she would become very agitated and would [pause] she would shout and scream her answers, instead of just talking and [pause] whereas now I noticed she will-she would do the tasks longer and more calmer” (Emily). Kate believed that using TEN-DD with the student that she worked with had positively affected his behavior “when he came to us he had a lot of behavior issues and stuff like that, but I think [pause] getting him to focus and do work, he’s just way better because he’s a completely changed child. Some of the behavior issues that he had when he first initially came into the class and he doesn’t have them anymore and I think that is just focusing on the curriculum work". Interestingly, Jacob reported that he used TEN-DD with some of his students to calm them down because they liked doing TEN-DD 's targets: "I even used the TEN-DD with some of the children to actually calm them down as well… They are sitting down, focused, energetic, they like the activities".

The impression conveyed by participants was one of a shift in attitude from initial scepticism to conviction in the use of TEN-DD. This seems to have also been reflected by a changing perception of students' behaviour; from challenging behaviours being a potential barrier to implementation, to becoming a means of pupil engagement. These shifts in attitude appear to either have been facilitated by or led to an increased sense of competence on the part of educators. This increased sense of competence is reflected in part by satisfaction with taking part in the intervention, and the intervention itself, as well as the increased sense of self-efficacy that this brought about.

Discussion

The importance of using evidence-based practices in any education setting is well established; and yet adoption of such practices is not routine (Kozleski, 2017). Qualitative methods can provide insight into this apparent paradox. This study represents the first qualitative exploration of special educators' experiences of using the TEN-DD intervention with their ASD students in a school setting and contributes to our understanding of the processes that may be involved in the adoption of evidence-based practices in special education settings. There is a strong evidence base for the teaching methods used in the TEN-DD intervention, systematic instruction, as well as for Maths Recovery, the programme upon which TEN-DD is based, and there is an emerging evidence base for the TEN-DD intervention. And yet special educators were initially sceptical about TEN-DD. Much of that scepticism appeared to stem from a fear of something new: TEN-DD not only is a different approach to teaching numeracy, but also includes new content and new processes such as data collection for teachers to learn. It also attempts to teach children skills that special educators had not had success with, in the past. It is clear that the training on the TEN-DD provided a good introduction to the intervention and educators highlighted the importance of knowing and understanding the principles behind TEN-DD implementation which then led them to be more motivated about delivering the intervention to students. However, information about an intervention and initial training is not enough. It was only by experiencing and becoming familiar with the materials and processes, as well as seeing the outcomes for students that an attitude of scepticism transformed to conviction during the implementation period. Support provided during mentoring visits over the implementation period was reported as helpful and may be an important part of the process of boosting educators' confidence in the delivery of any new intervention.

It is interesting that special educators reported a positive effect on their own learning and an increased sense of confidence in their teaching skills. It suggests that the fear of something new associated with the initial scepticism of TEN-DD may be related to a lack of confidence in their ability to deliver the intervention, and that however strong the evidence base, the longer-term success of any intervention depends on upskilling those who will be responsible for its delivery. That upskilling in this case goes beyond numeracy. TEN-DD provided educators not only with a strong background in numeracy, but also new strategies such as using reinforcement, task analysis and prompting and prompt-fading procedures for teaching skills to their students which could be applied to teach other academic domains.

Special educators were particularly satisfied with the outcomes of the intervention. Students were described as having improved numeracy skills and, interestingly, they too were able to generalize these skills. Learning extended beyond the planned intervention, with educators observing that students' speech, sitting ability, attitude to learning and concentration during schoolwork improved. These observations support the ideas cited in previous research of the relationship between the difficulties students with ASD have with mathematics and perceived differences in executive functioning.

This study has certain limitations that need to be taken into consideration. The first author was involved in training the participating educators on the use of the TEN-DD intervention and provided mentoring visits over the implementation period. She also conducted the interviews with the educators. It is possible that this influenced feedback regarding training and mentoring visits. In addition, the role of the first author in the delivery of the intervention as well as conducting interviews might be a limitation. Aware of these risks, the first author kept a reflective diary during data collection and discussed her own preconceptions about each interview with the second author (who was not part of the implementation research team) to minimize bias.

It is not enough for research to provide evidence of the efficacy of an intervention. To be effective, and to benefit the population that it has been designed for, any intervention needs to be adopted by real world settings. That adoption relies on developing a sense of competence in those involved in its delivery. It is only by understanding the experiences of special educators that implementation support can be developed to maximise the likelihood of successful uptake within special education. Qualitative studies such as this are a critical part of that understanding.

References

Alloway, T. P., Rajendran, G. & Archibald, L. M. (2009). Working memory in children with developmental disorders. *Journal of Learning Disabilities, 42* (4), 372-382.

Apanasionok, M., Alallawi, B., Grindle, C. F., Hastings, R. P., Watkins, R., Nicholls, G., Maguire, L., Staunton, D. (2021). Teaching Early Numeracy to Students with Autism Using a Teacher Delivery Model. *British Journal of Special Education*. https://doi.org/10.1111/1467-8578.12346

Baglama, B., Yikmis, A., & Demirok, M. S. (2017). Special education teachers' views on using technology in teaching mathematics. *European Journal of Special Education Research*, 2 (5), 120-134.

Brantlinger, E., Jimenez, R., Klingner, J., Pugach, M. & Richardson, V. (2005). Qualitative studies in special education. *Exceptional Children*, 71 (2), 195-207.

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3 (2), 77-101.

Browder, D. M., Spooner, F., Ahlgrim-Delzell, L., Harris, A., & Wakeman, S. (2008). A meta- analysis on teaching mathematics to students with significant cognitive disabilities. *Exceptional Children, 74*, 407-432. https://doi:10.1177/001440290807400401

Burney, S. L. (2015). Interventions to Improve Student Achievement in Mathematics for Middle School Students with Autism. *Specialist in Education Degree (Ed.S.) Theses*. 10. https://kb.gcsu.edu/eds/10.

Chiang, H.-M. & Lin, Y.-H. (2007). Mathematical ability of students with Asperger syndrome and high-functioning autism: A review of literature. *Autism*, 11 (6), 547-556.

Donaldson, J. B. & Zager, D. (2010). Mathematics interventions for students with high functioning autism/asperger's syndrome. *Teaching Exceptional Children,* 42 (6), 40-46.

Donlan, C. (2007). Mathematical development in children with specific language impairments. In D. B. Berch, & M. M. M. Mazzocco (Eds.), *Why is Math so Hard for some Children? The Nature and Origins of Mathematical Learning Difficulties and Disabilities,* pp. 151- 172. Paul H Brookes Publishing.

Greenwood, C. R. & Abbott, M. (2001). The research to practice gap in special education. *Teacher Education and Special Education*, 24 (4), 276-289.

Gregoire, J. & Desoete, A. (2009). Mathematical disabilities—An underestimated topic? *Journal of Psychoeducational Assessment,* 27(3), 171-174.

Grindle, C. F, Hastings, P. R., & Wright, R. J. (in press). *Teaching early numeracy to children with developmental disabilities.* London, England: SAGE Publications Ltd.

Happé, F., Booth, R., Charlton, R. & Hughes, C. (2006). Executive function deficits in autism spectrum disorders and attention-deficit/hyperactivity disorder: examining profiles across domains and ages. *Brain and Cognition, 61*, 25-39.

Kasap, C. & Ergenekon, Y. (2017). Effects of a Schema Approach for the Achievement of the Verbal Mathematics Problem-Solving Skills in Individuals with Autism Spectrum Disorders. *Kuram ve Uygulamada Egitim Bilimleri,* 17 (6), 1787-1809.

Kilpatrick, I, Swafford, J., & Findell, B. (2001). *Adding it up: Helping children learn mathematics*. Washington, DC: National Research Council.

King, S. A., Lemons, C. J., & Davidson, K. A. (2016) Math interventions for students with autism spectrum disorder: A best-evidence synthesis. *Exceptional Children, 82,* 443-462.

Kozleski, E. (2017) The Uses of Qualitative Research: Powerful Methods to Inform Evidence-Based Practice in Education. *Research and Practice for Persons with Severe Disabilities*, 1-14. https://doi.org/10.1177/1540796916683710

Mayes, S. D. & Calhoun, S. L. (2006). Frequency of reading, math, and writing disabilities in children with clinical disorders. *Learning and Individual Differences*, 16 (2), 145-157.

McDuffie, K. A. & Scruggs, T. E. (2008). The contributions of qualitative research to discussions of evidence-based practice in special education. *Intervention in School and Clinic*, 44 (2), 91-97.

McIntosh, A., Reys, B. J. & Reys, R. E. (1992). A proposed framework for examining basic number sense. *For the Learning of Mathematics, 12*, 2-44.

National Council of Teachers of Mathematics. (2000). Principles and standards for school mathematics. Reston, VA: Author.

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods, 16*, 1609406917733847.

O'malley, P., Jenkins, S., Wesley, B., Donehower, C., Rabuck, D. & Lewis, M. (2013). Effectiveness of Using iPads to Build Math Fluency. Online Submission, Paper presented at 2013 Council for Exceptional Children. http://files.eric.ed.gov/fulltext/ED541158. pdf

Pugach, M. C. (2001). The stories we choose to tell: Fulfilling the promise of qualitative research for special education. *Exceptional Children*, 67 (4), 439-453.

Root, J. R., Browder, D. M., Saunders, A. F. & Lo, Y. (2017). Schema-based instruction with concrete and virtual manipulatives to teach problem solving to students with autism. *Remedial and Special Education*, 38 (1), 42-52.

Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for information, 22*, 63-75.

Spooner, F., McKissick, B. R., & Knight, V. F. (2017). Establishing the state of affairs for evidence-based practices in students with severe disabilities. *Research and Practice for Persons with Severe Disabilities, 42*(1), 8-18. https:// doi:10.1177/1540796916684896

Spooner, F., Root, J. R., Saunders, A. F. & Browder, D. M. (2019). An updated evidence-based practice review on teaching mathematics to students with moderate and severe developmental disabilities. *Remedial and Special Education*. https://www.researchgate.net/profile/Jenny_Root2/publication/323485176

Starks, H., & Brown Trinidad, S. (2007). Choose your method: A comparison of phenomenology, discourse analysis, and grounded theory. *Qualitative health research, 17*, 1372-1380.

Su, H. (2003). Don't be puzzled by math. *NCSM Journal of Mathematics Education Leadership*, 6 (2), 1-7.

Tzanakaki, P., Grindle, C. F., Saville, M., Hastings, R. P., Hughes, J. C. & Huxley, K. (2014a). An individualised curriculum to teach numeracy skills to children with autism: programme description and pilot data. *Support for Learning*, 29 (4), 319-338.

Tzanakaki, P., Hastings, R. P., Grindle, C. F., Hughes, J. C. & Hoare, Z. (2014b). An individualized numeracy curriculum for children with intellectual disabilities: A single blind pilot randomized controlled trial. *Journal of Developmental and Physical Disabilities*, 26 (5), 615-632.

Wei, X., Christiano, E. R., Yu, J. W., Wagner, M. & Spiker, D. (2015). Reading and math achievement profiles and longitudinal growth trajectories of children with an autism spectrum disorder. *Autism*, 19 (2), 200-210.

Wright, R. J., Ellemor-Collins, D., & Tabor, P. D. (2012). *Developing number knowledge: Assessment, teaching & intervention with 7-11-years-olds.* London, England: SAGE Publications Ltd.

Zentall, S. S. (2007). Math performance of students with ADHD: Cognitive and behavioral contributors and interventions. In D. B. Berch, & M. M. M. Mazzocco (Eds.), *Why is Math so Hard for some Children? The Nature and Origins of Mathematical Learning Difficulties and Disabilities*, pp. 219-243. Paul H Brookes Publishing.

Appendix 4. Systematic review (Chapter 2) protocol registered on PROSPERO.

NIHR | National Institute for Health Research

PROSPERO
International prospective register of systematic reviews

Teaching science skills and knowledge to students with developmental disabilities: a systematic review

Magdalena Apanasionok, Richard Hastings, Corinna Grindle, Richard Watkins, Andreas Paris

Citation

Magdalena Apanasionok, Richard Hastings, Corinna Grindle, Richard Watkins, Andreas Paris. Teaching science skills and knowledge to students with developmental disabilities: a systematic review. PROSPERO 2017 CRD42017057323 Available from: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42017057323

Review question

Research question 1 (RQ1):What interventions have been developed to teach science skills and knowledge to children with developmental disabilities (DD)?i. Objective 1: To identify available interventions aiming to teach science content/knowledge to children with DD. ii. Objective 2: To identify available interventions aiming to teach science skills to children with DD. iii. Objective 3: To identify any evidence for effectiveness for interventions located and any factors that contribute to effectiveness intervention to teach science to children with DD.

Research question 2 (RQ2):What are the views and experiences of students with Developmental Disabilities (DD) and their teachers on interventions used to teach science? i. Objective 1: To summarise DD students' and their teachers' opinions and experiences on science interventions in terms of effectiveness, usefulness and ease of use.ii. Objective 2: To identify any tools used to collect data on students' and teachers' opinions about science interventions.

Searches

Search strategy will be developed based on terms related to Science Education, Intellectual Disability and Autism Spectrum Disorder and run in following online databases: ERIC, Education Research Complete, PsycINFO, Social Science Citation Index, British Education Index and ASSIA.

Sample search terms that will be applied:

List 1:
Autis*
ASD
"Autism Spectrum Disorder*"
"Intellectual Disabilit*"
ID
"Mental retardation"
"Developmental Disabilit*"
"Down syndrome"
"Pervasive developmental disorder"
PDD
Asperger*
"Learning Disabilit*"
"Learning Difficult*"
"Learning Impairment*"
"Intellectual Deficien*"
"Developmental Impairment*"
Handicap*

List 2:
Scien*
Physics
Chemistry

Biology
Plant*
Animal*
"Human bod*"
Material*
Force*
Earth
Electricity
Acid*
Rocks
Soil
Magnet*
Space
Chemical
Weather
Season*
Mass
Planet*
"Solar system*"
"Living organism*"
Cell*
Bodypart*
Fungus
Insect*
Temperature
"Work* scientifically"
"Scien* enquiry"
"Scien* inquiry"
"Scien* Experiment"
STEM
"Scien* model* and analog*"
"Scien* pattern-seek*"
"Scien* curriculum"
"Scien* intervention"
"Scien* program*"
"Scien* prediction"
"Scien* classification"
"Scien* test*"

Search line 1 – Terms from List 1 separated with OR
Search line 2 – Terms from List 2 separated with OR

Both search lines will be combined with AND. All terms will be scanned against titles, key words and abstracts.

The review will focus only on research papers published in English and Polish language. No restrictions regarding publication date will be applied.

Forward and backward reference searches will be conducted on papers included in this review to identify any potential papers that might have been missed during the initial screening.

Additionally, authors of papers included in this review will be contacted to enquire about any suggestions regarding papers that might have been missed during the screening or ongoing or unpublished research within the same area.

Citation searches of included papers will also be conducted to identify additional papers.

Types of study to be included

Research question 1 (RQ1):Inclusion criteria: any quantitative research with a form of comparison (controlled trials; randomised controlled trials; single group pre-post design; single case experimental design).Exclusion criteria: qualitative research; studies not reporting any data; insufficient methodological information; "case studies" of children or schools not involving a single case experimental design; A-B single case designs.Research question 2 (RQ2):Inclusion criteria: any qualitative or quantitative study reporting data on students' and teachers' opinions or experiences about a science intervention.Exclusion criteria: studies not reporting any data; insufficient methodological information.

Condition or domain being studied

Science Education for students with developmental disabilities.
Science Education will be defined as "scientific knowledge and conceptual understanding through the specific disciplines of biology, chemistry and physics" (National Curriculum, 2014). It will be also understood as "the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence" (Science Council, 2009).
Science Education equips students with knowledge about the world around them and it enables them to understand processes in nature. Students with developmental disabilities can benefit greatly from learning science as it gives them a chance to learn enquiry skills and explore their environment. It also equips them with skills that can be very helpful in accessing community and staying safe.

Participants/population

1. Children with intellectual disability (ID)

Children with ID will be defined as having IQ score below 70, assessed by standardised test and having deficits in intellectual and adaptive functioning.
2. Children with autism spectrum disorder (ASD)
Children with ASD will be defined as having deficits in social communication and interaction, as well as restrictive patterns of behaviour.
Inclusion criteria: Children and young adults from 5 to 25 years old with primary diagnosis of ID or ASD and/or administratively defined as having ID and/or ASD (e.g., enrolled in special school or SEN setting in a mainstream school); at least 70% of reported participants with primary diagnosis of ID and/or ASD, if less than 70% then results for all subgroups are reported separately.
Exclusion criteria: Children in home education; young adults in University education; less than 70% of reported participants with primary diagnosis of ID and/or ASD and for whom the results are not reported separately.

Intervention(s), exposure(s)

Review will be looking at research evaluating any educational interventions aiming to teach science knowledge and/or skills to children with DD (ASD and ID). Interventions can be applied in either individual or group settings. The duration of the implementation may vary, however this review will only include studies conducted in school and further education (or equivalent internationally) college settings.

Comparator(s)/control

Investigated interventions will be compared against:
a. Teaching as usual (students accessing normal lessons as per their timetable) or any other intervention.
b. With no comparison, but involving change from baseline measures.

Main outcome(s)

Students' gains in the science skills or knowledge.

Additional outcome(s)

Students with DD and their teachers' opinions on the effectiveness, usefulness and ease of use of the interventions.
Other educational outcomes relevant for students with DD such as reading comprehension, community skills and participation, communication, adaptive behaviours and levels of challenging behaviours.

Data extraction (selection and coding)

First author will do initial screening of titles and abstracts against inclusion criteria of all returned results. Second reviewer will independently verify inclusion of at least 20% of randomly selected records.

Full texts of studies obtained during the initial screening will be thoroughly reviewed by two independent researchers. Reasons for inclusion and exclusion will be recorded.
First author will then extract data from selected studies using standardised form and a second reviewer will verify at least 20% of randomly selected records. Extracted data will include article details, demographic data, setting details, methodology, intervention details (training and implementation), social validity details and all participant-related outcomes.
Any disagreements will be resolved during discussion with a third reviewer.

Risk of bias (quality) assessment

PRISMA guidelines to reporting results will be used while writing up the review.
Following assessment tools will be used depending on research design:
1. Randomised controlled trials – Critical Appraisal Skills Programme (CASP): RCT
2. Non-randomised controlled trials – CASP: RCT without randomisation question
3. Cohort Studies – CASP: Cohort
4. Case-control studies – CASP: Case-control
5. Single-Subject Research – Horner et al, 2005
6. Qualitative Studies – CASP: Qualitative Research.

In relation to SR Q2 the Quality Indicators of Social Validity from Spear et al. (2013) will be used.
Depending on number of studies selected, we will also consider using measures of research quality and strength from Evaluative Method (Reichow et al., 2008) in relation to SR Q1.
Studies not meeting quality norms will be excluded from the review after discussion with a third reviewer.

Strategy for data synthesis

Narrative synthesis. A meta-analysis is not planned for this review unless sufficient studies of the same intervention with the same outcome measures are found.

Analysis of subgroups or subsets

None planned.

Contact details for further information

Magdalena Apanasionok
M.Apanasionok@warwick.ac.uk

Organisational affiliation of the review

Centre for Educational Development, Appraisal & Research (CEDAR), University of Warwick, UK
http://www2.warwick.ac.uk/fac/soc/cedar/

Review team members and their organisational affiliations

Mrs Magdalena Apanasionok. CEDAR, University of Warwick
Professor Richard Hastings. CEDAR, University of Warwick
Dr Corinna Grindle. CEDAR, University of Warwick
Dr Richard Watkins. GwE School Effectiveness and Improvement Service for North Wales
Andreas Paris. CEDAR, University of Warwick

Type and method of review

Systematic review

Anticipated or actual start date

06 February 2017

Anticipated completion date

31 August 2017

Funding sources/sponsors

This systematic review was carried out as a part of Doctoral Dissertation funded in collaboration by University of Warwick and Calthorpe Academy.

Conflicts of interest

None known

Language
English

Country
England

Stage of review
Review Completed published

Details of final report/publication(s) or preprints if available
Apanasionok MM, Hastings RP, Grindle CF, Watkins RC, Paris A. Teaching science skills and knowledge to students with developmental disabilities: A systematic review. J Res Sci Teach. 2019;1–34. https://doi.org/10.1002/tea.21531
https://onlinelibrary.wiley.com/doi/abs/10.1002/tea.21531

Subject index terms status
Subject indexing assigned by CRD

Subject index terms
Child; Developmental Disabilities; Humans; Knowledge; Science

Date of registration in PROSPERO
14 February 2017

Date of first submission
30 January 2019

Stage of review at time of this submission

Stage	Started	Completed
Preliminary searches	Yes	Yes
Piloting of the study selection process	Yes	Yes
Formal screening of search results against eligibility criteria	Yes	Yes
Data extraction	Yes	Yes
Risk of bias (quality) assessment	Yes	Yes
Data analysis	Yes	Yes

The record owner confirms that the information they have supplied for this submission is accurate and complete and they understand that deliberate provision of inaccurate information or omission of data may be construed as scientific misconduct.

The record owner confirms that they will update the status of the review when it is completed and will add publication details in due course.

Versions
14 February 2017
13 March 2017
08 February 2019

Appendix 5. Bespoke information sheet used during database searches and study selection

(Chapter 2)

TEACHING SCIENCE SKILLS AND KNOWLEDGE TO CHILDREN WITH DEVELOPMENTAL DISABILITIES: A SYSTEMATIC REVIEW

Does the study meet each of these four criteria?

1. **Science education focus**

Science Education is "scientific knowledge and conceptual understanding through the specific disciplines of biology, chemistry and physics" and "the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence" Examples of different science skills and concepts are: forces and magnets, seasons, planets, rocks and soil, weather, living organisms, Inquiry skills, 'working scientifically', observations and experiments, hypothesising and testing.

2. **Population of children and teenagers with ASD and/or ID**

Inclusion criteria: Children and young adults from 5 to 25 years old with primary diagnosis of Intellectual Disability or Autism Spectrum Disorder and/or administratively defined as having ID and/or ASD (e.g., enrolled in special school or SEN setting in a mainstream school); at least 70% of reported participants with primary diagnosis of ID and/or ASD, if less than 70% then results for all subgroups are reported separately.
Exclusion criteria: less than 70% of reported participants with primary diagnosis of ID and/or ASD and for who the results are not reported separately.

- **Children with Intellectual Disability (ID)** - IQ score below 70, assessed by standardised test and having deficits in intellectual and adaptive functioning.
- **Children with Autism Spectrum Disorder (ASD)** - exhibiting deficits in social communication and interaction, as well as restrictive patterns of behaviour.

3. **School/FE college setting**

Inclusion criteria: Children and young adults enrolled in special schools or FE colleges OR SEN departments in mainstream schools.
Exclusion criteria: Children in home education; young adults in University education

4. **Design**

Inclusion criteria: any quantitative research with a form of comparison (controlled trials; randomised controlled trials; single group pre-post design; single case experimental design); any qualitative data or quantitative study reporting data on students' and teachers' opinions or experiences about a science intervention.
Exclusion criteria: studies not reporting any data; insufficient methodological information; "case studies" of children or schools not involving a Single Case Experimental Design; A-B single case designs.

Appendix 6. Quality appraisal scores of studies incorporating single-case experimental design.

Quality Indicators	Argan et al. 2006	Agran et al. 2006 (science only)	Carnahan and Williamson, 2013	Carnahan et al. 2016	Collins et al. 2007
1. Participants and Setting					
- Participants described	Y	Y	Y	Y	Y
- Selection described	Y	Y	Y	Y	Y
- Setting described	Y	Y	Y	Y	Y
2. Dependent Variable (DV)					
- DV described	Y	Y	Y	Y	N
- Quantifiable index	Y	Y	Y	Y	Y
- DV measurement described	Y	Y	Y	Y	Y
- DV measured repeatedly	Y	Y	Y	Y	Y
- Inter-observer agreement data reported	Y	Y	Y	Y	Y
3. Independent variable (IV)					
- IV described	Y	Y	Y	Y	Y
- IV systematically manipulated	Y	Y	Y	Y	Y
- Procedural fidelity data reported	N	N	Y	Y	Y
4. Baseline					
- DV repeatedly measured prior to IV implementation	Y	Y	Y	Y	Y
- Baseline procedures described	Y	Y	Y	Y	Y
5. Experimental Control					
- Three demonstrations of experimental control	Y	Y	Y	Y	Y
- Design controlled for common threats to internal validity	Y	Y	Y	Y	Y
- Pattern of results demonstrates experimental control	Y	Y	Y	Y	Y
6. External validity					
- Experimental effects replicated across participants, setting, or materials	Y	Y	Y	Y	Y

7. Social validity					
- DV is socially important	Y	Y	Y	Y	Y
- Magnitude of change in the DV from the intervention is socially important	Y	Y	Y	Y	Y
- Implementation of IV is practical and cost effective	Y	Y	Y	Y	Y
- IV implemented over extended time periods, by typical agents, in typical context	Y	Y	Y	Y	Y
Indicators met:	20/21	20/21	21/21	21/21	20/21
Categories met:	6/7	6/7	7/7	6/7	6/7

Quality Indicators	Collins et al. 2007 (science only)	Collins et al. 2011	Collins et al. 2011 (science only)	Collins et al. 2017	Collins et al. 2017 (science only)
1. Participants and Setting					
- Participants described	Y	N	N	Y	Y
- Selection described	Y	Y	Y	Y	Y
- Setting described	Y	Y	Y	Y	Y
2. Dependent Variable (DV)					
- DV described	N	Y	Y	Y	Y
- Quantifiable index	Y	Y	Y	Y	Y
- DV measurement described	Y	Y	Y	Y	Y
- DV measured repeatedly	Y	Y	Y	Y	Y
- Inter-observer agreement data reported	Y	Y	Y	Y	Y
3. Independent variable (IV)					
- IV described	Y	Y	Y	Y	Y
- IV systematically manipulated	Y	Y	Y	Y	Y
- Procedural fidelity data reported	Y	Y	Y	Y	Y

4. Baseline					
- DV repeatedly measured prior to IV implementation	Y	Y	Y	Y	Y
- Baseline procedures described	Y	Y	Y	Y	Y
5. Experimental Control					
- Three demonstrations of experimental control	Y	Y	Y	Y	Y
- Design controlled for common threats to internal validity	Y	Y	Y	Y	Y
- Pattern of results demonstrates experimental control	Y	Y	Y	Y	Y
6. External validity					
- Experimental effects replicated across participants, setting, or materials	N	Y	Y	Y	Y
7. Social validity					
- DV is socially important	Y	Y	Y	Y	Y
- Magnitude of change in the DV from the intervention is socially important	Y	Y	Y	Y	Y
- Implementation of IV is practical and cost effective	Y	Y	Y	Y	Y
- IV implemented over extended time periods, by typical agents, in typical context	Y	Y	Y	Y	Y
Indicators met:	19/21	20/21	20/21	21/21	21/21
Categories met:	5/7	6/7	6/7	6/7	7/7

Quality Indicators	Courtade et al. 2010	Courtade et al. 2010 (science only)	Fetko et al. 2013	Fetko et al. 2013 (science only)	Heinrich et al. 2016
1. Participants and Setting					
- Participants described	Y	Y	Y	Y	Y
- Selection described	Y	Y	Y	Y	Y

- Setting described	Y	Y	Y	Y	Y
2. Dependent Variable (DV)					
- DV described	Y	Y	N	N	N
- Quantifiable index	Y	Y	Y	Y	Y
- DV measurement described	Y	Y	Y	Y	Y
- DV measured repeatedly	Y	Y	Y	N	Y
- Inter-observer agreement data reported	Y	Y	Y	N	Y
3. Independent variable (IV)					
- IV described	Y	Y	Y	Y	Y
- IV systematically manipulated	Y	Y	Y	Y	Y
- Procedural fidelity data reported	Y	Y	Y	Y	Y
4. Baseline					
- DV repeatedly measured prior to IV implementation	Y	Y	Y	Y	Y
- Baseline procedures described	Y	Y	Y	Y	Y
5. Experimental Control					
- Three demonstrations of experimental control	Y	Y	Y	N	Y
- Design controlled for common threats to internal validity	Y	Y	Y	Y	Y
- Pattern of results demonstrates experimental control	Y	Y	Y	Y	Y
6. External validity					
- Experimental effects replicated across participants, setting, or materials	Y	Y	Y	Y	Y
7. Social validity					
- DV is socially important	Y	Y	Y	Y	Y
- Magnitude of change in the DV from the intervention is socially important	Y	Y	N	N	Y
- Implementation of IV is practical and cost effective	Y	Y	Y	Y	Y
- IV implemented over extended time periods, by typical agents, in typical context	Y	Y	Y	Y	Y
Indicators met:	21/21	21/21	19/21	16/21	20/21
Categories met:	7/7	7/7	5/7	4/7	6/7

Quality Indicators	Heinrich et al. 2016 (science only)	Hudson et al. 2014	Jameson et al. 2007	Jameson et al. 2007 (science only)	Jimenez et al. 2009
1. Participants and Setting					
- Participants described	Y	Y	Y	Y	Y
- Selection described	Y	Y	Y	Y	Y
- Setting described	Y	Y	Y	Y	Y
2. Dependent Variable (DV)					
- DV described	N	Y	Y	Y	Y
- Quantifiable index	Y	Y	Y	Y	Y
- DV measurement described	Y	Y	Y	Y	Y
- DV measured repeatedly	Y	Y	Y	Y	Y
- Inter-observer agreement data reported	Y	Y	Y	Y	Y
3. Independent variable (IV)					
- IV described	Y	Y	Y	Y	Y
- IV systematically manipulated	Y	Y	Y	Y	Y
- Procedural fidelity data reported	Y	Y	Y	Y	Y
4. Baseline					
- DV repeatedly measured prior to IV implementation	Y	Y	Y	Y	Y
- Baseline procedures described	Y	Y	Y	Y	Y
5. Experimental Control					
- Three demonstrations of experimental control	N	Y	Y	Y	Y
- Design controlled for common threats to internal validity	Y	Y	Y	Y	Y
- Pattern of results demonstrates experimental control	Y	Y	Y	Y	Y
6. External validity					
- Experimental effects replicated across participants, setting,	N	Y	Y	N	Y

or materials					
7. Social validity					
- DV is socially important	Y	Y	Y	Y	Y
- Magnitude of change in the DV from the intervention is socially important	Y	Y	Y	Y	Y
- Implementation of IV is practical and cost effective	Y	Y	Y	Y	Y
- IV implemented over extended time periods, by typical agents, in typical context	Y	Y	Y	Y	Y
Indicators met:	18/21	21/21	21/21	20/21	21/21
Categories met:	4/7	7/7	7/7	6/7	7/7

Quality Indicators	Jimenez et al. 2012a	Jimenez et al. 2014	Johnson et al. 2004	Johnson et al. 2004 (science only)	Karl et al. 2013
1. Participants and Setting					
- Participants described	Y	Y	N	N	Y
- Selection described	Y	Y	N	N	Y
- Setting described	Y	Y	Y	Y	Y
2. Dependent Variable (DV)					
- DV described	Y	Y	Y	Y	N
- Quantifiable index	Y	Y	Y	Y	Y
- DV measurement described	Y	Y	Y	Y	Y
- DV measured repeatedly	Y	Y	Y	Y	Y
- Inter-observer agreement data reported	Y	Y	Y	Y	Y
3. Independent variable (IV)					
- IV described	Y	Y	Y	Y	Y
- IV systematically manipulated	Y	Y	Y	Y	Y
- Procedural fidelity data reported	Y	Y	Y	Y	Y

4. Baseline					
- DV repeatedly measured prior to IV implementation	Y	Y	Y	Y	Y
- Baseline procedures described	Y	Y	Y	Y	Y
5. Experimental Control					
- Three demonstrations of experimental control	Y	Y	Y	Y	Y
- Design controlled for common threats to internal validity	Y	Y	Y	Y	Y
- Pattern of results demonstrates experimental control	Y	Y	Y	Y	Y
6. External validity					
- Experimental effects replicated across participants, setting, or materials	Y	Y	Y	Y	Y
7. Social validity					
- DV is socially important	Y	Y	Y	Y	Y
- Magnitude of change in the DV from the intervention is socially important	Y	N	Y	Y	Y
- Implementation of IV is practical and cost effective	Y	Y	Y	Y	Y
- IV implemented over extended time periods, by typical agents, in typical context	Y	Y	Y	Y	Y
Indicators met:	21/21	20/21	19/21	19/21	20/21
Categories met:	7/7	6/7	6/7	6/7	5/7

Quality Indicators	Karl et al. 2013 (science only)	Knight et al. 2012	Knight et al. 2013	Knight et al. 2014	Knight et al. 2017
1. Participants and Setting					
- Participants described	Y	Y	Y	Y	Y

- Selection described	Y	Y	Y	Y	Y
- Setting described	Y	Y	Y	Y	Y
2. Dependent Variable (DV)					
- DV described	N	Y	Y	Y	Y
- Quantifiable index	Y	Y	Y	Y	Y
- DV measurement described	Y	Y	Y	Y	Y
- DV measured repeatedly	Y	Y	Y	Y	Y
- Inter-observer agreement data reported	Y	Y	Y	Y	Y
3. Independent variable (IV)					
- IV described	Y	Y	Y	Y	Y
- IV systematically manipulated	Y	Y	Y	Y	Y
- Procedural fidelity data reported	Y	Y	Y	Y	Y
4. Baseline					
- DV repeatedly measured prior to IV implementation	Y	Y	Y	Y	Y
- Baseline procedures described	Y	Y	Y	Y	Y
5. Experimental Control					
- Three demonstrations of experimental control	Y	Y	Y	Y	Y
- Design controlled for common threats to internal validity	Y	Y	Y	Y	Y
- Pattern of results demonstrates experimental control	Y	Y	Y	Y	Y
6. External validity					
- Experimental effects replicated across participants, setting, or materials	Y	Y	Y	Y	Y
7. Social validity					
- DV is socially important	Y	Y	Y	Y	Y
- Magnitude of change in the DV from the intervention is socially important	Y	Y	Y	N	Y
- Implementation of IV is practical and cost effective	Y	Y	Y	Y	Y
- IV implemented over extended time periods, by typical agents, in typical context	Y	Y	Y	Y	Y
Indicators met:	20/21	21/21	21/21	20/21	21/21
Categories met:	6/7	7/7	7/7	6/7	7/7

Quality Indicators	McDonnell et al. 2006	McDonnell et al. 2006 (science only)	McMahon et al. 2016	Miller and Taber-Doughty 2014	Miller et al. 2015
1. Participants and Setting					
- Participants described	N	N	Y	Y	Y
- Selection described	Y	Y	Y	Y	Y
- Setting described	Y	Y	Y	Y	Y
2. Dependent Variable (DV)					
- DV described	Y	Y	Y	Y	Y
- Quantifiable index	Y	Y	Y	Y	Y
- DV measurement described	Y	Y	Y	Y	Y
- DV measured repeatedly	Y	Y	Y	Y	Y
- Inter-observer agreement data reported	Y	Y	Y	Y	Y
3. Independent variable (IV)					
- IV described	Y	Y	Y	Y	Y
- IV systematically manipulated	Y	Y	Y	Y	Y
- Procedural fidelity data reported	Y	Y	Y	Y	Y
4. Baseline					
- DV repeatedly measured prior to IV implementation	Y	Y	Y	Y	Y
- Baseline procedures described	Y	Y	Y	Y	Y
5. Experimental Control					
- Three demonstrations of experimental control	Y	Y	Y	Y	Y
- Design controlled for common threats to internal validity	Y	Y	Y	Y	Y
- Pattern of results demonstrates experimental control	Y	Y	Y	Y	Y
6. External validity					
- Experimental effects replicated across participants, setting, or materials	Y	Y	Y	Y	Y

7. Social validity					
- DV is socially important	Y	Y	Y	Y	Y
- Magnitude of change in the DV from the intervention is socially important	Y	Y	Y	Y	Y
- Implementation of IV is practical and cost effective	Y	Y	Y	Y	Y
- IV implemented over extended time periods, by typical agents, in typical context	Y	Y	Y	Y	Y
Indicators met:	20/21	20/21	21/21	21/21	21/21
Categories met:	6/7	6/7	7/7	7/7	7/7

Quality Indicators	Riesen et al. 2003	Riesen et al. 2003 (science only)	Riggs et al. 2013	Smith et al. 2013a	Smith et al. 2013b
1. Participants and Setting					
- Participants described	N	N	N	Y	N
- Selection described	Y	Y	Y	Y	Y
- Setting described	Y	Y	Y	Y	Y
2. Dependent Variable (DV)					
- DV described	Y	Y	N	Y	Y
- Quantifiable index	Y	Y	Y	Y	Y
- DV measurement described	Y	Y	Y	Y	Y
- DV measured repeatedly	Y	Y	Y	Y	Y
- Inter-observer agreement data reported	Y	Y	Y	Y	Y
3. Independent variable (IV)					
- IV described	Y	Y	Y	Y	Y

- IV systematically manipulated	Y	Y	Y	Y	Y
- Procedural fidelity data reported	Y	Y	Y	Y	Y
4. Baseline					
- DV repeatedly measured prior to IV implementation	Y	Y	Y	Y	Y
- Baseline procedures described	Y	Y	Y	Y	Y
5. Experimental Control					
- Three demonstrations of experimental control	Y	Y	Y	Y	Y
- Design controlled for common threats to internal validity	Y	Y	Y	Y	Y
- Pattern of results demonstrates experimental control	Y	Y	Y	Y	Y
6. External validity					
- Experimental effects replicated across participants, setting, or materials	Y	Y	Y	Y	Y
7. Social validity					
- DV is socially important	Y	Y	Y	Y	Y
- Magnitude of change in the DV from the intervention is socially important	Y	Y	Y	Y	Y
- Implementation of IV is practical and cost effective	Y	Y	Y	Y	Y
- IV implemented over extended time periods, by typical agents, in typical context	Y	Y	Y	Y	Y
Indicators met:	20/21	20/21	19/21	21/21	20/21
Categories met:	6/7	6/7	5/7	7/7	6/7

Appendix 7. Quality appraisal scores of studies incorporating group design.

	References	
CASP questions	Browder at el. 2010	Roberts and Joiner 2007
(A) Are the results of the trial valid?		
1. Did the trial address clearly focused issue?	Yes	Yes
2. Was the assignment of patients to treatment randomised?	Yes	N/A – non-randomised controlled trial design
3. Were all of the patients who entered the trial properly accounted for at its conclusion?	Yes	Yes
4. Were patients, health workers and study personnel 'blind' to treatment?	No	No
5. Were the groups similar at the start of the trial?	Yes	Yes
6. Aside from the experimental intervention, were the groups treated equally?	Yes	Yes
(B) What are the results?		
7. How large was the treatment effect?	Mathematic group had 27.9% gain at math post-test compared to pre-test and 2.9% gain at science post-test compared to pre-test. Science group had 1% gain at math post-	Difference in pre- and post-test results were greater for the concept mapping condition than the conventional teaching condition. Students in conventional teaching

	test compared to pre-test and 15.7% gain at science post-test compared to pre-test.	condition had 9.4 score increase at post-test compared to pre-test at questionnaires and 14.1 increase in concept map scores. Students in concept mapping condition had 35.6 score increase at post-test compared to pre-test at questionnaires and 33 increase in concept map scores.
8. How precise was the estimate of the treatment effect?	P<.001. Math group had much higher gains at math post-test than science group (Cohen's d = 2.41). Science group had much higher gains at science post-test than math group (Cohen's d = 1.33).	P<0.05. The effect size was large (r=0.66).
(C) Will the results help locally?		
9. Can the results be applied in your context? (or to the local population?)	Yes	Yes
10. Were all clinically important outcomes considered?	Yes	Yes

11. Are the benefits worth the harms and costs?	Yes	Yes

Appendix 8. Summary table of systematic instruction interventions.

Source and Origin	Intervention
Browder et al. 2010 USA	Task analyzed inquiry-based instruction. The intervention consisted of three main components: inquiry-based lessons, training targeting science vocabulary, and experiments. Vocabulary was taught using a time delay procedure (involving delivery of the prompt after a specific amount of time after the instruction, usually starting at zero seconds and systematically increasing the interval). The teacher used a range of materials related to the topic of the lesson and engaged students in hands-on experiments while introducing key concepts. All lessons were task analyzed (breaking down a complex task into smaller steps) and conducted by special education teachers in a self-contained classroom.
Collins et al. 2007 USA	Compared three interventions: 1. Simultaneous prompting (the prompt is delivered straight after the instruction and then gradually faded out; controlling probes are conducted before the training to determine if the skills have been acquired) with massed trial instruction (trials are conducted one after the other, without a break in-between). The intervention was delivered by a special education teacher in a resource room. 2. Simultaneous prompting with distributed trial instruction (trials are naturally distributed in daily activities to encourage generalization). The intervention was delivered by special education teacher, instructional assistant, or a peer tutor in general education setting. 3. Embedded instruction (embedded instruction means that the trials are naturally distributed across the sessions and occur as part of students' ongoing routines). The intervention was delivered by an instructional assistant or a peer tutor in a general education classroom.
Collins et al. 2011 USA	Constant time delay procedure (procedure involving delivery of the prompt after a specific amount of time after the instruction, usually starting at zero seconds and then increasing the interval to a specific number of seconds for the rest of the trials) was used to teach the properties of elements. The instructor used a 0-second delay during the first session and a 3-second delay during the consecutive sessions. The prompts were either a verbal model or a verbal model with a gesture.
Collins et al. 2017 USA	Simultaneous prompting procedure (see above for definition) was used to embed core content related to photosynthesis in teaching a practical skill (plant care). The plant care activity was task-analyzed, and core content was delivered as part of instructive feedback after completing plant care steps. No response was required of the students. After the intervention phase finished, students were taught photosynthesis content that they had not acquired previously using a simultaneous prompting procedure.
Courtade et al. 2010 USA	Multi-component training in task analyzed inquiry-based instruction for the teachers. The training included: a fidelity checklist, training manual, verbal explanation of content, video modelling, and time to develop one lesson and receive feedback from the researchers. The training was delivered in a one-to-one setting by a researcher and lasted 4 hours. The teachers were also trained in using the system of least-to-most prompts (hierarchy of prompts used to help the students, starting from the least intrusive) error correction and reinforcement.
Fetko et al. 2013	Simultaneous prompting procedure with core content (science vocabulary) embedded as non-target information while teaching a leisure skill

USA	activity (UNO game). Peer tutors taught a task-analyzed UNO game to disabled students using the simultaneous prompting procedure. The core content (science vocabulary) was delivered after praise for completing each step of the task analysis as part of the instructive feedback.
Heinrich et al. 2016 USA	Embedded simultaneous prompting procedure (see above for definitions). The intervention was delivered by paraprofessionals and peer tutors and took place during several points of the day. Controlling probes to check students' progress were conducted daily before the start of the session.
Hudson et al. 2014 USA	Peer-delivered system of least prompts with adopted science read-alouds – Prior to the start of the intervention peer tutors were trained in the teaching procedure (system of least prompts; see above for the definition) and participants were trained to request help and in the use of self-monitoring tools. The intervention was delivered in a one-to-one format. During each session, the peer tutor read science related text while stopping at predisposed points and asking one of six comprehension questions. If the participant requested help the peer tutor delivered the next step of the predetermined prompting hierarchy. If the participant did not respond or responded incorrectly the peer tutor delivered the correction procedure.
Jameson et al. 2007 USA	Comparison of two interventions: 1. One-to-one embedded instruction (see above for the definition) – implemented by the special education teacher and a paraprofessional in the general education class. The intervention trials were delivered during transitions, breaks, etc. The procedure also involved constant time delay (see above for definition), differential reinforcement (procedure involving rewarding independent correct response and withholding reward when prompt is needed), and error correction. 2. One-to-one massed trials instructional format (see above for definition) - implemented by the special education teacher and a paraprofessional in the self-contained special education class. The same procedures were used in the mass trial condition as in embedded instruction. The main difference was that the trials were staggered together and delivered during one session per day one after the other without any pause in between.
Jimenez et al. 2009 USA	Multicomponent training package for students – the package consisted of multiple exemplar training (procedure involving teaching a target instruction across different materials, settings, or people at the same time to facilitate generalization), time delay (see above for definition) and self-directed learning prompts (KWHL chart - What we know?; What we want to know?; How to find out?; What was learned?). The training occurred in a one-to-one setting and was delivered by a researcher. Students were taught to turn pages of the workbook, state their response, and complete the KWHL chart to facilitate self-directed learning. Students' generalization of the use of the KWHL chart was assessed during general education classes.
Jimenez et al. 2012a USA	Peer-mediated embedded instruction with time delay (see above for definitions) – during each lesson peer tutors trained participants on science responses using time delay and embedded instruction and on the use of a KWHL chart using embedded instruction. The intervention took place in the general education classroom and was delivered by peers without disabilities who received one-hour training prior to the start of the study. The science teacher delivered instruction for the whole class first and then peer tutors delivered the teaching trials one-to-one to the participants.
Jimenez et al. 2014 USA	Inquiry-based curriculum for students with severe disabilities – Early Science Curriculum – was implemented across two experimental conditions: 1. Scripted lessons (a detailed script outlining what the teacher needs to say, the teaching procedures to be used, and the order in which the lesson

	has to progress) – the teacher delivered the content covered in the Early Science Curriculum script using a range of systematic instruction procedures such as time delay (see above for definition), system of least-to-most prompts (see above for definition), specific praise (clearly labelling behavior that the child is being praised for) and an example/nonexample procedure (procedure involving presenting the child with an example and nonexample of a target item while clearly labelling: ‘This is….’ or ‘This is not…’). A KWHL chart was also used. All three students were taught in one group. 2. Scripted lessons with guided notes – the teaching procedure was the same as outlined above except for the inclusion of guided notes for the participants to help retention of key concepts. These materials included printed notes with symbols and appropriate space for the students to insert picture or vocabulary cards.
Johnson et al. 2004 USA	Embedded instruction (see above for definition) – instructional procedures used were: constant time delay (see above for definition), error correction and reinforcement. Initially a zero second delay was used. Later the delay was increased to four seconds. The intervention was delivered by the teacher in the general education classroom.
Karl et al. 2013 USA	Simultaneous prompting procedure (see above for definition) was used to teach science core content within a functional activity. Students had daily cooking sessions with embedded core content training (science, math and reading). The intervention was delivered in a small group format by a teacher.
Knight et al. 2012 USA	Explicit instruction (errorless teaching procedure focused on teaching the student to recognize examples and non-examples) - the teaching procedure involved a model-lead-test strategy (three step teaching procedure involving the teacher modelling the response for the student first, then doing it with the student and then testing student’s understanding) with the teacher waiting for student’s response for 3 seconds during the final test. The intervention was delivered in a one-to-one setting by the researcher.
Knight et al. 2013 USA	Systematic instruction treatment package which consisted of a constant time delay procedure (see above for definition), an example/non-example procedure (see above for definition) and graphic organizers (visual display that helps with organizing key concepts and facts). Initially a 0-second delay was used and was later increased to a 5-second delay. The intervention was delivered in a one-to-one setting by the researcher.
Knight et al. 2014 USA	Book Builder (BB; software that allows teachers to create their own eTexts/digital books) implemented across three phases: 1. BB only – the software was used on its own with embedded resources, such as hyperlinks, and coaches delivering prompts. 2. BB and explicit instruction (see above for definition) – the procedure was the same as in phase 1 but the coaches delivered explicit prompting (model-lead-test) and students were provided with examples and non-examples of key vocabulary and concepts. 3. BB, explicit instruction and referring to definition – the procedure was the same as in phase 2 with one exception – the coaches provided students with reasoning about why one item was an example and the other a non-example by referring student back to the definition.
Knight et al. 2017 USA	Modified Book Builder (see above for the definition) – the procedure included embedded animated coaches delivering: model-lead-test, examples and non-examples of key concepts and vocabulary (including coaches providing reasons why one item was an example and the other a non-example), and referrals to the definitions. Additionally, students were required to verbally refer to the definitions. The intervention was

	implemented by the teacher in the classroom setting.
McDonnell et al. 2006 USA	Comparison of two interventions: 1. One-to-one embedded instruction (see above for definition) – The teaching procedures involved constant time-delay, differential reinforcement, and error correction. The trials were implemented during transitions and breaks. The intervention was implemented by a paraprofessional in a one-to-one format in a general education classroom. 2. Small-group spaced-trial instruction (procedure involved delivering teaching trials to individual students with short breaks or with an activity in-between) – The teaching procedures involved constant time-delay, differential reinforcement, and error correction. The trials were presented to students individually in turns. The intervention was implemented by a paraprofessional in a small group format (target pupils and two peers) in a self-contained special education classroom.
Riesen et al. 2003 USA	Embedded instruction (see above for definition) with comparison between: 1. Constant time delay (see above for definition) – Initially a 0-second delay was implemented. After the student correctly defined all target words two for two consecutive times, a 3-second delay was introduced. Error correction was implemented for incorrect responses. The intervention was delivered by paraprofessionals in the general education class during transitions and breaks. 2. Simultaneous prompting (see above for definition) – One test trial was always presented before prompted trials. The correct response was always modelled straight after the instruction. Error correction was implemented for incorrect responses. The intervention was delivered by paraprofessionals in the general education class during transitions and breaks.
Riggs et al. 2013 USA	Constant time delay procedure with examples and non-examples (see above for definitions) – A 0-second time delay was used during the first session and 5-second delay during following sessions. Error correction was implemented for incorrect responses. The intervention was delivered by a special education teacher in a one-to-one or small group format in a special education classroom.
Smith et al. 2013a USA	Embedded computer-assisted explicit instruction (see above for definitions) – An iPad was used to deliver the intervention in a model-test explicit instruction format. The intervention was implemented by a researcher in a one-to-one format in a general education classroom during students' independent study time.
Smith et al. 2013b USA	Task analyzed science inquiry lessons – Early Science Curriculum – The curriculum included scripted lessons, task analyses, explicit instruction (see above for definition), and practical activities/experiments. The intervention was delivered by a teacher in a group format in the students' usual classroom.

Appendix 9. Summary table of studies using self-directed learning procedures.

Source and Origin	Intervention
Agran et al. 2006 USA	Self-determined learning model of instruction (instructional model involving teaching students to implement teaching strategies themselves) – Participants were assisted to select their own target skills and the teaching procedure. The goal of the intervention was to teach students to set their own goals, plan how to achieve them, evaluate their progress, and modify their plan if needed. Each participant was trained in goal setting, self-instruction, and self-evaluation prior to the start of the intervention. Students implemented the intervention in their general education classrooms where they were observed until they reached the mastery criterion.
McMahon et al. 2016 USA	Augmented Reality (technology integrating live view of the setting with digital content) – The augmented reality application was used on an iPad. All participants were trained on how to operate the application before the intervention started. At the beginning of each training session students completed a vocabulary test. After that, they practiced all target words individually using the augmented reality application until they reached mastery criterion.
Miller and Taber-Doughty, 2014 USA	Self-monitoring checklist and science notebook – The intervention was implemented during task analyzed guided science inquiry lessons. The checklist contained five steps of inquiry that participants ticked off as they finished each task. The science notebook was used to assist students with recording their findings during each step of inquiry. Prior to the start of the intervention, participants were trained to use a self-monitoring checklist. All intervention sessions were delivered in the kitchenette (separate to the students' usual classroom).
Miller et al. 2015 USA	Self-monitoring checklist - Intervention was implemented during task analyzed guided science inquiry lessons. The checklist was displayed on an iPad and included five steps of the inquiry that participants ticked off after completing. Prior to the start of the intervention, participants were trained in the use of an iPad and five steps of inquiry. All intervention sessions were delivered in a room separate to students' usual classroom.
Roberts and Joiner, 2007 UK	Concept mapping (process of creating a visual map containing knowledge known to the person and adding new information and how it relates to an existing network) – Prior to the start of the intervention, participants were trained in creating concept maps manually and on the computer. Students were divided into two groups of five with the science teacher and the researcher delivering either teaching as usual or the concept mapping intervention. All participants took part in both conditions.

Appendix 10. Summary table of studies using comprehension-based instruction.

Source and Origin	**Intervention**
Carnahan and Williamson, 2013 USA	Intervention package of compare-contrast strategy (including compare-contrast signal words, guiding questions and Venn diagram) - Students' comprehension of science text was supported using the compare-contrast signal words and the graphic organizer (Venn diagram) and students were asked to summarize each read paragraph while the teacher was asking them guiding questions. At the end of each session, participants completed a set of comprehension questions. The intervention was implemented by a teacher in a group setting.
Carnahan et al. 2016 USA	Multicomponent text structure intervention (including text structure organization sheet, text analysis and summary sheet) - Students' comprehension of science text was supported using the text structure sheet before reading a passage. During and after reading, participants used text analysis and summary sheets, as well as identifying signal words. At the end of each session, students completed ten comprehension questions. The intervention was implemented by a teacher in a group setting.

Appendix 11. Ethics for Chapter 3.

WARWICK
THE UNIVERSITY OF WARWICK

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS SUB-COMMITTEE (HSSREC)

Application for Expedited Review

Expedited review of research can occur where the potential for risk of harm to participants and others affected by the proposed research is **minimal**, for this reason the following may be undertaken via an expedited review process:

- The review of amendments to studies previously approved by HSSREC (**Annex A**);
- Research involving only secondary or historical data (**Annex B**);
- Involvement in research on a consultancy basis (**Annex C**).

Please complete sections 1 and 2 of this form together with **one** of the annexes and return to hssrec@warwick.ac.uk.

No research project involving human participants, their tissue, or their data may begin before the relevant sub-committee of the Research Governance and Ethics Committee has issued its written approval. Written confirmation of the sub-committee's decision will be emailed to the applicant as soon as possible after the expedited review. The sub-committee may request a full ethical review for this research project if deemed necessary.

If you have not already done so, you are advised to undertake the Research Integrity Online Training Course. All details relating to this course can be found here.

SECTION 1. GENERAL INFORMATION
1.1 APPLICANT DETAILS
Applicant's Title: Mrs **Applicant's Forename:** Magdalena **Applicant's Surname:** Apanasionok **Applicant's Faculty/School and Department:** CEDAR **Applicant's Status:** **Staff** ☐ **Postgraduate Research Student** ☒ **Other** ☐ **Please specify:** **If this is a student study, please advise why application has been referred to HSSREC:** CEDAR does not have an Ethics Panel.
1.2 APPLICANT'S CONTACT DETAILS
Warwick email address: M.Apanasionok@warwick.ac.uk **Telephone number:**

1.3 SUPERVISOR – This should be completed for all student projects	
Supervisor's name: Professor Richard Hastings	
1.4 OTHER INVESTIGATORS	
Please provide the details of any other investigators involved in the project: **Dr Corinna Grindle – Associate Fellow in CEDAR** **Dr Richard Watkins – Associate Fellow in CEDAR**	
1.5 Project Title:	**Teaching Early Science to Students with Developmental Disabilities: A Feasibility Study**
1.6 Estimated start date for data collection:	**February 2018**
1.7 Estimated end date for data collection:	**July 2018**
1.8 Funder If unfunded please state 'N/A'	**This project will be conducted as part of Magdalena's Apanasionok PhD funded by Calthorpe Academy and University of Warwick.**

SECTION 2. DECLARATION

The information in this form together with any accompanying information is complete and correct to the best of my knowledge and belief and I take full responsibility for it.

I undertake to abide by the ethical principles underlying the Declaration of Helsinki and to abide by the University's Research Code of Practice alongside any other relevant professional bodies' code of conduct and/or ethical guidelines.

I understand that I must not begin research and related projects with human participants, their tissue, or their data, must not commence without full approval from the relevant research ethics committee of the University of Warwick.

I understand that any changes that I would like to make to this study after receiving approval from HSSREC may require further review. As such they must be submitted to hssrec@warwick.ac.uk before such changes are implemented.

Signature of Applicant: [redacted] Date: 20.12.2017

Signature of Supervisor (If applicable): [redacted] Date: 20.12.17

[redacted]

Signature of Head of Department: Date: 20.12.17

Please send an electronic copy of the application to hssrec@warwick.ac.uk
Note. Your electronic submission should contain wet-ink or electronic signatures of all relevant parties. Applications without the necessary signatures will be returned.

Annex A: Project amendments
1. Please provide the HSSREC reference number: This can be found on the approval letter for the original application
2. Is this is the first amendment? ☐ **Yes** ☐ **No** **If no, please state what number this amendment will be:**
3. Please give a brief summary of the original project (in lay terms):
4. Please detail the proposed changes to the research:
5. Please describe any ethical issues and / or sensitive topics that will arise from these changes: e.g. subject matter (sensitive/contentious/embarrassing), matters around participant group and/or recruitment of participants, confidentiality issues, method of data collection, etc.
6. Please detail how you intend to handle the areas noted above:
7. Please provide any additional information that you believe to be relevant:

Annex B: Review of secondary or Historical data (No participant involvement)
1. Please give a brief summary of the project (in lay terms), including the scientific benefit:
2. Please provide a description of the data source to be used, specifying the era the data relates to and if possible how the data was originally collected:
3. Please provide details of any ethical review that has taken place regarding the initial collection of data:

4. Will approval from another organisation be required in order to gain access the data, if so please provide the details:

5. Who will have access to the data?
Please also note any varying levels of access to the data.

6. Please describe any ethical issues and / or sensitive topics that will be covered during the course of this research:

7. Please detail how you intend to handle the areas noted above:

8. When publishing the research findings what precautions will be taken to safeguard, in the case of:

a) **Literary review:** the sensitivities and / or anonymity of living relatives

b) **Pre-existing datasets**: the continued confidentiality and anonymity of personal data

9. Please provide any additional information that you believe to be relevant:

Annex C: Involvement in research on a consultancy basis

1. Please give a brief summary of the project (in lay terms), including the scientific benefit:

The purpose of this study is to explore the feasibility of a new science curriculum implemented in Calthorpe Academy for children diagnosed with developmental disability (DD) and/or intellectual disability (ID).

Background

Science is one of the core subjects in the National Curriculum in the UK (Department for Education, 2014) and it provides students with many benefits, including enhancing their curiosity and understanding of the world around them (Browder & Spooner, 2011).

The research team (Apanasionok, Hastings, Grindle, Watkins and Paris) conducted a systematic review to identify research literature on teaching science to students with DD and/or ID (manuscript in preparation for publication). The results of the review indicate that systematic instruction - an approach derived from behaviour analysis and focused on teaching observable and measurable behaviours and promoting generalisation (Browder & Spooner, 2011) - is a promising approach to teaching science to students with DD. Additionally, the review identified two studies evaluating effectiveness of a comprehensive science curriculum (Early Science) based on the systematic instruction that has been created for students with moderate to severe disabilities (Jimenez et al., 2014; Smith et al., 2013).

The results of the systematic review were shared with Calthorpe Academy who decided to implement the newly identified science curriculum (Early Science) with one class of primary aged students and asked Magdalena Apanasionok to evaluate its feasibility to inform Academy's science curriculum planning in the future years.

Curriculum overview

Early Science curriculum was developed to teach science to students with moderate to severe disabilities and is based on principles of the systematic instruction (Jimenez et al., 2014). The curriculum includes four core units: Five Senses, The Rock Cycle, Earth and Space and The Life Cycle of Plants and Animal and aligns with elementary science standards in United States. Science lead in Calthorpe Academy confirmed that the content of Early Science curriculum corresponds well with science standards in the UK and covers content relevant to Calthorpe's pupils.

Setting

Calthorpe Academy is a special school in Birmingham catering for around 380 children aged two to 19 with severe learning disabilities. Students attending the school have diagnoses of intellectual disability, autism spectrum disorder, down's syndrome and profound and multiple learning disabilities among others.

Teaching procedure

One class of students (approximately 12 pupils) will be taught science using the Early Science curriculum during twice a weekly lessons. The science teacher will deliver all instructions and lead the lesson. During the lessons, the science teacher will use materials provided in the Early Science kit. She will follow the script and procedures outlined in the implementation guide.

Scientific benefit

Information obtained from this feasibility project will contribute to future plans to evaluate this curriculum in the UK special school context.

2. Please summarise the methodology to be used:

Feasibility will be explored through two routes. First, the project will involve use of the school's own assessments to examine any changes in science knowledge and skills of the students. Second, the project will involve informal feedback conversations (conducted by Magdalena Apanasionok) with staff members involved in the project to contribute to understanding of Early Science curriculum feasibility. Areas that will be discussed include general feedback on the implementation of the curriculum, most and least useful resources used, and suggested areas of development/change. These conversations will not be recorded. Magdalena Apanasionok will only take notes during the conversations and will not use staff members' names in the report.

Two assessment tools will be used by Calthorpe Academy during the project.

1. B-squared – The school will collect data on students' science related targets using their usual assessment tool just before the introduction on the curriculum and immediately after the feasibility project finishes.
2. Early Science built-in assessment – Calthorpe is in the process deciding on the best schedule of assessment using tools provided within the Early Science curriculum. It will likely involve probes using unit assessments and short quizzes following each lesson to check knowledge retention and make informed decisions about the introduction of new lessons.

The new curriculum will be implemented with one class of pupils from the primary department. This will be approximately 12 students. This class have been chosen to take part in the project by the science lead in Calthorpe Academy based on their progress data in science.

Data access and analysis

Magdalena Apanasionok will examine the assessment data with the Science lead for Calthorpe, and write a report on the feasibility of the science curriculum including reference to these data and information from the feedback discussions with teachers. The report will be jointly authored with the school's science lead. The authors may also consider publishing this report in a practice-focused journal, although the primary objective is to inform potential future research.

Calthorpe Academy is happy for Magdalena Apanasionok to access the assessment data (see attached statement from Calthorpe Academy Principal – Richard Chapman).

3. Please give details of the involvement Warwick will have in the research:

Magdalena Apanasionok will analyse students' anonymised progress data collected by Calthorpe Academy and conduct informal feedback discussions with involved staff members. A report on the feasibility of the science curriculum will be written including reference to the assessment data and information from the feedback discussions with teachers. The report will be jointly authored with the school's science lead. The authors may also consider publishing this report in a practice-focused journal, although the primary objective is to inform potential future research.

4. Please describe any ethical issues and / or sensitive topics that will be covered during the course of this research:

Researchers are only asking for access to data from b-squared and Early Science assessments that will be collected by Calthorpe Academy as a part of their feasibility study. The ethical considerations are mainly around ensuring confidentiality of data.

5. Please detail how you intend to handle the areas noted above:

Each child will be assigned a code which only Calthorpe Academy staff members will know. Magdalena Apanasionok will be given access to already anonymised database and it will be shared in this form with PhD supervisors.

Raw data from the assessments will be stored in the locked cabined in Calthorpe Academy, which (after data entry) only Calthorpe Academy staff will have access to and will be kept for 3 years as per Calthorpe Academy policy. In compliance with University of Warwick and Calthorpe Academy data protection policies, anonymised database will be transferred to the University of Warwick using an encrypted USB stick. The anonymised data will be stored by research team members in password protected folders on University and personal computers for the duration of the research study. If the report is also published, anonymised data in electronic format will be kept for 10 years before being destroyed in accordance with University of Warwick Research Data Policy.

6. Please provide any additional information that you believe to be relevant:

Browder, D. M., & Spooner, F. (2011). Teaching Students with Moderate and Severe Disabilities. New York, NY: The Guilford Press.

Department for Education. (2014, December). The national curriculum in England: Framework document. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/381344/Master_final_national_curriculum_28_Nov.pd

Jimenez, B. A., Lo, Y., & Saunders, A. (2014). The Additive Effects of Scripted Lessons Plus Guided Notes on Science Quiz Scores of Students with Intellectual Disabilities and Autism. Journal of Special Education, 47(4), 231-244. DOI: 10.1177/0022466912437937.

Smith, B. R., Spooner, F., Jimenez, B. A., & Browder, D. (2013). Using an Early Science Curriculum to Teach Science Vocabulary and Concepts to Students with Severe Developmental Disabilities. Education and Treatment of Children, 36(1), 1-31.

CALTHORPE ACADEMY
Skills for the life we want

To whom it may concern,

I am writing to confirm that Calthorpe Academy is introducing a new science curriculum for some pupils in the Primary Department in Spring and Summer term of 2018. We have invited Magdalena Apanasionok to support us with an examination of the feasibility of using this new curriculum. The new curriculum will be implemented in one class in primary department in Calthorpe Academy as a part of an initiative to develop a stronger science curriculum and inform educational practice across the whole school. We have made arrangements to gather science skills and knowledge assessment data from the approximately 12 children involved, using the b-squared and Early Science assessments. Calthorpe Academy staff will gather the b-squared and Early Science assessment data during the feasibility project in spring and summer terms of 2018.

Calthorpe Academy is happy for the data collected from the science assessments (b-squared and Early Science assessment) by the school to be accessed and used in a report by Magdalena Apanasionok and our staff.

All data will be anonymised for the use in the report so that no pupil can be identified.

Calthorpe Academy is also happy for Mrs Magdalena Apanasionok to have informal feedback conversations with staff members involved with the new science curriculum to establish its feasibility, and to include relevant comments in the Report.

Yours sincerely,

[redacted]

Richard Chapman
Head Teacher

CALTHORPE ACADEMY Darwin Street, Highgate, Birmingham B12 0TP T 0121 773 4637 E enquiry@calthorpe.bham.sch.uk W calthorpe.bham.sch.uk

WARWICK
THE UNIVERSITY OF WARWICK

Humanities and Social Sciences Research Ethics Committee
Kirby Corner Road
Coventry
CV4 8UW

Monday, 29 January 2018

Mrs Magdalena Apanasionok
CEDAR
University of Warwick
Coventry
CV4 7AL

Dear Mrs Apanasionok,

Ethical Application Reference: 68/17-18
Title: Teaching Early Science to Students with Development Disabilities: A Feasibility Study

Thank you for submitting your expedited application to the Humanities and Social Sciences Research Ethics Sub-Committee for consideration.

We are pleased to advise you that, under the authority delegated to us by the University of Warwick Research Governance and Ethics Committee, full approval for your project is hereby granted.

Before conducting your research it is strongly recommended that you complete the on-line ethics course:
https://www2.warwick.ac.uk/services/ldc/researchers/opportunities/development_support/research_integrity/
Support is available from your Departmental contact in Research & Impact Services

Any material changes to any aspect of the project will require further consideration by the Committee and the PI is required to notify the Committee as early as possible should they wish to make any such changes.

May I take this opportunity to wish you the very best of luck with this study.

Yours sincerely

[redacted]

Dr Fiona MacCallum
Chair, Humanities and Social Sciences Research Ethics Sub-Committee

Appendix 12. TEN-DD mentoring visit record.

Mentoring visit record

Class: **Date:**
Trainer name:

Key	
0	Incorrect for most of the time
1	Correct for approximately half of the trials
2	Correct for most of the trials

1. Implementation

Delivery	**Circle correct**		
1. Gathers needed materials for TEN-ID delivery (teaching plans, data sheet and MR kit).	**0**	**1**	**2**
2. Ensures students' table is clear of distractions before starting each trial.	**0**	**1**	**2**
3. Uses appropriate materials for each trial as specified in the teaching plan.	**0**	**1**	**2**
4. Establishes child's attention.	**0**	**1**	**2**
5. Delivers S^D (instruction) as written in the teaching plan.	**0**	**1**	**2**
6. Delivers S^D (instruction) while the child is attending to task.	**0**	**1**	**2**
7. Delivers appropriate consequence (choose from options below):			
a. Correct response – delivers praise.	**0**	**1**	**2**
i. Delivers praise with enthusiastic voice while maintaining an eye contact.	**0**	**1**	**2**
ii. The praise is delivered within 5 seconds after the response.	**0**	**1**	**2**
b. Incorrect response – delivers correction/prompting procedure.	**0**	**1**	**2**
i. Follows procedure as described in the teaching plan.	**0**	**1**	**2**
ii. Prompts are effective in helping the child make the correct response.	**0**	**1**	**2**
iii. Provides only as much prompting as needed to help the student to be successful.	**0**	**1**	**2**
iv. Fades prompts as early as possible.	**0**	**1**	**2**
8. Inter-trial interval is discrete, but brief.	**0**	**1**	**2**
9. Session pace (S^Ds, prompts, reinforces and inter-trial intervals) is appropriate to students' needs.	**0**	**1**	**2**
10. Maintains students' attention and engagement throughout the session.	**0**	**1**	**2**

11. Encourages students to observe each other during teaching (when one student is working on a trial with the teacher the rest of the group is encouraged to observe).	**0**	**1**	**2**
12. Teaches an appropriate target as per the data sheet.	**0**	**1**	**2**
13. Conducts one of entry activities at the beginning of the session as described in the protocol.	**YES**		**NO**
14. Ensures appropriate ratio of sequential and choral responses (approximately 75:25).	**YES**		**NO**
15. Ensures appropriate ratio of work and breaks (approximately 25-30 minutes of work and 10 minutes of breaks within one session).	**YES**		**NO**
16. Conducts trials for all current targets for each student.	**YES**		**NO**
Data collection	**Circle correct**		
1. Collects data for the first trial of each target only.	**0**	**1**	**2**
2. Collects accurate data (correct or incorrect) for each student in the group.	**0**	**1**	**2**
2. Folder review	**Circle correct**		
1. Introduces one target per Key Topic at the time.	**0**	**1**	**2**
2. Ensures mastery criteria is implemented correctly (three consecutive correct trials).	**0**	**1**	**2**
3. Updates data sheet on regular basis.	**YES**		**NO**

3. Points to be discussed (successes and areas for improvement)

4. Any problems reported by the teacher or TA?

Problem:

Discussed solutions:

Follow up – yes or no?

5. Feedback
<u>Teaching assistant:</u>
<u>Teacher:</u>
Comments

Signature of the Trainer:
Signature of the Teaching Assistant:
Signature of the Teacher:

Appendix 13. TEN-DD sample entry activities.

Sample entry/starter group activities

(based on Maths Recovery Assessment Task Groups and Instructional Activities)

1. Based on Forward Number Word Sequences (MR Task Group A3.1)

TEN-ID stage:	Emergent and up
Task:	Forward counting in sequences up to 20
Duration:	5 minutes
Materials:	None
Number of students:	3
Procedure:	Start by explaining the task: *“We will play a game now. I will ask one of you to start counting until I say stop.”* *“(Student’s 1 name) Start counting forward.”* When student gets to 6 say “*Stop*”. *“(Student’s 2 name) Start counting from 7”*. When student gets to 12 say “*Stop*”. *“(Student’s 3 name) Start counting from 13”*. When student gets to 19 say “*Stop*”. *“Now everybody, what is the next number after 19?”*
Tips:	Watch out for number omissions and correct when that happens. You can extend the task if your students can count above 20.

2. Based on Number Word After (MR Task Group A3.2)

TEN-ID stage:	Emergent and up
Task:	Next number up to 20
Duration:	5 minutes
Materials:	None
Number of students:	3
Procedure:	Start by explaining the task: *“We will play a game now. I will say a number and I would like to tell me the number that comes after”*.

	"(Student's 1 name) What comes after 3?" *"(Student's 2 name) What comes after 7?"* *"(Student's 3 name) What comes after 2?"* Continue the same procedure with numbers up to 20.
Tips:	If student is struggling with the answer you can prompt him/her to count from 1 up to the appropriate number. You can extend the task if your students can count above 20.

3. Based on Backward Number Word Sequences (Task Group A3.3)

TEN-ID stage:	Emergent and up
Task:	Backward counting in sequences from 10
Duration:	5 minutes
Materials:	None
Number of students:	3
Procedure:	Start by explaining the task: *"We will play a game now. I will ask one of you to start counting backward until I say stop."* *"(Student's 1 name) Start counting backward from 10."* When student gets to 7 say *"Stop"*. *"(Student's 2 name) Start counting backward from 6".* When student gets to 4 say *"Stop"*. *"(Student's 3 name) Start counting backward from 3".*
Tips:	Watch out for number omissions and correct when that happens. You can extend the task if your students can count backward above 10.

4. Based on Number Word Before (Task Group A3.4)

TEN-ID stage:	Emergent and up

Task:	Next number down from 10
Duration:	5 minutes
Materials:	None
Number of students:	3
Procedure:	Start by explaining the task: *"We will play a game now. I will say a number and I would like to tell me the number that comes before that".* *"(Student's 1 name) What comes before 3?"* *"(Student's 2 name) What comes before 6?"* *"(Student's 3 name) What comes before 2?"* Continue the same procedure with numbers up to 10.
Tips:	If student is struggling with the answer you can prompt him /her to count from 1 up to the appropriate number. You can extend the task if your students can count above 10.

5. Based on Count Around (Activity IA3.1)

TEN-ID stage:	Emergent and up
Task:	Counting forward up to 5
Duration:	5 minutes
Materials:	None
Number of students:	3
Procedure:	Ask all children to stand in the circle. Start by explaining the task: *"We will play a game now. I want you to start counting one by one. Person that gets 10 needs to jump as high as they can.".* *"(Student's 1 name) Start counting forward from 1."* Prompt students to count around the circle. The student who gets 10 needs to jump. *"(Student's 2 name) Start counting forward from 1."* *"(Student's 3 name) Start counting forward from 5."*
Tips:	If student is struggling with the answer you can prompt

	him /her to count from 1 up to the appropriate number. You can extend the task if your students can count above 10. To make to task more fun you can join students in the circle.

6. Based on Stand in Line (Activity IA3.5)

TEN-ID stage:	Emergent and up
Task:	Counting forward and backward up to 3
Duration:	5 minutes
Materials:	Numeral cards from 1 to 3
Number of students:	3
Procedure:	Ask all children to stand in line and give each one numeral card. Start by explaining the task: *"We will play a game now. (Student's 1 name) Come to the middle."* Depending which number the student is holding, say "*Which number comes after (Student's 1 name)?"* Ask student with an appropriate number to come to the middle and stand next to Student 1. Depending which numbers, the student in the middle is holding, say "*Which number comes after (Student's 2 name)?"* Ask student with an appropriate number to come to the middle and stand next to Student 2 and say, "*Now we have all numbers - 1, 2 and 3"*. Continue with the activity changing student's numeral cards and building the sequence forward and backward.
Tips:	If student is struggling with the answer you can prompt him /her to count from 1 up to the appropriate number. You can extend the task by asking other students to join (doing the activity as a whole class exercise).

7. Based on What Comes Next? (Task Group IA3.4)

TEN-ID stage:	Emergent and up
Task:	Saying the number after any given number
Duration:	5 minutes
Materials:	Numeral track
Number of students:	3
Procedure:	Display the numeral track from 1 to 10. Lift the flaps to show 1 and 2. Start by explaining the task: *‘’We will play a hiding game. You will say the numbers with me, and I would like to tell me what number is hiding here (3)? What comes next?* *“(Student’s 1 name) What comes next after 3?”* *“(Student’s 2 name) What comes next after 6?”* *“(Student’s 3 name) What comes next after 4?”*
Tips:	If student is struggling with the answer you can prompt him /her to count from 1 up to the appropriate number. You can use longer sequences on the numeral track if your students can count above 10.

8. Based on Can You See Me? (Task Group IA3.7)

TEN-ID stage:	Emergent and up
Task:	Identify and recognise digits from 1 to 9
Duration:	5 minutes
Materials:	Large numeral cards (1 to 5 or 1 to 10), screen and small numeral cards
Number of students:	3
Procedure:	Display a collection of large numeral cards - each card has one of the numerals from 1 to 5. After the children have had a chance to look at the cards, place them face down on a pile. Then select one of the cards and screen the numeral. Gradually reveal part of the numeral. Start by explaining the task: *‘’We will play a guessing game. I want you to look at these*

	numbers (from 1 to 5) then I will choose a number and screen it. I would like you to guess what number could it be? *"(Student's 1 name) What number could it be?"* *"(Student's 2 name) What number could it be?"* *"(Student's 3 name) What number could it be?"*
Tips:	If student is struggling with the answer you can prompt him /her by moving the screen in several ways e.g., moving the screen down or to the left. You can ask the children to draw the numeral in the air.

9. Based on Numeral Identification? (Task Group A3.5)

TEN-ID stage:	Emergent and up
Task:	Identify numerals from 1 to 10
Duration:	5 minutes
Materials:	Numeral Cards from 1 to 10
Number of students:	3
Procedure:	Display the cards from 1 to 10, not in numerical order. Start by explaining the task: *''We will play a game now. I will put the cards on the table, and I would like to tell me the number on the card".* *"(Student's 1 name) What the number on the card?"* *"(Student's 2 name) What the number on the card?"* *"(Student's 3 name) What the number on the card?"*
Tips:	If student is struggling with the answer you can prompt him /her to count from 1 up to the appropriate number. You can extend the task (the numerals from 11 to 20) if your students can easily identify numerals from 1 to 10. To make the task more fun you allow students to ask you.

10. Based on Numeral Recognition? (Task Group A3.6)

TEN-ID stage:	Emergent and up
Task:	Recognise numerals from 1 to 10

Duration:	5 minutes
Materials:	Numeral Cards from 1 to 10
Number of students:	3
Procedure:	Arrange the cards randomly on the table from 1 to 10, not in numerical order. Start by explaining the task: *‘’We will play a game now. I will put the cards on the table, and I would like to tell me which number is 2?* *“(Student’s 1 name) which number is 5?”* *“(Student’s 2 name) which number is 8?”* *“(Student’s 3 name) which number is 1?”*
Tips:	If student is struggling with the answer you can prompt him/her to count from 1 up to the appropriate number. You can extend the task (the numerals from 11 to 20) if your students can easily recognise numerals from 1 to 10. To make the task more fun you allow students to arrange the numeral cards on the table and ask you.

11. Based on Sequencing Numerals from 1 to 5? (Task Group A3.7)

TEN-ID stage:	Emergent and up
Task:	Numerals order from 1 to 5
Duration:	5 minutes
Materials:	Numeral cards from 1 to 5
Number of students:	3
Procedure:	Arrange the numeral cards from 1 to 5 randomly on the table. Start by explaining the task: *‘’We will play a game now. I will put numbers on the table, and I would like you to put the numbers in order? Start from the smallest.* *“(Student’s 1 name) put the numbers in order?”* *“(Student’s 2 name) put the numbers in order?”* *“(Student’s 3 name) put the numbers in order?”*
Tips:	If student is struggling with the answer you can prompt

	him /her using the term ‘least’ rather that ‘smallest’. You can extend the task (the numerals from 6 to 10) if your students can easily order numerals from 1 to 5. To make the task more fun you have a turn to put the numbers incorrectly order and ask the students to show if the numbers are ordered correctly.

Appendix 14. Sample TEN-DD data sheet.

Stage: Emergent

Weekly TEN-ID Group Data Sheet

Date: 06.09.2017

Students' names:	Tom	Jane	Joe	Group targets	Data (√ or ×):
Key topic 1 (Verbal counting 1-20)	**A.1.2 Backward Number Sequences** e. Counts backward from 5 to 1 by himself	**A1.1 Forward Number Sequences** f. Counts from 1 to 5 by herself	**A1.1 Forward Number Sequences** f. Counts from 1 to 5 by himself	A1.1 Count 1-3, 4-6, 7-10, 1-5, 6-10. Child repeats. A1.2 Count backward 3-1, 6-4, 10-6, etc. Child A1.4 Count 2 number, child says the next number (1- A1.5 Count 2 numbers backward, child says next (1- A2.1 Child counts forward numberals 1-10.	
Data (√ or ×):				A2.4 Child points to different numbers on cards (1-	
Key topic 2 (Written numerals 1-10)	**A2.2 Numeral Sequences** c. "Count forward and backward" numberlines 1-10	**A2.2 Numeral Sequences** c. "Count forward and backward" numberlines 1-10	**A2.2 Numeral Sequences** c. "Count forward and backward" numberlines 1-10	A2.5 Child says number that teacher points to (1-3).	
Data (√ or ×):					
Key topic 3 (Counting visible items up to 20)	**A3.2 Taking number of items** a. Takes 6 counters of of 30 on the table	**A3.1 Counting items** a. Child counts 8 counters in the row	**A3.1 Counting items** a. Child counts 8 counters in the row		
Data (√ or ×):					
Key topic 4 (Spatial Patterns)	**A4.2 Patterns in air** a. "Make pattern in the air to show me how many dots" (cards 1-4)	**A4.1 Dots on cards** a. "How many domino cards?" with cards 1-4 in order	**A4.2 Patterns in air** a. "Make pattern in the air to show me how many dots" (cards 1-4)		
Data (√ or ×):					
Key topic 5 (Finger Patterns)	**A5.1 Sequential finger patterns** a. Raising fingers and counting by one. Child imitates.	**A5.1 Sequential finger patterns** a. Raising fingers and counting by one. Child imitates.	**A5.1 Sequential finger patterns** a. Raising fingers and counting by one. Child imitates.		
Data (√ or ×):					
Key Topic 6 (Temporal Patterns and Sequences)	**A6.1 Sequences** a. Copies and counts chopping movements.	**A6.1 Sequences** a. Copies and counts chopping movements.	**A6.2 Rhytmic Patterns** a. Copies rhytmic movements.		
Data (√ or ×):					

Appendix 15. Sample non-vocal response equivalents for students with limited verbal communication.

Non-vocal response equivalents guidelines

When working with a student with limited verbal communication consider following examples of response equivalents:

1. Pointing with correspondence (student points to specific numbers while the teacher counts).
2. Matching numbers/numbers to quantities.
3. Receptive number recognition (student points to specific numbers when asked).
4. Counts using number lines or number cards.
5. Shows numbers on fingers/counts on fingers.
6. Counts or shows quantities on counters/blocks.
7. Students writes down the number.

Examples:

1. **<u>A1.1 Step 1</u>**

Original teaching plan: For saying FNWSs with a modelling prompt, establish attention and tell the child “Let’s count.1, 2, 3”. Tell him it is his turn. The child should repeat: 1, 2, 3. Reinforce the response.

Non-vocal equivalent example 1: Establish attention and tell the child “Let’s count 1, 2, 3” while pointing to the number line. Tell the student it is his/her turn. The child should point to 1, 2, and 3 on the number line while you count. Reinforce the response.

Non-vocal equivalent example 2: Establish attention and tell the child “Let’s count 1, 2, 3” while putting up one, two and three fingers. Tell the student it is his/her turn. The child should put up one, two and three fingers while you count. Reinforce the response.

2. **<u>A2.1 Step 1</u>**

Original teaching plan: For numeral sequence 1-3 with modelling prompt, place the number line on the table in front of the child. Establish attending and tell the child “Lets Count”. The therapist models by counting 1, 2, 3, pointing to each number as she says the words. Tell the child it is his turn. Prompt the child to touch the correct numeral as they say the number words. The child should repeat “1, 2, 3” pointing to each number as they say the words. Reinforce the response.

Non-vocal equivalent example 1: Place the number line on the table in front of the child. Establish attending and tell the child “Lets Count”. The therapist models by counting 1, 2, 3, pointing to each number as she says the words. Tell the child it is his turn. The child should independently point to “1, 2, 3” on the number line as you count. Reinforce the response.

Non-vocal equivalent example 2: Place the number line and number cards on the table in front of the child. Establish attending and tell the child “Lets Count”. The therapist models by counting 1, 2, 3, while matching number card to each number. Tell the child it is his turn. The child should independently match number cards “1, 2, 3” to the numeral on the number line as you count. Reinforce the response.

3. **<u>A3.1 Step 1</u>**

Original teaching plan: Place a row of 8 counters on the table in front of the child. Establish attending and say, “How many?” The child might not realize that when counting, the last number word is the answer to “How many?” In other words, he might think that the correct answer is “1, 2, 3, 4, 5, 6, 7, 8”. So, after he/she has finished counting the counters you should repeat the question and prompt him/her to answer “eight”.
SD1: How many?
R1: 1-2-3-4-5-6-7-8 (counting each counter with one-to-one correspondence)
SD2: Good, so how many altogether?
R2: 8
Non-vocal equivalent example 1: Place a row of 8 counters on the table in front of the child. Establish attending and say, “How many?” Student puts up eight fingers. If child is struggling, you can model the response by counting to eight while putting up one finger at a time and then asking student to do the same.
Non-vocal equivalent example 2: Place a row of 8 counters and a few number cards (including 8) on the table in front of the child. Establish attending and say, “How many?” Student points to number card with 8 on it. If the students are struggling, you can start by placing number line below counters and counting them while pointing to the numbers on the number line.

4. <u>**A4.1 Step 1**</u>
Original teaching plan: Domino cards 1-4 long display, when presented in sequence
SD1: (Hold up domino card throughout duration of SD and R). How many dots?
R1: One
Sd2: (Hold up domino card throughout duration of SD and R). How many dots?
R2: Two
SD3: (Hold up domino card throughout duration of SD and R). How many dots?
R3: Three
Sd4: (Hold up domino card throughout duration of SD and R). How many dots?
R4: Four
Non-vocal equivalent example 1: Domino cards 1-4 long display, when presented in sequence. Place range of number cards on the table (including 1-4):
SD1: (Hold up domino card throughout duration of SD and R). How many dots?
R1: Students points to number card with 1.
Sd2: (Hold up domino card throughout duration of SD and R). How many dots?
R2: Students points to number card with 2.
SD3: (Hold up domino card throughout duration of SD and R). How many dots?
R3: Students points to number card with 3.
Sd4: (Hold up domino card throughout duration of SD and R). How many dots?
R4: Students points to number card with 4.
If the student is struggling, you can start by using number line and counting with the student.
Non-vocal equivalent example 2: Domino cards 1-4 long display, when presented in sequence.
SD1: (Hold up domino card throughout duration of SD and R). How many dots?
R1: Student puts up 1 finger.
Sd2: (Hold up domino card throughout duration of SD and R). How many dots?
R2: Student puts up 2 fingers.
SD3: (Hold up domino card throughout duration of SD and R). How many dots?
R3: Student puts up 3 fingers.

Sd4: (Hold up domino card throughout duration of SD and R). How many dots?
R4: Student puts up 4 fingers.

Appendix 16. TEN-DD group teaching framework.

TEN-ID Group Teaching Framework

The aim is to do 45 minutes long lessons of TEN-ID three times a week and using the fourth day for the TEN-ID generalisation and the fifth day for teaching other maths strands.

TEN-ID sessions:

The instructor will use the first 5-10 minutes of each session to do an entry activity tailored to needs of students in the group. Activities will be done in most entertaining way possible to ensure students' positive association with numbers.
Students will be divided into groups of two or three based on their TEMA-3 scores and will be working with one member of staff. The aim will be for the groups to be as homogeneous as possible (to ensure the instructor have enough targets mastered by all students to be used for generalization and maintenance).
The teaching will follow trial structure of Discrete Trial Teaching (DTT):

1. Teacher presents a brief instruction (as outlined in the teaching plan).
2. If needed, a prompt is provided after or along with the instruction.
3. Child responds correctly or incorrectly.
4. Teacher provides a consequence (reinforcer or correction).
5. Inter-trial interval
6. Teacher pauses for 1-5 before presenting the next trial.
    a. Data may be recorded at this time.
    b. Responding will be either sequential or choral.

There will be two types of responding used:

1. Sequential (one-to-one) responding will be used for acquisition (teaching new targets to students). Students will be called out by their name and instruction will be delivered. Teaching will follow guidelines set up in TEN-ID teaching plans and at the end of each trial the instructor will deliver praise and corrective feedback/prompt when necessary. Responses by other students will be ignored; however, they will be encouraged to listen to provide opportunity for observational learning.
2. Choral (group) responding will be used for generalization and maintenance of targets mastered by all students in a group. For this teacher will choose targets already mastered by all students based on individual TEN-ID skills tracker. The instructor will say 'Everybody' alongside Makaton sign (using it as a signal to elicit choral responding) and then say the instruction. All students will be required to respond. At the end of each trial the teacher will deliver praise and corrective feedback when necessary.

Sequential (acquisition) and choral (generalization and maintenance) responding will be used inter-changeably during the session, ensuring approximately 75/25 ratio (sequences of one 1:1 target for each student in the group concluded by a group target).
Instructor needs to ensure that students are spending approximately 25-30 minutes on work and 10 minutes on breaks during the session. Instructor will make the decision about a schedule that is best suited for all students in the group (for example delivering individual targets to all students in the group, followed by a group target and then giving 1-2 minutes of break to all students; or doing work for 10 minutes and having longer break for around 3-4 minutes).

Despite the schedule used, the fast pace of the session will be crucial to maintain students' attention.

Generalisation sessions:

Once per week instructor will conduct a generalisation session (separate to three TEN-ID lessons). The aim of generalisation is for student to be able to perform learned skills in a variety of different situations. During those sessions, the instructor will be working on generalisation across different:

1. Setting – teaching can take place in different place than usual, e.g., different room, different place in the classroom, playground, etc.
2. Tutors – teaching takes place with a different staff member, than the one who usually delivers the curriculum, e.g., different TA, class teacher, mentor, etc.
3. Materials – students work on their targets using different materials than usual (but still having the same function), e.g., instead of using counters - using blocks, balls, small objects, etc.
4. Instruction – during teaching instructor uses differed instruction (S^D) than usual, e.g., instead of asking "What number comes next?"- "Say the next number after mine".

The instructor will still use the same basic teaching procedure as during TEN-ID teaching, but ensuring students have plenty of opportunities to generalise acquired skills and knowledge to different situations (as outlined above).

Appendix 17. TEN-DD general session structure.

Always follow teaching procedure outlined in the TEN-DD teaching plans.	
Duration	Three 45-minutes sessions per week
Materials	As per TEN-DD teaching plans
Data collection	**First see criteria for correct and incorrect responses on specific TEN-ID teaching plans!** Take data for the first trial (for each target) of the session only (✔ for correct or ✘ for incorrect) for each student.
Mastery criterion	Three consecutive ticks
1. Starter activity/ Warm up	Select one of the activities outlined in the manual that corresponds with your students' skills. You can simplify the activities if needed. The activity should take no more than 5-10 minutes.
2. TEN-ID teaching	Ensure that session consists of approximately: - 25-30 minutes of work - 10 minutes of breaks Specific schedule should be tailored to the needs of your students. Instructions should be delivered at fast pace to keep students engaged. **Present each student with an individual target and then proceed to present one group trial.** Individual instructions: - Say student's name and then appropriate instruction (eye contact should be maintained only with that student) - Deliver verbal praise or corrective feedback (see TEN-ID teaching plans) after each trial - Responses from other students should be ignored, but listening should be encouraged Group instructions: - Start by saying 'Everybody' (paired with a Makaton sign) and then appropriate instruction - All students are expected to respond. Prompt if needed (follow procedure outlined in an appropriate TEN-ID teaching plans). - Deliver verbal praise or corrective feedback after each trail

Appendix 18. TEN-DD sample lesson plan.

<table>
<tr><td colspan="2">A1: Key Topic: Number Word Sequences from 1 to 20</td></tr>
<tr><td>Target: A1.1</td><td>Purpose: To develop knowledge of forward number word sequences in the range 1 to 20</td></tr>
<tr><td colspan="2">Copying and Saying Short Forward Number Word Sequences (FNWS)</td></tr>
<tr><td>Materials</td><td>None</td></tr>
<tr><td>Teaching Procedure</td><td>Check that the student is ready to learn (looking at the teacher, sitting up straight, etc).

<u>Step one- Copying</u>
For saying FNWSs with a modelling prompt.
<u>Teacher:</u> “Let’s count. 1, 2, 3. Now your turn”
<u>Student:</u> Repeats: “1, 2, 3”.
Reinforce the response.

Once mastered, continue the procedure with:
• 4 to 6
• 7 to 10
• 1 to 5
• 6 to 10
• 11 to 15
• 16 to 20
• 11 to 20

<u>Step two- Saying</u>
For saying FNWSs without a modelling prompt.
<u>Teacher:</u> “Count from one up to five”.
<u>Student:</u> Says “1-2-3-4-5”.
Reinforce the response.

Once mastered, continue the procedure with:
• 4 to 6
• 7 to 10
• 1 to 5
• 6 to 10
• 11 to 15
• 16 to 20
• 11 to 20

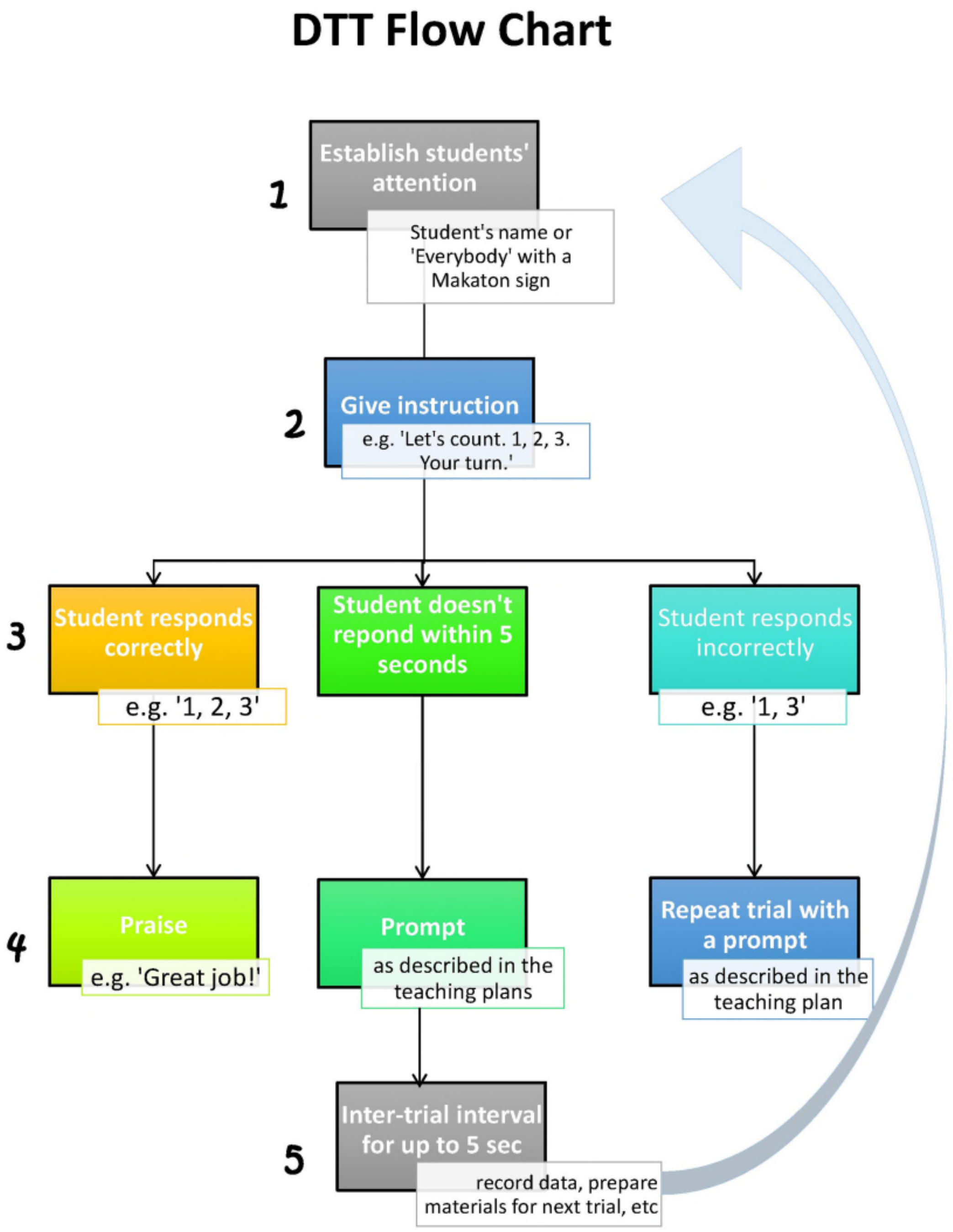
The student should respond within 3 seconds after the instruction has been given and say the correct number sequence. If not, please refer to: Help that may be provided.

Test each new task to see if the student generalises the skill. If the student is correct on the first attempt at a new task, you do not need to teach this task, and you can move on to the next task.

If the student struggles with these extensions to the task, they will</td></tr>
</table>

	need to be systematically taught using the procedure outlined previously.
Generalisation plan	• Another teacher asks the student to complete the task. • Use different instructions – e.g., “Copy me: 1-2-3”. • Teach in a different setting or at a different time of the day.
Help that may be provided	• If the student omits a number (e.g., says 1, 2, 3, 5), the next time the sequence is modelled say the omitted number in a very loud voice, e.g., 1, 2, 3, **4** (loud), 5. • If the error continues, count backward and/or forward for example, work on 4, 5 until consistent, then on 3, 4, 5, then on 2, 3, 4, 5 etc. • If the student continues counting on (e.g., says 1, 2, 3, 4, 5, 6… for “count up to 5”) put up your hand to indicate when the student should stop. Alternatively, show a number card (e.g., card with the number 5) to remind them when to stop. • Each step can be introduced initially with shorter number word sequences (e.g., with 2 numbers), gradually building up to the longer sequences (e.g., 5 numbers). • If the student has difficulty pronouncing thirteen, fourteen, fifteen etc, do some separate work where you practice working on articulation, emphasising the part of the word they are struggling with, e.g., say, thirteen
Mastering criterion	Three ticks (√) in a row across 3 consecutive days.

Appendix 19. DTT flow chart.



Appendix 20. TEN-DD skill tracker for the Emergent stage.

TEN-ID Individual Target List

A. Emergent

Student's name:

Key Topic 1: Verbal Counting 1-20 ***AIM: Fluency in counting forwards (1-20) and backwards (1-10)***	Introduction date	Mastery date (Three consecutive ✔)
A1.1. Saying short Forward Number Sequences		
a. Count from 1 to 3, child repeat.		
b. Count from 4 to 6, child repeats.		
c. Count from 7 to 10, child repeats.		
d. Count from 1 to 5, child repeats.		
e. Count from 6 to 10, child repeats.		
f. Child counts from 1 to 5 by himself.		
g. Child counts from 6 to 10 by himself.		
h. Child counts from 1 to 10 by himself.		
i. Child counts from 7 to 10 by himself.		
j. Child counts from 11 to 15 by himself.		
k. Child counts from 15 to 20 by himself.		
A1.2. Saying short Backward Number Sequences		
a. Count backwards from 3 to 1, child repeats.		
b. Count backwards from 6 to 4, child repeats.		
c. Count backwards from 10 to 8, child repeats.		
d. Count backwards from 4 to 1, child repeats.		
e. Count backwards from 8 to 5, child repeats.		
f. Count backwards from 10 to 7, child repeats.		
g. Child counts backwards from 5 to 1 by himself.		
h. Child counts backwards from 8 to 3 by himself.		
i. Child counts backwards from 10 to 5 by himself.		
j. Child counts backwards from 10 to 1 by himself.		
A1.3. Alternate Numbers		
a. Alternate counting 1 to 5, teacher starting with 1.		
b. Alternate counting 1 to 5, child starting with 1.		
c. Alternate counting 1 to 10, teacher starting with 1.		
d. Alternate counting 1 to 10, child starting with 1.		
e. Alternate counting backwards 6 to 1, teacher starting.		
f. Alternate counting backwards 8 to 1, child starting.		
g. Similarly, with random forward sequences to 20.		
h. Similarly, continue with random backward sequences to 10.		
A1.4. Next Number Forward		
a. Teacher counts **four** numbers and child says next number word (range 1-5).		
b. Teacher counts **four** numbers and child says next number word (range 1-10).		
c. Teacher counts **two** numbers and child says next number word (range 1-10).		
d. Teacher counts **two** numbers and child says next		

number word (range 11-20).		
A1.5. Next Number Backward		
a. Teacher counts **three** numbers backwards and child says next number (range 1-4).		
b. Teacher counts **three** numbers backwards and child says next number (range 1-10).		
c. Teacher counts **two** numbers backwards and child says next number (range 1-10).		
A1.6. Number Word After		
a. Teacher says "1" and child says "2".		
b. Teacher says a number and child says the next number (range 1-10).		
c. Teacher says a number and child says the next number (range 11-20).		
A1.7. Number Word Before		
a. Teacher says "2" and child says "1".		
b. Teacher says a number and child says the number before (range 1-10).		

Key Topic 2: Written Numerals 1-10 ***AIM: Knowledge of numerals and numeral sequences in the range 1-10***	Introduction date	Mastery date (Three consecutive ✔)
A2.1. Forward Numeral Sequences		
a. Teacher counts 1-2-3 pointing to each numeral. Child imitates.		
b. Similarly, with number lines 1-4, 1-5....1-10.		
c. Child counts 1-2-3 and points to each numeral by himself.		
d. Similarly, with number lines 1-4, 1-5....1-10.		
A2.2. Numeral Sequences, Forwards & Backwards		
a. Teacher counts "1-2-3, 3-2-1" pointing to each numeral. Child imitates.		
b. Number lines 1-4, 1-5....1-10. Teacher counts first while pointing to each numeral. Child imitates.		
c. Number line 1-3. "Count forwards & backwards". Child counts *without* modelling prompt.		
d. Number lines 1-4, 1-5....1-10. "Count forwards & backwards". Child counts *without* modelling prompt.		
A2.3. Sequencing Numerals		
a. Child orders numeral cards 1 to 3.		
b. Child orders numeral cards 1 to 4.		
c. Child orders numeral cards 1 to 5.		
d. Child orders numeral cards 4 to 7.		
e. Child orders numeral cards 6 to 9.		
f. Child orders numeral cards 6 to 10.		
g. Child orders numeral cards 1 to 6.		
h. Child orders numeral cards 1 to 8.		
i. Child orders numeral cards 1 to 10.		
A2.4. Receptive Number Identification		
a. From cards 1-3 randomly arranged, child is asked to point to different numbers.		
b. Similarly, with cards up 10.		
A2.5. Expressive Number Identification		
a. From cards 1-3 randomly arranged, teacher		

points to a number and asks child to identify.		
b. Similarly, with cards up to 10.		
c. From cards 1-5 face down randomly arranged, teacher turns over the card and asks child to identify.		
d. Similarly, with cards up to 10.		
A2.6. Numeral Track 1-5 and 1-10		
a. Numeral track 1-5; teacher counts forwards & backwards pointing to each number. Child imitates.		
b. Numerals 1-5 covered. Repeat previous activity, uncovering each numeral after saying the word. Child imitates.		
c. Numerals 1-5 covered. Uncover number 3. "What number?" Then point to covered 4 and ask child to identify. Child checks.		
d. Similarly, with other numerals 1 to 5.		
e. Repeat previous activities with numeral track 1-10. Shorter tracks (1-6, 1-8) can also be used.		

Key Topic 3: Counting Visible items (up to 20) ***AIM: Initial counting strategies***	Introduction date	Mastery date (Three consecutive ✔)
A3.1. Counting Items in One Collection		
a. 8 counters in a row. Child counts and says the total number.		
b. Similarly, with collections up to 20 counters.		
A3.2. Taking the required number of items from a larger collection		
a. Place 30 counters on the table. Child is asked to take 6 from the group.		
b. Similarly, with up to 20 counters.		
A3.3. Counting Items in a Row, Forwards & Backwards		
a. A row of 6 dots. Teacher counts forwards & backwards pointing to each dot. Child imitates.		
a. Similarly, with rows of up to 20 dots.		
A3.4. Counting Items of two Collections		
a. Place 6 red counters in a row. Place 4 green counters next to them. Ask the child to say how many altogether.		
b. Similarly, with 8 red and 2 green.		
c. Similarly, with 12 red and 1 green.		
d. Similarly, with 5 red and 3 green.		
e. Similarly, with 14 red and 2 green.		
A3.5. Counting Items in Two Rows		
a. Place out a row of 10 red dots. Place a row of 3 green dots next to them. Ask the child to say how many altogether.		
a. Similarly, with 8 red and 3 green.		
b. Similarly, with 12 red and 4 green.		

Key Topic 4: Spatial Patterns (Patterns on Cards) ***AIM: Initial facility to ascribe number to patterns and random arrays***	Introduction date	Mastery date (Three consecutive ✔)
A4.1. Saying "how many dots" on Different Cards		

	a. Display domino card 1. “How many dots?”. Similarly, for domino cards 2, 3, & 4 in order.		
	b. Repeat above displaying domino cards 1-4 in random order.		
	c. Flash domino card 1 quickly. “How many dots did you see?” Continue with cards 2, 3, & 4 in order.		
	d. Repeat above with cards 1-4 in random order.		
	e. Display domino card 1 with random configuration. “How many dots?”. Similarly, for domino cards 2, 3, & 4 in random configurations.		
	f. Repeat above displaying domino cards 1-4 (random configurations) in random order.		
	g. Flash domino card 1 (random configuration) quickly. “How many dots?”. Continue with cards 2, 3, & 4.		
	h. Repeat above with cards 1-4 (random configurations) in random order.		
	i. Display domino card 1. “How many dots?”. Similarly, for domino cards 2, 3, 4, 5, & 6 in order.		
	j. Repeat above displaying domino cards 1-6 in random order.		
	k. Flash domino card 1 quickly. “How many dots did you see?”. Continue with cards 2, 3, 4, 5, & 6 in order.		
	l. Repeat above with cards 1-6 in random order.		
	m. Display pair pattern card 1. “How many dots?”. Similarly, for pair pattern cards 2, 3, 4, 5, &6.		
	n. Repeat above displaying pair pattern cards in random order.		
	o. Flash pair pattern card 1 quickly. “How many dots did you see?”. Continue with cards 2, 3, 4, 5, & 6 in order.		
	p. Repeat above with pair pattern cards 1-6 in random order.		
A4.2. Making Patterns in the air to match to match patterns on cards			
	a. Domino cards 1-4 in order. “Make a pattern in the air to show me how many dots”. Child makes a pattern.		
	b. Similarly, with cards 1-4 flashed briefly in order.		
	c. Similarly, with domino cards 1-4 flashed briefly in random order.		
	d. Random array cards 1-4 in order. “Make a pattern in the air to show me how many dots”. Child makes the pattern.		
	e. Similarly, with random array cards 1-4 flashed briefly in order.		
	f. Similarly, with random array cards 1-4 flashed briefly in random order.		
	g. Domino cards 1-6 in order. “Make a pattern in the air to show me how many dots”. Child makes the pattern.		
	h. Similarly, with domino cards 1-6 flashed briefly in order.		
	i. Similarly, with domino cards 1-6 flashed briefly in random order.		
	j. Pair pattern cards 1-6 in order. “Make a pattern in the air to show me how many dots”. Child makes the pattern.		
	k. Similarly, with pair pattern cards 1-6 flashed quickly in order.		

l. Similarly, with pair pattern cards 1-6 flashed quickly in random order.		
A4.3. Making Auditory Patterns to Match Spatial Patterns		
a. Display domino card 1. "Clap to show me how many dots". Similarly, with other domino cards 1-4.		
b. Repeat with flashing the domino cards 1-4 quickly.		
c. Random array cards 1-4. "Clap to show me how many dots".		
d. Random array cards 1-4. Repeat with flashing the cards quickly.		
e. Domino cards 1-6. "Clap to show me how many dots".		
f. Domino cards 1-6. Repeat with flashing the cards quickly.		
g. Pairs patterns cards 1-6. "Clap to show me how many dots".		
h. Pair pattern cards 1-6. Repeat with flashing the cards quickly.		

Key Topic 5: Finger Patterns ***AIM: Initial facility with finger patterns***	Introduction date	Mastery date (Three consecutive ✔)
A5.1. Sequential Finger Patterns 1-5, Fingers Seen		
a. Teacher raises 1 finger. "One". Child imitates. Teacher raises two fingers 1 by 1 saying "one, two". Child imitates. Continue with 3, 4, 5 fingers.		
b. Repeat activity with non-preferred hand.		
A5.2. Sequential Finger Patterns 1-5, Fingers Unseen (bunny ears)		
a. Teacher counts 3 fingers with hand on top of head. Brings hand down with fingers outstretched to check. Child imitates.		
b. Continue with finger patterns 1 to 5.		
c. Repeat activity with non-preferred hand.		
A5.3. Simultaneous Finger Patterns 1-5, Fingers Seen		
a. Teacher raises 2 fingers simultaneously and says "two". Child imitates. Similarly, with 3, 4, & 5 fingers.		
b. "Make a finger pattern of two". Child makes the pattern. Similarly, with 3, 4, & 5 fingers.		
c. Repeat previous steps with number of fingers in random order (with modelling).		
d. Repeat previous step with number of fingers in random order (without modelling).		
e. Non-preferred hand. Teacher raised 2 fingers simultaneously and says "two". Child imitates. Similarly, with 3, 4, & 5 fingers.		
f. Non-preferred hand. "Make a finger pattern of two. Child makes the pattern. Similarly, with 3, 4, & 5 fingers.		
g. Non-preferred hand. Repeat previous steps with number of fingers in random order (with modelling).		
h. Non-preferred hand. Repeat pervious step with number of fingers in random order (without modelling).		
A5.4. Simultaneous Finger Patterns 1-5, Fingers Unseen (bunny ears)		
a. Teacher places hand on top of head and raises two fingers simultaneously saying "two". Child imitates. Continue with 3, 4, & 5 finger patterns		

b. “Make a finger pattern of two, bunny ears without looking”. Child makes the pattern. Similarly, with 3, 4, & 5 fingers.		
c. Repeat pervious step with number of fingers in random order (with modelling).		
d. Repeat pervious step with number of fingers in random order (without modelling).		
e. Non-preferred hand. Teacher places hand on top of head and raises two fingers simultaneously saying “two”. Child imitates. Continue with 3, 4, & 5 finger patterns.		
f. Non-preferred hand. “Make a finger pattern of two, bunny ears without looking”. Child makes the pattern. Similarly, with 3, 4, & 5 fingers.		
g. Non-preferred hand. Repeat previous step with number of fingers in random order (with modelling).		
h. Non-preferred hand. Repeat previous step with number of fingers in random order (without modelling).		
A5.5. Double Patterns for 1 to 5		
a. Child makes 2 in each hand. “Let’s count to see how many altogether. 1-2-3-4” (teacher points to each finger). 2+2 make 4. How much is 2+2?”.		
b. Similarly, for 3+3, 4+4, 5+5, 1+1.		
c. Hand on top of head. Child makes 2 in each hand. “Let’s count to see how many altogether. 1-2-3-4” (teacher points to each finger). 2+2 make 4. How much is 2+2?”.		
d. Similarly, for 3+3, 4+4, 5+5, 1+1 with hand on top of head.		
A5.6. Using Fingers to Keep Track of Sequences of Movements		
a. Teacher makes 3 chopping motions. Child is asked to keep track of motions with his fingers. Continue with 2, 4, and 5 chops.		
b. Similarly, with 2, 3, 4, & 5 movements in random order.		
c. Non-preferred hand. Teacher makes 3 chopping motions. Child is asked to keep track of motions with his fingers. Continue with 2, 4, and 5 chops.		
d. Non-preferred hand. Similarly, with 2, 3, 4, & 5 movements in random order.		
A5.7. Using Fingers to Keep Track of Sequences of Sounds		
a. Teacher makes a slow sequence of 3 claps. Child is asked to keep track with his fingers. Continue with 2, 4, & 5 claps.		
b. Similarly, with 1-5 claps in random order.		
c. Non-preferred hand. Teacher makes a slow sequence of 3 claps. Child is asked to keep track with his fingers. Continue with 2, 4, & 5 claps.		
d. Non-preferred hand. Similarly, with 1-5 claps in random order.		
e. Preferred hand. Teacher makes a slow sequence of 3 claps *out of sight* (e.g., under the table). Child is asked to keep track with his fingers. Continue with 2, 4, & 5 claps.		
f. Preferred hand. Similarly, with 1-5 claps made *out of sight* in random order.		
g. Non-preferred hand. Teacher makes a slow sequence of 3 claps *out of sight* (e.g., under the table). Child is asked to keep track with his fingers. Continue with 2, 4, & 5 claps.		

h. Non-preferred hand. Similarly, with 1-5 claps made *out of sight* in random order.		

<u>Key Topic 6: Patterns of Movements and Sounds (Temporal Patterns)</u> ***AIM: Facility with copying and counting temporal patterns and sequences***	Introduction date	Maste (Three c
A6.1. Copying and Counting a Number of Movements		
a. Teacher makes 6 chopping movements and counts. Child copies and counts together with teacher. Similarly, for numbers 1-10.		
b. Teacher makes 6 chops and child counts. Similarly, for numbers 1-10.		
c. Teacher says a number and child makes correct number of chops. Continue with all numbers 1-10.		
A6.2. Copying and Counting Rhythmic Patterns		
a. Teacher claps a 2 pattern and child copies.		
b. Teacher claps a 2-2 pattern and child copies. Similarly, with patterns: 1-2, 2-1, 1-3, 3-1, 3-3, 2-3 and 3-2.		
c. Teacher claps a 2-2 pattern and child asked to count the claps. Similarly, with 1-2, 2-1, 1-3, 3-1, 3-3, 2-3 and 3-2.		
A6.3. Copying and Counting Monotonic Sequences of Sounds		
a. Teacher makes a slow, monotonic sequence of 4 claps. Child is asked “How many claps?”.		
b. Similarly, for sequences in the range 1-10.		
c. Teacher instructs child to make 4 claps.		
d. Similarly, for sequences in the range 1-10.		
A6.4. Copying and Counting Arhythmical Sequences		
a. Teacher makes a fast, arhythmical sequence of 3 claps. Child is asked “How many claps?”.		
b. Similarly, with numbers 1-5.		
c. Teacher makes 3 fast claps and child counts. Then child makes 3 fast claps.		
d. Similarly, with numbers 1-5.		
e. Child is asked to make four claps (without modelling).		
f. Similarly, with numbers 1-5.		

Appendix 21. Ethics for Chapter 4.

WARWICK
THE UNIVERSITY OF WARWICK

HUMANITIES & SOCIAL SCIENCES
RESEARCH ETHICS SUB-COMMITTEE (HSSREC)

Application for Approval of Research Involving Human (Non-NHS) Participants

SECTION 1. GENERAL INFORMATION

1.1 APPLICANT DETAILS

Applicant's Title: **Mrs**
Applicant's Forename: **Magdalena**
Applicant's Surname: **Apanasionok**

Applicant's Faculty/School and Department: **CEDAR**

Applicant's Status:
Staff ☐
Postgraduate Research Student ☒
Other ☐
Please specify:

If this is a student study, please advise why application has been referred to HSSREC:
CEDAR does not have an Ethics Panel.

1.2 APPLICANT'S CONTACT DETAILS

Warwick email address: **M.Apanasionok@warwick.ac.uk**
Telephone number:

1.3 SUPERVISOR – This should be completed for all student projects

Supervisor's Title: **Professor**
Supervisor's Forename: **Richard**
Supervisor's Surname: **Hastings**
Supervisor's Post: **Professor**
Supervisor's Faculty/School and Department: **CEDAR**
Supervisor's Warwick email address: **R.Hastings@warwick.ac.uk**
Supervisor's telephone number: **External: +44 (0)24 76522197 | Internal: 22197**

1.4 OTHER INVESTIGATORS

Please provide the details of any other investigators involved in the project:
Barah Alallawi – PhD student in CEDAR
Dr Corinna Grindle – Associate Fellow in CEDAR
Dr Richard Watkins – Associate Fellow in CEDAR

SECTION 2. PROJECT DETAILS	
2.1 Project Title:	**Evaluation of small group numeracy curriculum for children diagnosed with Autism Spectrum Disorder**
2.2 Estimated start date for data collection:	**07.09.2017**
2.3 Estimated end date for data collection:	**24.07.2018**
2.4 Funder If unfunded please state 'N/A'	**This project will be conducted as part of Magdalena's Apanasionok PhD funded by Calthorpe Academy and University of Warwick, as well as part of Barah's Alallawi PhD funded by Mutah University. JORDAN. AL KARAK.**

2.5 Are there any potential conflicts of interest?

☐ **Yes**

☒ **No**

If yes, please provide details:

N/A

Please provide a summary of the project (in lay terms) including the scientific benefit:

The purpose of this study is to pilot and examine the feasibility of a new numeracy curriculum implemented in Calthorpe Academy for children diagnosed with Autism Spectrum Disorder (ASD).

Numeracy can be especially difficult to learn for students with learning disabilities and often requires a systematic approach. Calthorpe Academy decided to implement a new evidence-based numeracy curriculum – TEN-ID. The curriculum will be first implemented across Autism Department in school year 2017/2018 with the plan to implement it across the whole school in the following years.

Curriculum overview

Maths Recovery is an evidence based numeracy curriculum originally developed by Bob Wright for lower attaining students in mainstream schools (Wright et al. 2006). In 2014, Tzanakaki et al. published an adaptation of Math Recovery (TEN-ID) designed to meet the needs of students with Intellectual Disability and Autism Spectrum Disorder. Those adaptations included: shorter instructions, prompting procedures, use of task analyses (breaking down complex tasks into smaller, more achievable steps), additional generalisation step, clearly defined goals and frequent use of reinforcement (Tzanakaki et al. 2014a). Initially TEN-ID has been developed as an individualised instructional model but has been recently adapted to be used in small group setting as well.

There have been two evaluations of TEN-ID curriculum published so far. In the first study researchers used pre- and post-test assessments to evaluate TEN-ID curriculum in teaching numeracy to six children with Autism Spectrum Disorder (Tzanakaki et al. 2014a). Results indicated that all participants made substantial gains in their numeracy knowledge and skills and that those gains were maintained over time. The second study involved a pilot randomised controlled trial of TEN-ID with 24 students with severe Intellectual Disability and/or Autism Spectrum Disorder (Tzanakaki et al, 2014b). Results indicated that TEN-ID was more effective in teaching numeracy to students than school's standard numeracy curriculum and results of the intervention were maintained over time.

Research available so far investigated effectiveness of TEN-ID in one-to-one setting and implemented by researchers. The current project aims to evaluate the TEN-ID curriculum implemented in small group setting by the teachers and teaching assistants in a large special school – Calthorpe Academy.

Setting

Calthorpe Academy is a special school in Birmingham catering for around 380 children aged two to 19 with severe learning disabilities. Students attending the school have diagnoses of Intellectual Disability, Autism Spectrum Disorder, Down's syndrome and Profound and multiple learning disabilities among others. The Autism Department provides education for around 80 students with diagnosis of ASD.

Teaching procedure

The school has decided to introduce TEN-ID curriculum in its Autism Department in the school year 2017-2018. Teaching instruction will be delivered in small groups. Students will be put into groups by class teachers ensuring ability grouping. One group of three students will be working with one member of staff (either teacher or teaching assistant). Students will have three sessions of TEN-ID per week, one generalisation session and one session of working on other maths education strands, as per school's requirements. Each session will last approximately 45 minutes. The teaching procedure will involve a mixture of individual and group targets with approximately two breaks in-between.

Scientific benefit

Results obtained from this evaluation will enhance scientific knowledge of numeracy education for children with ASD. This project will also contribute to an existing research on the outcomes of the TEN-ID curriculum to teach students diagnosed with ASD in a special school setting. It will also contribute to an ongoing discussion about the feasibility of a small group teaching approach for students with ASD.

Please provide details on the methodology to be used:

This project will involve pre- and post-test measures to evaluate a numeracy curriculum implemented in small group settings with children diagnosed with Autism Spectrum Disorder.

Assessment tool overview

Children's learning will be evaluated using data from the Test of Early Mathematics Ability – Third Edition (TEMA 3). This is a standardised assessment designed for students aged three to nine that measures numeracy skills and knowledge. The TEMA 3 is not a time limited assessment and testing can last from 10 to 60 minutes depending on student's skills. The TEMA 3 will be administered in an individual format by Calthorpe Academy staff and research students working at the request of Calthorpe Academy, who wish to evaluate the outcomes from their introduction of a new maths curriculum for their students with ASD. The TEMA 3 assessments will take place in Summer Term 2017 and Summer Term 2018.

Data from the TEMA 3 assessments will be entered into an anonymised digital database alongside descriptive information from the Calthorpe Academy system (ethnic origin, gender, age, primary language, and pupil premium eligibility) and passed on in this form to the research team. Completed TEMA 3 record sheets will be stored in a lockable cupboard in Calthorpe Academy that (after data entry) only Calthorpe Academy staff will have access to.

Participants

The curriculum will be evaluated with all students in the school's Autism Department that have the necessary skills to access it. This is estimated be around 30 students. Final decisions about included students will be made by school's Assistant Head and Head of Autism Department by the time of the summer 2017 TEMA 3 testing period.

Data access and analysis

Data from TEMA 3 assessments will be analysed by Magdalena Apanasionok and Barah Alallawi using paired samples t tests (comparing pre to post intervention scores).

Calthorpe Academy is collecting TEMA 3 data as part of their evaluation of the new curriculum and pupils' progress tracking. Calthorpe Academy is happy for researchers to access and analyse the data (see attached statement from Calthorpe Academy Principal – Richard Chapman). Magdalena Apanasionok and Barah Alallawi will also be supporting Calthorpe Academy in conducting TEMA 3 assessments – at the request of the Academy.

Please describe any ethical issues and / or sensitive topics that will be covered during the course of the project: e.g. subject matter (sensitive/contentious/embarrassing), matters around participant group and/or recruitment of participants, confidentiality issues, method of data collection, etc. **Researchers are only asking for access to data from TEMA 3 assessments that will be collected by Calthorpe Academy, so the ethical considerations are mainly around ensuring confidentiality of accessed data.**
How do you intend to handle these areas? **Data used for research purposes will be kept separately in a password-protected folder according to the Academy's data protection policy. All data will be anonymised using codes prior to be imputed into a research database for analysis. Only anonymised data will be shared with the research team.**
What possible risks are there for the researcher? e.g. lone working, physical safety, emotional safety, etc. **No risks have been identified.**

2.6 LOCATION
Will all or part of the project take place overseas? ☐ **Yes** ☒ **No** **Please state all locations involved in the project, whether in the UK or overseas, e.g. university, public place, schools, etc.** **Calthorpe Academy, Birmingham, UK** **University of Warwick, Coventry, UK**

2.7 PARTICIPANTS	
How many participants will be recruited?	**30 (estimate)**
How will participants be recruited? e.g. via email, posters, social media, etc.	**The Assistant Head and Head of Autism Department in Calthorpe Academy will identify students to receive the new numeracy curriculum. Those students will complete the TEMA 3 assessment on two occasions – at the end of school years 2017 and 2018. Anonymised data from those assessments will be made available to Magdalena Apanasionok and Barah Alallawi to analyse.**
How will informed consent be obtained from the participants?	

No consent forms will be obtained.

If no consent will be obtained please explain why:

Researchers will be analysing data already collected and stored by Calthorpe Academy as a part of their evaluation of pupil progress in relation to their new numeracy curriculum.

Will deception be used during the course of the research?

☐ Yes

☒ No

If yes, please state why it is deemed necessary:

N/A

Will the participant group include any children or vulnerable adults?

☒ Yes

☐ No

If yes, please provide details and explain the necessity of recruiting these individuals:

The intervention aims at evaluating a small group numeracy curriculum for children with Autism Spectrum Disorder in Calthorpe Academy.

Will you or any of the research team, who will come into contact with participants be required to obtain criminal record clearance (Disclosure and Barring Service, DBS)?

☒ Yes

☐ No

If yes, please confirm that such clearance will be obtained before any data collection begins:

DBS clearance is already available for Magdalena Apanasionok and Barah Alallawi.

Will participants be given payment and/or incentives for participating in the research?

☐ Yes

☒ No

If so, please provide details:

N/A

What possible benefits to participants are there to this research?

Please note that incentives should not be presented as a benefit to participation.

Pupils participating in this research will have an opportunity to develop their numeracy skills. Findings from this research will be used to inform curriculum planning and practice in Calthorpe Academy.

What possible risks to participants are there to this research?

This project poses minimal risks to the participants. The intervention is a part of typical education practice and is being evaluated as it is applied within Calthorpe Academy. We have used the TEMA 3 with many children with special educational needs, with no problems and no distress for the students. Because the TEMA 3 is not timed, there is less pressure on children to "perform" under test conditions.

What arrangements have been made for reporting the results of the research to and/or debriefing the participants?

Findings of this research will be shared directly with the school and the teaching staff. The evaluation will also be written up for a peer reviewed journal paper.

SECTION 3. DATA

3.1 How will you ensure confidentiality? Please give details on how and at what stage in the project you will anonymise the data.

Each participant will be assigned a code which only Calthorpe Academy staff members will know. Magdalena Apanasionok and Barah Alallawi will be given access to already anonymised database and it will be shared in this form with PhD supervisors.

3.2 Who will have access to the data? The levels of access should also be noted.

Lead researchers (Magdalena Apanasionok and Barah Alallawi) and PhD supervisors will have access to already anonymised data.

3.3 How and where will the data be stored? Please ensure you are familiar with the advice provided by Research Data Management, and have given due consideration to the format of the data (i.e. hard copy or electronic copy).

Raw data from the assessments will be stored in the locked cabined in Calthorpe Academy, which (after data entry) only Calthorpe Academy staff will have access to. In compliance with University of Warwick and Calthorpe Academy data protection policies, anonymised database will be transferred to the University of Warwick using an encrypted USB stick. The anonymised data will be stored by research team members in password protected folders on University and personal computers for the duration of the research study.

3.4 For how long will the above data be kept? Please ensure you are familiar with the university's Research Data Management Policy, and any necessary requirements from your funder.

Raw data will be kept for 3 years as per Calthorpe Academy policy. After publication, anonymised research data in electronic format will be kept for 10 years before being destroyed in accordance with University of Warwick Research Data Policy.

3.5 Is it anticipated that there will be any future use of the data?

☐ **Yes**

☒ **No**

If yes, please ensure you have made this clear in the participant information sheet, and have provided an option on the consent form for a participant to opt out of future use, if they so wish.

3.6 Will any research activities be audio or video-taped?

☐ **Yes**

☒ **No**

If yes, please ensure you have made this clear in the participant information sheet. If audio/video recording is optional this should be clear in the participant information sheet and participants should be provided the appropriate option on the consent form.

SECTION 4. PUBLICATIONS

How will publications of research findings recognise the contributions of all researchers engaged in the study?

All researchers working on this project will be included as co-authors in the publication. Order of researchers will illustrate contributions to the project and will be agreed by all team members.

SECTION 5. FURTHER INFORMATION

Please provide any additional information you believe to be relevant to this project:

References:

Tzanakaki, P., Grindle, C. F., Saville, M., Hastings, R. P., Hughes, J. C., & Huxley, K. (2014a). An individualised curriculum to teach numeracy skills to children with autism: programme description and pilot data. *Support for Learning,* 29(4), pp. 319-338.

Tzanakaki, P., Hastings, R. P., Grindle, C. F., Hughes, J. C., & Hoare, Z. (2014b). An Individualised Numeracy Curriculum for Children with Intellectual Disability: A Single Blind Pilot Randomised Controlled Trail. *Journal of Developmental & Physical Disabilies,* 26, pp. 615-632.

Wright, R. J., Martland, J., Stafford, A. K., & Stanger, G. (2006). *Teaching number: advancing children's skills and strategies* (3rd ed). London: Sage.

SECTION 6. DECLARATION

The information in this form together with any accompanying information is complete and correct to the best of my knowledge and belief and I take full responsibility for it.

I undertake to abide by the ethical principles underlying the Declaration of Helsinki and to abide by the University's Research Code of Practice alongside any other relevant professional bodies' code of conduct and/or ethical guidelines.

I understand that I must not begin research and related projects with human participants, their tissue, or their data, must not commence without full approval from the relevant research ethics committee of the University of Warwick.

I understand that any changes that I would like to make to this study after receiving approval from HSSREC may require further review. As such they must be submitted to hssrec@warwick.ac.uk before such changes are implemented.

Signature of [redacted] Applicant: Date: 28.06.2017

Signature of Supervisor (If applicable): [redacted] Date: 28.06.17

Signature of Head of Department: [redacted] Date: 28.06.17

Please send an electronic copy of the application to hssrec@warwick.ac.uk

Note. Your electronic submission should contain wet-ink or electronic signatures of all relevant parties. Applications without the necessary signatures will be returned.

If you have not already done so, you are advised to undertake the Research Integrity Online Training Course. All details relating to this course can be found here.

SECTION 7. APPLICANT CHECKIST

Please indicate below the documents that are being submitted along with this application form:

Participant Information Sheet	☐
Consent Form	☐
Recruitment material	☐ Please provide details:
Interview topic guide	☐
Questionnaire(s)	☐
Other (please specify):	

Statement from Calthorpe Academy Principal – Richard Chapman

CALTHORPE ACADEMY
Skills for the life we want

To whom it may concern,

I am writing to confirm that Calthorpe Academy is introducing a new numeracy curriculum for pupils with Autism Spectrum Disorder in 2017/18. We have invited Magdalena Apanasionok and Barah Alallawi to support us with an evaluation of the outcomes from this new curriculum over the course of the academy school year, as part of their PhD studies with the University of Warwick. The new curriculum will be implemented in the Autism department in Calthorpe Academy as a part of an initiative to develop a stronger numeracy curriculum and inform educational practice across the whole school. We have made arrangements to gather numeracy skills data from the approximately 30 children with Autism involved, using the Test of Early Mathematics Ability 3rd Edition (TEMA 3) assessment. Calthorpe Academy staff, along with Mrs Apanasionok and Mrs Alallawi, will gather the TEMA 3 data at the end of the school year 2017 and again in 2018.

Calthorpe Academy is happy for data collected from the numeracy assessment (TEMA 3) by the school to be accessed and analysed by Magdalena Apanasionok and Barah Alallawi as part of their research project at University of Warwick.

All data will be anonymised for use in this research so that no pupil can be identified.

Yours sincerely,

[redacted]

Head Teacher

CALTHORPE ACADEMY Darwin Street, Highgate, Birmingham B12 0TP T 0121 773 4637 E enquiry@calthorpe.bham.sch.uk W calthorpe.bham.sch.uk

WARWICK
THE UNIVERSITY OF WARWICK

Humanities and Social Sciences Research Ethics Committee
Kirby Corner Road
Coventry
CV4 8UW

Wednesday, 26 July 2017

Professor Richard Hastings
CEDAR
University of Warwick
Coventry
CV4 7AL

Dear Professor Hastings,

Ethical Application Reference: 119/16-17
Title: Evaluation of small group numeracy curriculum for children diagnosed with Autism Spectrum Disorder

Thank you for submitting your updated ethics application to the Humanities and Social Sciences Research Ethics Sub-Committee, following the letter of conditional approval on **20 July 2017**. We are pleased to advise you that, under the authority delegated to us by the University of Warwick Research Governance and Ethics Committee, full approval for your project is hereby granted for the duration of the study.

Before conducting your research it is strongly recommended that you complete the on-line ethics course:
https://www2.warwick.ac.uk/services/ldc/researchers/opportunities/development_support/research_integrity/
Support is available from your Departmental contact in Research & Impact Services

Any material changes to any aspect of the project will require further consideration by the Committee and the PI is required to notify the Committee as early as possible should they wish to make any such changes.

May I take this opportunity to wish you the very best of luck with this study.

Yours sincerely

[redacted]

Dr Friederike Schlaghecken
Chair, Humanities and Social Sciences Research Ethics Sub-Committee

HUMANITIES & SOCIAL SCIENCES
RESEARCH ETHICS SUB-COMMITTEE (HSSREC)

Application for Expedited Review

Expedited review of research can occur where the potential for risk of harm to participants and others affected by the proposed research is **minimal**, for this reason the following may be undertaken via an expedited review process:

- The review of amendments to studies previously approved by HSSREC (**Annex A**);
- Research involving only secondary or historical data (**Annex B**);
- Involvement in research on a consultancy basis (**Annex C**).

Please complete sections 1 and 2 of this form together with **one** of the annexes and return to hssrec@warwick.ac.uk.

No research project involving human participants, their tissue, or their data may begin before the relevant sub-committee of the Research Governance and Ethics Committee has issued its written approval. Written confirmation of the sub-committee's decision will be emailed to the applicant as soon as possible after the expedited review. The sub-committee may request a full ethical review for this research project if deemed necessary.

If you have not already done so, you are advised to undertake the Research Integrity Online Training Course. All details relating to this course can be found here.

SECTION 1. GENERAL INFORMATION

1.1 APPLICANT DETAILS

Applicant's Title: Mrs
Applicant's Forename: Barah
Applicant's Surname: Alallawi

Applicant's Faculty/School and Department: CEDAR

Applicant's Status:

Staff	☐
Postgraduate Research Student	☒
Other	☐

Please specify:

If this is a student study, please advise why application has been referred to HSSREC:
CEDAR does not have an Ethics Panel.

1.2 APPLICANT'S CONTACT DETAILS

Warwick email address: B.Alallawi@warwick.ac.uk
Telephone number:

1.3 SUPERVISOR – This should be completed for all student projects	
Supervisor's name: **Professor Richard Hastings - the University of Warwick** **Dr Corinna Grindle – Associate Fellow in CEDAR** **Dr Louise Denne – Senior Research Fellow in CEDAR** **Dr Richard Watkins – Associate Fellow in CEDAR**	
1.4 OTHER INVESTIGATORS	
Please provide the details of any other investigators involved in the project: **Magdalena Apanasionok – PhD student in CEDAR**	
1.5 Project Title:	**Staff members' experiences of a numeracy curriculum for children with Autism Spectrum Disorder**
1.6 Estimated start date for data collection:	**May 2018**
1.7 Estimated end date for data collection:	**July 2018**
1.8 Funder If unfunded please state 'N/A'	**This project will be conducted as part of Barah's Alallawi PhD funded by Mutah University- Jordan as well as part of Magdalena's Apanasionok PhD funded by Calthorpe Academy and University of Warwick.**

SECTION 2. DECLARATION

The information in this form together with any accompanying information is complete and correct to the best of my knowledge and belief and I take full responsibility for it.

I undertake to abide by the ethical principles underlying the Declaration of Helsinki and to abide by the University's Research Code of Practice alongside any other relevant professional bodies' code of conduct and/or ethical guidelines.

I understand that I must not begin research and related projects with human participants, their tissue, or their data, must not commence without full approval from the relevant research ethics committee of the University of Warwick.

I understand that any changes that I would like to make to this study after receiving approval from HSSREC may require further review. As such they must be submitted to hssrec@warwick.ac.uk before such changes are implemented.

Signature of Applicant: **Barah Alallawi** Date: **28.03.2018**

Signature of Supervisor (If applicable): [redacted] Date: **28.03.2018**

Signature of Head of Department: [redacted] Date: **28.03.2018**

Please send an electronic copy of the application to hssrec@warwick.ac.uk

Note. Your electronic submission should contain wet-ink or electronic signatures of all relevant parties. Applications without the necessary signatures will be returned.

Annex A: Project amendments

1. Please provide the HSSREC reference number: **119/16-17**

This can be found on the approval letter for the original application

2. Is this is the first amendment?

☒ **Yes**

☐ **No**

If no, please state what number this amendment will be:

3. Please give a brief summary of the original project (in lay terms):

The original project aims were to pilot and examine the feasibility of a small group numeracy curriculum called TEN-ID (Teaching Early Numeracy to children with Intellectual Disability) with children with Autism Spectrum Disorder in Calthorpe Academy. 17 students from five classes are currently taking part in the study.

Children's learning will be evaluated using data from the Test of Early Mathematics Ability – Third Edition (TEMA 3). This is a standardised assessment designed for students aged three to nine that measures numeracy skills and knowledge. The initial TEMA 3 assessments took place in Summer Term 2017 and will be repeated in Summer Term 2018.

4. Please detail the proposed changes to the research:

Although we are testing numeracy outcomes for children, to examine feasibility of using TEN-ID in other schools and in future research it is also important to gather information from school staff about their experiences of the intervention. We would thus like to add a component to the approved project to interview teachers/teaching assistants.

Method:

The project will involve semi-structured interviews. The interview questions are designed to elicit staff members' experiences of the TEN-ID curriculum (see attached interview protocol).

The interviews will be conducted with approximately 12 members of staff (including teachers and teaching assistants) at the end of school year 2017/2018 after their involvement in delivering the TEN-ID intervention. Researchers already know the teachers and teaching assistants who are delivering the TEN-ID curriculum. Barah Alallawi and Magdalena Apanasionok will invite them personally, through an initial conversation one-to-one, to participate.

Data from the interviews will be transcribed and analysed by Barah Alallawi and Magdalena Apanasionok.

Data access and analysis:

Data from the interviews will be analysed by Barah Alallawi and Magdalena Apanasionok using thematic analysis. According to Braun and Clarke (2006) "thematic analysis is a method for identifying, analysing and reporting patterns (themes) within data." (pp. 79).

5. Please describe any ethical issues and / or sensitive topics that will arise from these changes:

e.g. subject matter (sensitive/contentious/embarrassing), matters around participant group and/or recruitment of participants, confidentiality issues, method of data collection, etc.

Researchers will only have access to data from the interviews with Calthorpe Academy staff members who were involved with the delivery of the TEN-ID curriculum. The researchers want to understand their

experiences of the TEN-ID curriculum. Therefore, the ethical considerations are mainly around ensuring confidentiality of the interview data. Interviews will be recorded if participants give their consent for this. If participants do not consent to an audio recording, the interviewer will take detailed notes during the interview.
6. Please detail how you intend to handle the areas noted above: Barah Alallawi and Magdalena Apanasionok will transcribe interviews data anonymously, so participants won't be identified. Once the interviews have been fully transcribed, recordings will be deleted. In line with CEDAR research procedures (which are kept in line with the University's research data management policy) interview transcriptions will be kept in password protected folders on University servers. Before transcription is completed, the audio files will also be stored only in password protected folders on University computers.
7. Please provide any additional information that you believe to be relevant: References: Braun, V & Clarke, V. (2006). Using Thematic Analysis in Psychology. Qualitative Research in Psychology, 3:2, pp. 77- 101. Appendices: A1 Participants Information Sheet A2 Consent Forms A3 Interviews protocol
Annex B: Review of secondary or Historical data (No participant involvement)
1. Please give a brief summary of the project (in lay terms), including the scientific benefit:
2. Please provide a description of the data source to be used, specifying the era the data relates to and if possible how the data was originally collected:
3. Please provide details of any ethical review that has taken place regarding the initial collection of data:
4. Will approval from another organisation be required in order to gain access the data, if so please provide the details:
5. Who will have access to the data? Please also note any varying levels of access to the data.
6. Please describe any ethical issues and / or sensitive topics that will be covered during the course of this research:

7. Please detail how you intend to handle the areas noted above:
8. When publishing the research findings what precautions will be taken to safeguard, in the case of: a) **Literary review:** the sensitivities and / or anonymity of living relatives b) **Pre-existing datasets**: the continued confidentiality and anonymity of personal data
9. Please provide any additional information that you believe to be relevant:
Annex C: Involvement in research on a consultancy basis
1. Please give a brief summary of the project (in lay terms), including the scientific benefit:
2. Please summarise the methodology to be used:
3. Please give details of the involvement Warwick will have in the research:
4. Please describe any ethical issues and / or sensitive topics that will be covered during the course of this research:
5. Please detail how you intend to handle the areas noted above:
6. Please provide any additional information that you believe to be relevant:

WARWICK
THE UNIVERSITY OF WARWICK

PARTICIPANT INFORMATION SHEET

version 1, 20/04/2018

Study Title: Staff members' experiences of a numeracy curriculum for children with Autism Spectrum Disorder

Investigator(s): Barah Alallawi and Magdalena Apanasionok (University of Warwick)

Introduction

You are invited to take part in a research study. Your participation in this study will help to understand your views about TEN-ID (Teaching Early Numeracy to children with Intellectual Disability) and your experiences of using the curriculum with children with autism this school year. We are very keen to hear from you. Before you decide, please take time to read the following information carefully. It is important for you to understand what the research would involve. If there is anything that is unclear, or if you would like more information please contact us using the details provided at the end.

Part 1 tells you the purpose of the study and what will happen to you if you take part. Part 2 gives you more detailed information about the conduct of the study.

Please ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

PART 1

What is the study about?

During school year 2017/18, some students from Autism Department in Calthorpe Academy have been taught numeracy using the TEN-ID curriculum (Teaching Early Numeracy to children with Intellectual Disability). We have assessed students' numeracy skills to see if they have made progress while accessing the curriculum. We would also like to understand staff views about TEN-ID and their experiences of using the curriculum with children with autism. This information will help us understand how to better support staff members and students and how to improve the curriculum in the future. We would like to interview staff who have used the TEN-ID curriculum during 2017/18.

Do I have to take part?

It is entirely up to you to decide. We will describe the study and go through this information sheet, which we will give you to keep. If you choose to participate, we will ask you to sign a consent form to confirm that you have agreed to take part. You will be free to withdraw at any time without any repercussions.

WARWICK
THE UNIVERSITY OF WARWICK

Will my taking part be kept confidential?

Yes. We will follow strict ethical and legal practice and all information about you will be handled in confidence. Transcribed data will be anonymised, so you will not be identified. Further details are included in Part 2.

What will happen to me if I take part?

You will be invited to attend an interview by Barah Alallawi and Magdalena Apanasionok. The interview will take place at Calthorpe School at a time that suits you. We will explain what is involved and check that you have fully understood everything covered in this information sheet. We also need to check that you agree to participate in the research. Once you have read this study information, you will be asked to read some statements and to indicate your agreement to each one. We will ask if it is ok to audio record an interview with you. You do not have to agree to this recording. You can still take part in the research interview even if you do not want to be recorded. The interview will last about 30 minutes. We shall be asking you about your experiences of delivering TEN-ID curriculum over the school year 2017/18. We would like to find out about your thoughts on the curriculum, particularly what went well and what could be improved if you were to use the curriculum again.

If you say we can record the interview, the research team will transcribe the interview later and destroy the recording. If you do not agree to the interview being recorded, the interviewer will take written notes when they meet with you.

What are the possible disadvantages, side effects, risks, and/or discomforts of taking part in this study?

We do not anticipate any disadvantages or risks associated with taking part in this research. We just want to know about your experiences of delivering the TEN-ID curriculum.

What are the possible benefits of taking part in this study?

Participants in this research study will have an opportunity to discuss/share their experiences of using TEN-ID. We want to understand what we can do to improve TEN-ID in the future.

Expenses and payments

We will not be offering payments for taking part in this study. Taking part in this study will incur no expenses for you.

What will happen when the study ends?

At the end of the study, all interview transcripts/notes and consent forms will be stored anonymously by University of Warwick for 10 years (in line with University of Warwick policy) on secure university servers in a password protected files which only the research team will have access to. The findings may also be used anonymously in academic conferences and publications.

What if there is a problem?

Any complaint about the way you have been dealt with during the study or any possible harm that you might suffer will be addressed. Detailed information is given in Part 2.

This concludes Part 1.
If the information in Part 1 has interested you and you are considering participation, please read the additional information in Part 2 before making any decision.

PART 2

Who is organising and funding the study?

The University of Warwick is responsible for this research. The research has received funding from:

1. Mutah University (Jordan) who are supporting Barah's Alallawi PhD studies at the University of Warwick.
2. Calthorpe Academy and University of Warwick who are supporting Magdalena's Apanasionok PhD studies at the University of Warwick.

What will happen if I don't want to carry on being part of the study?

Participation in this study is entirely voluntary. Refusal to participate will not affect you in any way. If you decide to take part in the study, you will need to sign a consent form, which states that you have given your consent to participate. You can withdraw at any time without any repercussions. You can also refuse to answer any question that you're not comfortable with.

Who should I contact if I wish to make a complaint?

Any complaint about the way you have been dealt with during the study or any possible harm you might have suffered will be addressed. Please address your complaint to the person below, who is a senior University of Warwick official entirely independent of this study:

Head of Research Governance
Research & Impact Services
University House
University of Warwick
Coventry
CV4 8UW
Email: researchgovernance@warwick.ac.uk
Tel: 024 76 522746

Will my taking part be kept confidential?

Yes, your name will not be used in any report of the research study and the interview transcripts and notes will be anonymised.

WARWICK
THE UNIVERSITY OF WARWICK

What will happen to the results of the study?

Data from this research will be anonymised and the research findings shared with Calthorpe Academy and the teaching staff. The anonymised findings may also be used in academic conferences and publications.

Who has reviewed the study?

This study has been reviewed and given favourable opinion by the University of Warwick's Humanities and Social Science Research Ethics Committee (HSSREC): 119/16-17. 20-04-2018.

What if I want more information about the study?

If you have any questions about any aspect of the study, or your participation in it, not answered by this participant information sheet, please contact:

Barah Alallawi, University of Warwick, B.Alallawi@warwick.ac.uk
Magdalena Apanasionok, University of Warwick, M.Apanasionok@warwick.ac.uk

Thank you for taking the time to read this Participant Information Sheet.

WARWICK
THE UNIVERSITY OF WARWICK

CONSENT FORM

version 2, 20/04/2018

Participant ID number:

Title of Project: Staff members' experiences of a numeracy curriculum for children with Autism Spectrum Disorder

Name of researcher(s): Barah Alallawi and Magdalena Apanasionok - CEDAR, University of Warwick

Name of Academic Supervisors: Professor Richard Hastings - CEDAR, University of Warwick
Dr. Corinna Grindle - Associate Fellow, CEDAR, University of Warwick
Dr. Louise Denne - Senior Research Fellow, CEDAR, University of Warwick
Dr. Richard Watkins - Associate Fellow, CEDAR, University of Warwick

Please tick initial box

1. I confirm that I have read and understood the information sheet (version 1, 20/04/2018) provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary, and I can withdraw at any time without any repercussions. I can refuse to answer any question that I'm not comfortable with. ☐

3. I am happy for my interview to be audio recorded so the research team can transcribe the interview later. ☐

4. I understand that verbatim quotes from my interview might be used by the research team for research purposes. All used quotes will be anonymized. ☐

5. I understand that my data will be securely stored for 10 years, in line with the University of Warwick's Research Data Management Policy and data from my interview will be transcribed anonymously so I will not be identified. ☐

6. I agree to take part in the above study. ☐

____________________	__________	______________
Name of Participant	Date	Signature
____________________	__________	______________
Name of Researcher	Date	Signature

taking consent

WARWICK
THE UNIVERSITY OF WARWICK

Humanities and Social Sciences Research Ethics Committee
Kirby Corner Road
Coventry
CV4 8UW

Friday, 20 April 2018

Professor R Hastings
CEDAR
University of Warwick
Coventry
CV4 7AL

Dear Professor Hastings,

Ethical Application Reference: 119/16-17
Amendment number: 1
Title: Evaluation of small group numeracy curriculum for children diagnosed with Autism Spectrum Disorder

Thank you for submitting your project amendments to the Humanities and Social Sciences Research Ethics Sub-Committee for consideration. We are pleased to advise you that, under the authority delegated to us by the University of Warwick Research Governance and Ethics Committee, full approval for your project is hereby granted.

Before conducting your research it is strongly recommended that you complete the on-line ethics course: https://www2.warwick.ac.uk/services/ldc/researchers/opportunities/development_support/research_integrity/
Support is available from your Departmental contact in Research & Impact Services.

Any material changes to any aspect of the project will require further consideration by the Committee and the PI is required to notify the Committee as early as possible should they wish to make any such changes.

May I take this opportunity to wish you the very best of luck with this study.

Yours sincerely

[redacted]

Dr Fiona MacCallum
Chair, Humanities and Social Sciences Research Ethics Sub-Committee

Appendix 22. Survey used after the initial TEN-DD training session.

Post- Training Survey

Strongly Disagree	Disagree	Neither agree not disagree	Agree	Strongly Agree
1	2	3	4	5

Please select an answer to indicate what you thought about the training

Please circle as appropriate.

Category	Item	Rating				
Overall	The training session was well organised.	1	2	3	4	5
	The content of the training session was covered in the time available.	1	2	3	4	5
	Trainers provided all that I needed to complete training tasks.	1	2	3	4	5
Process: materials	The presentation slides were relevant, clear and useful.	1	2	3	4	5
	The handouts were relevant, clear and useful.	1	2	3	4	5
	The example plans were relevant, clear and useful.	1	2	3	4	5
	The videos were relevant, clear and helpful.	1	2	3	4	5
Process: trainers	Trainers presented TEN-ID curriculum in clear and concise way.	1	2	3	4	5
	Trainers demonstrated practical skills and knowledge.	1	2	3	4	5
	Trainers' feedback was clear and concise.	1	2	3	4	5
Process: aspects	I learned a good deal from the presentation.	1	2	3	4	5
	I learned a good deal from the practical activities and role play.	1	2	3	4	5
Outcomes	I understand this year plan for implementation of the TEN-ID curriculum.	1	2	3	4	5
	I understand the rationale of using 'TEN-ID' curriculum.	1	2	3	4	5
	I understand what 'TEN-ID' aims to do.	1	2	3	4	5
	I understand how to use 'TEN-ID' curriculum to teach numeracy to a small group of pupils.	1	2	3	4	5
	I understand how to read the teaching plans.	1	2	3	4	5
	I will be able to follow the lesson plans available to adapt my teaching to the needs of the individual child.	1	2	3	4	5
	I understand what Discrete Trial Teaching (DTT) is.	1	2	3	4	5
	I will be able to follow trial structure of Discrete Trial Teaching (DTT).	1	2	3	4	5
	I understand what TEN-ID generalisation sessions aims to do.	1	2	3	4	5
Goals	Training in a small group outside the classroom is very useful for learning how to use 'TEN-ID' curriculum.	1	2	3	4	5

Any other comments:

....

....

Appendix 23. Survey used after ten-DD data collection training.

Post- Training Survey

Strongly Disagree	Disagree	Neither agree not disagree	Agree	Strongly Agree
1	2	3	4	5

Please select an answer to indicate what you thought about the training

Please circle as appropriate.

Category	Item	Rating				
Overall	The training session was well organised.	1	2	3	4	5
	The content of the training session was covered in the time available.	1	2	3	4	5
	Trainers provided all that I needed to complete training tasks.	1	2	3	4	5
Process: materials	The presentation slides were relevant, clear and useful.	1	2	3	4	5
	The handouts were relevant, clear and useful.	1	2	3	4	5
	The example plans were relevant, clear and useful.	1	2	3	4	5
	The videos were relevant, clear and helpful.	1	2	3	4	5
Process: trainers	Trainers presented TEN-ID curriculum in clear and concise way.	1	2	3	4	5
	Trainers demonstrated practical skills and knowledge.	1	2	3	4	5
	Trainers' feedback was clear and concise.	1	2	3	4	5
Process: aspects	I learned a good deal from the presentation.	1	2	3	4	5
	I learned a good deal from the practical activities and role play.	1	2	3	4	5
Outcomes	I understand this year plan for implementation of the TEN-ID curriculum.	1	2	3	4	5
	I understand the rationale of using 'TEN-ID' curriculum.	1	2	3	4	5
	I understand what 'TEN-ID' aims to do.	1	2	3	4	5
	I understand how to use 'TEN-ID' curriculum to teach numeracy to a small group of pupils.	1	2	3	4	5
	I understand how to read the teaching plans.	1	2	3	4	5
	I will be able to follow the lesson plans available to adapt my teaching to the needs of the individual child.	1	2	3	4	5
	I understand what Discrete Trial Teaching (DTT) is.	1	2	3	4	5
	I will be able to follow trial structure of Discrete Trial Teaching (DTT).	1	2	3	4	5
	I understand what TEN-ID generalisation sessions aims to do.	1	2	3	4	5
Goals	Training in a small group outside the classroom is very useful for learning how to use 'TEN-ID' curriculum.	1	2	3	4	5

Any other comments:

....

....

Appendix 24. TEN-DD interview questions.

Interview protocol

Researchable question: What are the views, perceptions and experiences of Calthorpe Academy staff delivering TEN-ID curriculum to students with autism?

Introduction

We are interested in your experience of using the TEN-ID curriculum in your day-to-day work at the school over the school year 2017/18. We would like to find out what you thought about the TEN-ID curriculum - what went well and what could be improved if you were to use TEN-ID curriculum again.

I would like to thank you for agreeing to talk to us. You have signed a consent form agreeing to take part in the interview. I will record this interview if you have consented for this, so I can transcribe it later. If you did not consent to audio recording, I will take detailed notes during our conversation. Everything that you tell me today will remain confidential and anonymous. If at any point during the interview you decide you do not want to continue, please let me know. You do not have to give me a reason for your decision.

Our discussion today should last about 30 minutes, but you can talk for as little or as long as you would like.

If you are happy with all these, we can begin.

Topic 1: Implementation

1. What is your role in the school and in the TEN-ID project?
2. Tell me about your experience of implementing the TEN-ID curriculum with your students?
    - Did you encounter any difficulties?
    - What did you enjoy and what would you change?
3. Could you give me an example of something you found easy and something you found hard in implementing the TEN-ID curriculum?
    - Why?

Topic 2: Training and materials

1. Tell me about your experience of the training that you have received at the beginning of the school on the TEN-ID curriculum?

- What was useful? (Why? Examples?)
- What wasn't useful? (Why? Examples?)
- What, if anything, would you change?
- Do you think you need more training?

2. Tell me about your experience of using the TEN-ID materials, including the folder, and teaching materials?
    - Was the folder useful? What would you change?
    - Were the materials useful?

Topic 3: Support

1. Tell me about your experience of the mentoring visits?
    - What was useful? (Why? Examples?)
    - What wasn't useful? (Why? Examples?)
    - Feedback from the trainers (myself and Magda) was part of the mentoring visits, what are your views on it? Did you find it useful?
2. Thinking about the wider school (SLT, heads of departments and your colleagues), how much support have you received?
    - Can you give me some examples?
    - Would you like to have more support?

Topic 4: Outcomes

1. How do you think your pupils are doing after eight months of the TEN-ID curriculum?
    - Why?
    - Examples?
    - Did you notice generalisation of the skills they have learned?
2. Think of a specific pupil that you work with, take me through his/hers journey during this school year.
    - Do you think he/she enjoyed the intervention?
    - Why?
    - How do you know?
3. Thinking about your professional development, did you experience any benefits from learning about and implementing the TEN-ID curriculum?
    - Why?
    - Examples?

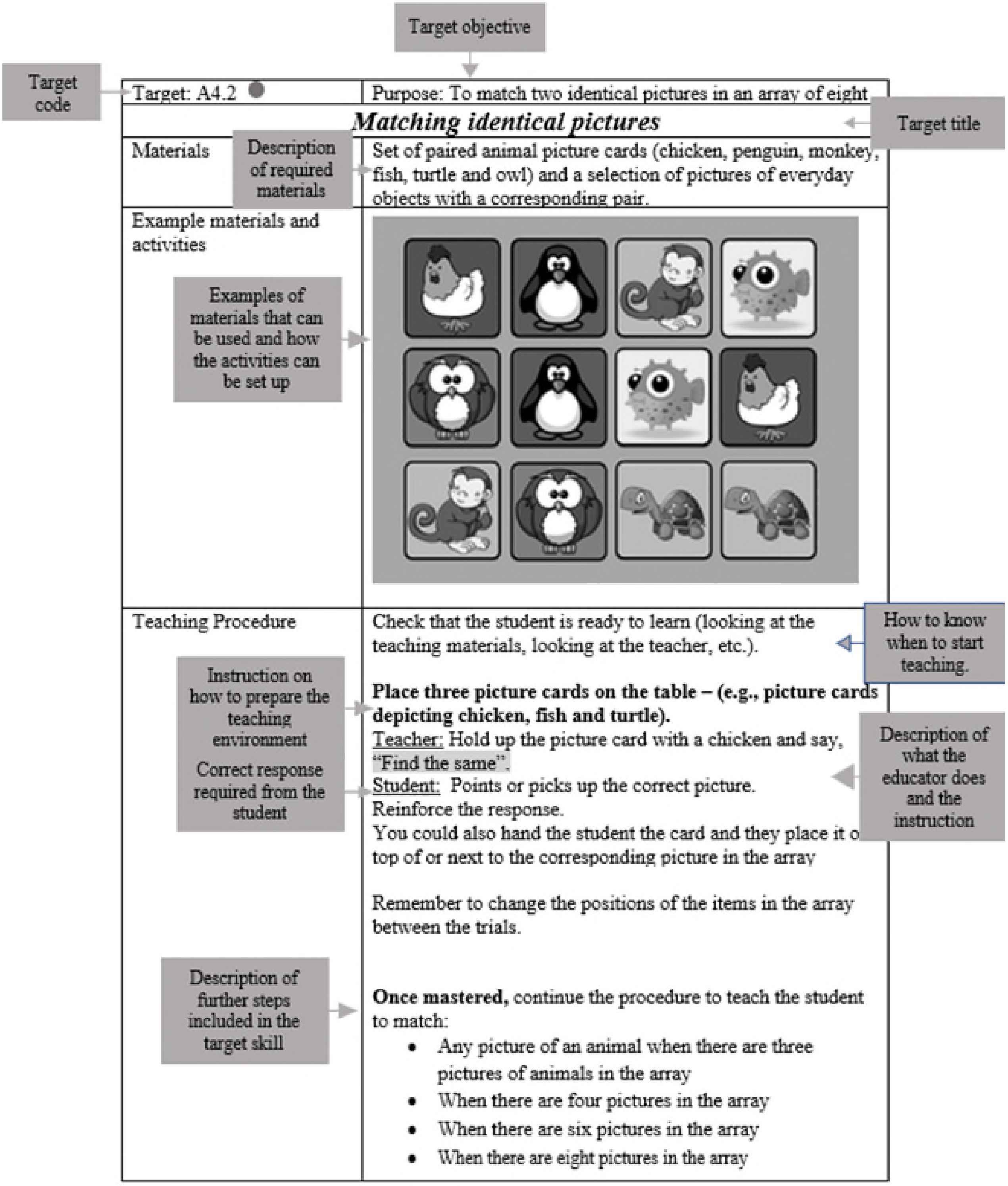
4. Thinking about this school year, did TEN-ID have impact on teaching in general in your class?
    - Did it impact students that were not working on TEN-ID?
    - Any implication of the knowledge and practice on the TEN-ID on how you work with other students?
    - Did the project cause any disruptions to your class?
5. Did the training and experience on the TEN-ID you have acquired during this school year had impact on your confidence in teaching in general?
    - If yes, can you give me a few examples?

Topic 5: Wider implications

1. Can you tell me about your experience of participating in a research project?
    - Did you enjoy it?
    - Did you feel part of the project?
    - Would you like to take part in a research project in the future?
    - Would you like your school to take part in more research projects in the future?
2. Would you like to see the TEN-ID curriculum continue to be used with your pupils?
    - If yes, why?
    - If no, what would have to change?
3. Would you like to see the TEN-ID curriculum being used in the rest of the school?
    - If yes, why?
    - If no, what would have to change?
4. What changes would be helpful to implement the TEN-ID curriculum with students with different needs than autism?
    - How about older or younger students?
    - Why?

Thank you very much for your time. Are you happy for us to use data from your interview?

Appendix 25. TEN-DD R sample lesson plan.



Target: A4.2	Purpose: To match two identical pictures in an array of eight
Matching identical pictures	
Materials	Set of paired animal picture cards (chicken, penguin, monkey, fish, turtle and owl) and a selection of pictures of everyday objects with a corresponding pair.
Example materials and activities	
Teaching Procedure	Check that the student is ready to learn (looking at the teaching materials, looking at the teacher, etc.). **Place three picture cards on the table – (e.g., picture cards depicting chicken, fish and turtle).** Teacher: Hold up the picture card with a chicken and say, "Find the same". Student: Points or picks up the correct picture. Reinforce the response. You could also hand the student the card and they place it on top of or next to the corresponding picture in the array Remember to change the positions of the items in the array between the trials. **Once mastered,** continue the procedure to teach the student to match: • Any picture of an animal when there are three pictures of animals in the array • When there are four pictures in the array • When there are six pictures in the array • When there are eight pictures in the array

	The student should respond within 3 seconds of the instruction being given and attempt to point to or otherwise select the matching card. If not, please refer to: Help that may be provided. Test each new task to see if the student generalizes the skill. If the student is correct on the first attempt at a new task, you do not need to teach this task, and you can move on to the next task.
Generalization plan Guidance on how the skill can be generalised	• Another teacher asks the student to complete the task. • Use different instructions – e.g. "Find the match", "where does this go" • Teach in a different setting or at a different time of the day. • Test using new combinations of pictures (e.g., of everyday items) that were not included in the initial teaching procedure, until the student can match any novel picture that is given to them on the first trial that they are asked. This means that the skill has generalized and no longer needs to be taught. • Use naturally occurring play opportunities to generalize the skill. For example, play lotto games or sorting card activities
Help that may be provided Possible alternations and prompting suggestions to be used if the student is struggling to acquire the target skill	• Model - the teacher demonstrates first and the student copies after. You can also model this activity with another student. This should be faded over subsequent trials. • If the student lacks the motivation to match the picture cards, consider increasing the quality/level of reinforcement on offer for completing the task (differential reinforcement). Alternatively, you could also start with the student matching pictures of preferred (liked) items like a favourite toy or an edible treat. They could have the chance to play with the favourite toy or eat the edible treat as a reward for matching correctly. Once the student consistently matches the picture of the preferred item, you could try the same procedure with matching pictures of more neutral items. • You could teach first matching photographs of the objects that you taught in A4.1 (matching objects) • You could use positional prompts where you place the corresponding picture closer to the student. Other simple prompts you could use are pointing to the correct picture to match or guiding the student's hand towards the correct picture. • If the student continues to struggle, you can start with just one identical pair of pictures (e.g. two chicken cards). Once they consistently pick up the matching card,

	introduce the non-identical card (e.g. owl). Gradually build up the size of the array. • Use Augmentative and Alternative (AAC) communication methods to support verbal instruction (e.g., Makaton sign for "to find" or "same").
Mastery criterion	Three ticks (√) in a row across 3 consecutive days

Appendix 26. TEN-DD R mentoring visit record.

Mentoring visit record

Educator's name: **Date:**

Key	
0	Incorrect for most of the time
1	Correct for approximately half of the trials
2	Correct for most of the trials

6. Implementation

Delivery	**Circle correct**		
17. Gathers needed materials for TEN-DD R delivery (teaching plans, data sheet and resources).	**0**	**1**	**2**
18. Ensures student's table is clear of distractions before starting each trial.	**0**	**1**	**2**
19. Uses appropriate materials for each trial as specified in the teaching plan.	**0**	**1**	**2**
20. Establishes student's attention.	**0**	**1**	**2**
21. Delivers S^D (instruction) as written in the teaching plan.	**0**	**1**	**2**
22. Delivers S^D (instruction) while the student is attending to task.	**0**	**1**	**2**
23. Delivers appropriate consequence (choose from options below):			
c. Correct response – delivers praise.	**0**	**1**	**2**
i. Delivers praise with enthusiastic voice while maintaining an eye contact.	**0**	**1**	**2**
ii. The praise is delivered within 5 seconds after the response.	**0**	**1**	**2**
d. Incorrect response – delivers correction/prompting procedure.	**0**	**1**	**2**
i. Follows procedure as described in the teaching plan.	**0**	**1**	**2**
ii. Prompts are effective in helping the student make the correct response.	**0**	**1**	**2**
iii. Provides only as much prompting as needed to help the student to be successful.	**0**	**1**	**2**
iv. Fades prompts as early as possible.	**0**	**1**	**2**
24. Inter-trial interval is discrete, but brief.	**0**	**1**	**2**
25. Session pace (S^Ds, prompts, reinforces and inter-trial intervals) is appropriate to student's needs.	**0**	**1**	**2**
26. Maintains student's attention and engagement throughout the session.	**0**	**1**	**2**
27. GROUP MODEL ONLY **-** Encourages students to observe each other during teaching (when one student is working on a trial with the teacher the rest of the group is encouraged to observe).	**0**	**1**	**2**
28. Teaches an appropriate target as per the data sheet.	**0**	**1**	**2**
29. GROUP MODEL ONLY **-** Ensures appropriate ratio of sequential	**YES**		**NO**

and choral responses (approximately 75:25).		
30. Ensures appropriate ratio of work and breaks (approximately 75:25).	**YES**	**NO**
31. Conducts trials for all current targets for each student.	**YES**	**NO**

Data collection	**Circle correct**		
3. Collects data for all trials completed during the session.	**0**	**1**	**2**
4. Collects accurate data (correct or incorrect) for each student.	**0**	**1**	**2**
7. Folder review	**Circle correct**		
4. Introduces one current target at the time.	**0**	**1**	**2**
5. Ensures mastery criteria is implemented correctly.	**0**	**1**	**2**
6. Updates data sheet on regular basis.	**YES**	**NO**	

8. Points to be discussed (successes and areas for improvement)

9. Any problems reported by the educator?

Problem:

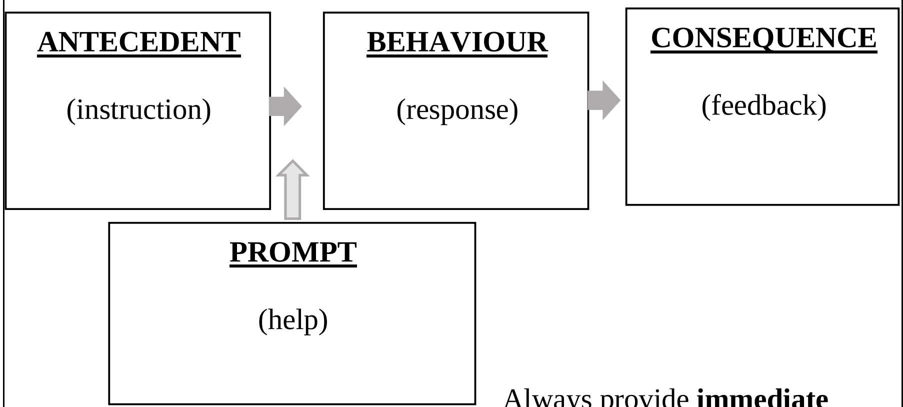
Discussed solutions:

Follow up – yes or no?

Signature of the designated TEN-DD R lead: Signature of the Educator:

Appendix 27. TEN-DD R implementation protocol

TEN-DD R implementation protocol

<u>Frequency</u>	**Three** 20 minutes long sessions a week
<u>Session structure</u>	During each TEN-DD R session you should work **multiple times** on student's current target. At least quarter of the session should be spent on **maintenance** and **generalization** of already learnt targets (see below).
<u>How to teach new skills</u> **Discrete Trial Teaching**	For teaching new targets you will use **Discrete Trial Teaching (DDT)**. It is a method that focuses on breaking down skills and teaching them in short trials ensuring quick pace. Each session should consist of **multiple trials**. General structure of one trial is:  Always provide **immediate feedback** after the student responds – either **praise** (when correct) or **neutral redirection** such as "Try again" (when incorrect). Make sure you are using enthusiastic voice when praising the student. Few trials should be done at **quick pace** before giving the student a brief break to ensure optimal learning. Always ensure the student is **ready to learn** (sitting down and attending to you) before starting to teach. <u>Please read Discrete Trial Teaching and Motivation & Learning guides for more details.</u>
<u>How to help the student when he is struggling</u> **Prompting and error-correction**	When the student is struggling to respond it is important to deliver appropriate **prompt**. Prompt is a hint or a cue that you can use to help the student respond correctly. Types of prompts: - **Physical -** the teacher helps the child give the correct response by providing the child with manual help (e.g., guiding child's hand towards correct numeral card) - **Modelling** – the teacher provides a visual demonstration of what the correct response looks like (e.g., teacher picks up the correct numeral card) - **Gestural** – the teacher makes a gesture that can indicate the correct response to the student (e.g., the teacher points to the correct numeral card) - **Verbal** – the teacher demonstrates the verbal response to the student (e.g., when the task is to identify numeral card 3 the teacher can say 'three' or can say only the beginning of the word 'th….' and see if the child will finish). - **Visual** – the teacher shows picture, text, photo, or video to the

	student in order to cue the correct response (e.g., when the task is to identify number of dots the teacher can show the numeral card with a corresponding number to the student; alternatively, when the task is to select numeral card 3 from array of four different cards, the teacher can move numeral card 3 closer to the student to cue the correct answer). Which type of prompt you should use will depend on the skill and the amount of help the student needs. Always use the **least amount of help** possible to help the student find the correct response. It is crucial to **fade prompt** as soon as possible to avoid students getting overly reliant on them. Help should be **withdrawn** as soon as student starts responding correctly. Also, the student should always have the opportunity to **respond independently** before help is provided. When a student responds incorrectly it is important to follow an **error-correction procedure**: 1. In a <u>neutral</u> voice say e.g., 'Try again', 'No, that's not right' to signal to the student that his response was incorrect. 2. Repeat the instruction. 3. Immediately deliver appropriate for that skill prompt (see above). 4. When student provides correct response praise him in mildly positive voice, 'Good' (so he can distinguish between being correct with your help and on his own). 5. Retest the skill giving the student chance to answer independently. <u>Please read Prompting and Prompt Fading guides for more details.</u>
<u>When to move on to the next skill</u> **Mastery criterion**	For new skills, if the student is **correct (without any help) on the first two ever tries** of a new target then it is considered mastered (we assume he knows it) and next target can be introduced. If not, target should be introduced and taught until student achieves **9 out of 10 correct responses over 2 consecutive days** before moving on to the next skill. Student should always **work on one target at the time** and can move on to the next one only when the previous one is mastered.
<u>How to make sure student maintains his newly learnt skills</u> **Maintenance and generalisation**	At least **quarter** of weekly time assigned to TEN-DD R should be spent on **maintenance** (student is able to continue to consistently respond correctly after the structured teaching is finished) and **generalization** (student is able to perform taught skills under new conditions, e.g., new workplace, new teacher, new materials, etc.) of targets. This is an **extremely important** part of teaching new skills. To achieve that teachers should make sure that mastered targets are still practiced under below conditions: **1. Maintenance** **Regularly practice already mastered skills** to make sure the student can still perform them confidently. It might be helpful to mix maintenance trials with trials on student's current target to provide him with a break and occasion for reward. If the student responds **incorrectly multiple** times during trials on already mastered skill, then the teacher should consider to re-

	introduce the skills in the structured way (DDT). **2. Generalisation** a. Skill practiced with **different people** at a place it was taught (e.g., usual workstation but working with a different teacher/TA or asking another student to say the instruction). b. Skill practiced in **different places** (e.g., after the student can do a task consistently at his own desk move to another place in the same room like different desk in the same classroom, carpet; later practice the skills outside of the classroom – dining hall, playground – and outside of school – shop, bus, café). c. Skill practiced using **different instruction** (e.g., after the student can point to numeral card 2 when asked "Find 2" practice the same skill by asking differently – e.g. "Where is 2?"; "Show me 2"). d. Skill practiced using **different materials** (when possible) (e.g., after the student can count 5 dots start working on counting 5 starts, teddies, biscuits, steps, jumps, etc.).
How to track progress **Data collection**	Record data on a TEN-DD R data sheet for the **first 10 trials** you do during one session (✔ for correct independent or ✘ for incorrect response) for each student. After 10 trials continue teaching without collecting data. If the student responds correctly but the teacher delivers a prompt, it is counted as incorrect. Only fully independent responses can be recorded as correct.

Appendix 28. Bespoke ABLLS-R tracker for domain B - visual performance.

Student:

ABLLS-R Skills Tracker - B

Level		Target	Probe (√ or ×)	Date
B1	**TO**	**The student will put the puzzle pieces into the puzzle frame**		
	1	Student places up to 3 pieces seperately using trial and error		
	2	Student places up to 5 pieces seperately using trial and error		
	3	Student places 3 pieces as a group by looking and positioning		
	4	Student places 5 pieces as a group by looking and positioning		
B2	**TO**	**The student will put the pieces into the correct holes in the shape sorter**		
	1	Student places 2 pieces by trial and error		
	2	Student places 4 pieces by trial and error		
	3	Student places 4 pieces by look and locate		
	4	Student places 6 pieces by look and locate		
B3	**TO**	**The student will match to an identical object (array of 3)**		
	1	Student will match 1 object to a display of 2		
	2	Student will match 2 objects to a display of 2		
	3	Student will match 5 objects to a display of 4		
	4	Student will match 10 objects to a display of 8		
B4	**TO**	**The student will match the object to a picture (array of 3)**		
	1	Student can match a single item per presentation		
	2	Student can match 3 items in a row		
B5	**TO**	**The student will match identical pictures (array of 3)**		
	1	Student can match 1 picture to a display of 2 pictures		
	2	Student will match 2 pictures to a display of 2 pictures		
	3	Student will match 5 pictures to a display of 4 pictures		
	4	Student will match 10 pictures to a display of 8 pictures		
B6	**TO**	**The student will match pictures to the object (array of 3)**		
	1	Student can match a single item per presentation		
	2	Student can match 3 items in a row		
B7	**TO**	**The student will match pictures fluently**		
	1	Student will match 5 pictures in 15 seconds		
	2	Student will match 10 pictures in 30 seconds		
B8	**TO**	**The student will sort non-identical items**		
	1	Student will sort 4 items into 2 groups		
	2	Student will sort 6 items into 3 groups		
	3	Student will sort 12 items into 4 groups		
	4	Student will sort 20 items into 4 groups		
B9	**TO**	**The student will match a block design**		
	1	Student will match a 2 block design		
	2	Student will match a 4 block design		
	3	Student will match 4+ block design (with left over blocks)		
	4	Student will match a 6+ block design (with left over blocks)		
B10	**TO**	**The student will complete a puzzle with multiple connecting pieces**		
	1	Student will complete a puzzle with 5 pieces		
	2	Student will complete 2 puzzles with 5 pieces		
	3	Student will complete 4 puzzles with 5 pieces		
	4	Student will complete 4 puzzles with 8 pieces		

Student: ABLLS-R Skills Tracker - B

Level		Target	Probe (√ or ×)	Date
B11	TO	**The student will complete a puzzle with a square border**		
	1	Student will complete 3 puzzles with 2 pieces		
	2	Student will complete 3 puzzles with 3 pieces		
	3	Student will complete 3 puzzles with 4 pieces		
	4	Student will complete 3 puzzles with 5 pieces		
B12	TO	**The student will copy a block design**		
	1	Student will copy a 2 block design		
	2	Student will copy a 4 block design		
	3	Student will copy a 4+ block design (extra parts)		
	4	Student will copy a 6+block design (extra parts)		
B13	TO	**The student will match a sequence pattern**		
	1	Student will match a sequence of 6 pieces of 2 items		
	2	Student will match a sequence of 6 pieces of 3 items		
	3	Student will match a sequence of 8 pieces of 4 items		
	4	Student will match a sequence of 8 pieces of 4 items with extras		
B14	TO	**The student will complete an irregular shaped puzzle**		
	1	Student will complete a puzzle with 3 pieces		
	2	Student will complete 2 puzzles with 3 pieces		
	3	Student will complete 4 puzzles with 4 pieces		
	4	Student will complete 4 puzzles with 12 pieces		
B15	TO	**The student will complete a standard puzzle**		
	1	Student will complete 1 puzzle with 8 pieces		
	2	Student will complete 2 puzzles with 8 pieces		
	3	Student will complete 2 puzzles with 12 pieces		
	4	Student will complete 4 puzzles with 12 pieces		
B16	TO	**The student will match picture associations**		
	1	Student will match 1 related picture for 5 items		
	2	Student will match 1 related picture for 10 items		
	3	Student will match 2 related pictures for 10 items		
	4	Student will match 2 related pictures for 20 items		
B17	TO	**The student will sort pictures by function**		
	1	Student will sort 2 items from 2 functions		
	2	Student will sort 5 items from 2 functions		
	3	Student will sort 5 items from 3 functions		
	4	Student will sort 5 items from 4 functions		
B18	TO	**The student will sort pictures by feature**		
	1	Student will sort 2 items for 2 features		
	2	Student will sort 5 items for 2 features		
	3	Student will sort 5 iitems for 3 features		
	4	Student will sort 5 items for 4 features		

Student: ABLLS-R Skills Tracker - B

Level		Target	Probe (√ or ×)	Date
B19	**TO**	**The student will sort pictures by class**		
	1	Student will sort 2 items from 2 classes		
	2	Student will sort 5 items from 2 classes		
	3	Student will sort 5 items from 3 classes		
	4	Student will sort 5 items from 4 classes		
B20	**TO**	**The student will replicate a sequence from memory**		
	1	Student will replicate a 2 item pattern with a 2 second delay with prompts		
	2	Student will replicate a 2 item pattern with a 2 second delay, no prompts		
	3	Student wil replicate a 3 item pattern with a 2 second delay		
	4	Student will replicate a 3 item pattern with a 5 second delay		
B21	**TO**	**The student will find a picture from memory**		
	1	Student will find uo ti 3 items (array of 2) with 2 second delay		
	2	Student will find up to 5 items (array of 3) with 3 seconds delay		
	3	Student will find up to 5 items (array of 3) with 5 seconds delay		
	4	Student will find up to 10 items (array of 5) with 5 second delay)		
B22	**TO**	**The student will continue a pattern**		
	1	Student will continue a pattern using 2 items (alternating sequence)		
	2	Student will continue a pattern using 3 items (regular sequence)		
	3	Student will continue a pattern using 3 items (distractor pieces)		
	4	Student will continue an irregular pattern using 3 items (distractor pieces)		
B23	**TO**	**The student can replicate simple 3D objects**		
	1	Student will replicate 2 objects using 3+ blocks		
	2	Student will replicate 2 objects using 6+ blocks		
B24	**TO**	**The student will be able to complete a matching sequence**		
	1	Student will put correct item on another item for 3 responses		
	2	Student will put correct item on another item for 6 responses		
B25	**TO**	**The student can arrange items in a logical order**		
	1	Student will order 2 sets of items for 1 attribute		
	2	Student will order 2 sets of items for 2 attributes		
	3	Student will order 2 sets of items for 3 attributes		
	4	Student will order 4 sets of items for 4 attributes		
B26	**TO**	**The student will sequence pictures**		
	1	Student will complete a 3 card sequence for 2 items		
	2	Student will complete a 3 card sequence for 3 items		
	3	Student will complete a 3 card sequence for 5 items		
	4	Student will complete a 4 card sequence for 5 items		
B27	**TO**	**The student will complete simple mazes**		
	1	The student will complete a maze with 1 path option		
	2	The student will complete a maze with 3 choices for path option		

Appendix 29. TEN-DD R bespoke assessment.

TEN-DD R structured interview for teachers

Rating criteria		
0 - Never	1 – Sometimes (50% of time or with support/prompt)	2 - Usually (without support/prompt)

1. **Looks at the teacher counting**
Task: Watches when teacher counts up to five objects one by one.
Question: What does he/she do when you count out up to five objects?
2. **Attends to, and copies, teacher counting**
Task: Copies pointing/touching while the teacher counts up to five objects and points to them.
Question: How about when you count up to five objects while pointing, does he\she attempt to copy you to touch the objects?
3. **One-to-one correspondence in everyday situations**
Task: Gives out one plate, cup, or candy to each student in a group of students/teddy at the table, for example.
Question: When you give him/her a few (up to 5) plates, cups or candies does he give one to each student or teddy at the table?
4. **Attends during singing number songs.**
Task: Watches and tries to imitate number words while the teacher is singing a number song.
Question: What does he/she do when you are singing number songs such as ‘1, 2, 3, 4, 5 Once I caught a fish’ or ‘Five little ducks’ or ‘One, Two, Buckle my shoe’?
5. **Counts during singing number songs/reading books.**
Task: Attempts to count with the teacher/sing along with familiar number songs.
Question: How about when he/she hear the song multiple times, does he/she attempt to sing along or count?
6. **Copies rhythmical movements.**
Task: Copies teacher doing a single clap/stomp of foot/tap on a table.
Question: What does he/she do when you clap, stomp your feet, or tap the table once?
7. **Copies multiple (up to 5) rhythmical movements.**
Task: Copies teacher clapping/stomping feet/tapping on the table up to 5 times.
Question: How about when you clap, stomp your feet, or tap the table up to 5 times, does she/he attempt to imitate you?
8. **Takes one from an array of objects in known situations.**
Task: Takes one biscuit from a plate/one pen from a pencil holder/one sweet from a bag/one object during number songs.
Question: When you offer him/her a sweet or a biscuit and ask him/her to take only one, what does he/she do?
9. **Matches numbers 1-5 (identical).**
Task: Matches identical numbers cards 1-5.
Question: When you put on a table number cards 1 to 5 and give him/her a second set of number cards 1 to 5 and ask him/her to match, what does he/she do?
10. **Matches numbers 1-5 (non-identical).**
Task: Matches non-identical number cards 1-5.
Question: How about when the number cards from two sets are not identical, e.g., different font, colour?
11. **Sorts 3s.**
Task: Sorts number card 3 from non-3s in a range 1-5.

Question: When you give him/her multiple copies of number cards 1 to 5 and ask him/her to sort threes, does he/she attempt to separate threes from non-threes?

12. Counts 1-5 with the teacher.

Task: Counts 1-5 simultaneously with the teacher.

Question: When you count 1 to 5, does he/she attempt to count with you?

13. Counts 1-5 with the teacher while pointing to objects/numbers on the number line.

Task: Counts 1-5 simultaneously with the teacher while pointing to objects or numbers on the number line.

Question: How about when you put five objects in front of him/her, does he/she attempt to point to them while counting with you?

14. Produces set of 5 objects with a prompt.

Task: Copies teacher producing a set of 5 objects (e.g., blocks, counters, tokens).

Question: When you take 5 blocks out of a box what does he/she do?

15. Produces set of 5 objects without a prompt.

Task: Produces a set of 5 objects (e.g., blocks, counters, tokens) when asked.

Question: How about when you give him/her box of blocks or other objects and ask him/her to give you 5 without showing him/her first, what does he/she do?

16. Matches 3D quantity to 2D quantity 1-5.

Task: Matches number card to a set of objects (e.g., blocks, teddys, counters, pens).

Question: When you put up to 5 blocks or other objects on the table and give him a choice of two number cards (one matching quantity of the objects), what does he/she do?

17. Counts 1-5 independently.

Task: Counts 1-5 when asked without a prompt.

Question: When you ask him/her to count to 5, what does he/she do?

Appendix 30. Ethics for Chapter 6.

WARWICK
THE UNIVERSITY OF WARWICK

Humanities & Social Sciences Research Ethics Committee (HSSREC):

Application Form for Research Ethical Approval

Date: 17/12/2019	**Version:** 3

SECTION 1. APPLICANT DETAILS

1.1 APPLICANT

Applicant's Title (optional):	Mrs
Applicant's Forename:	Magdalena
Applicant's Surname:	Apanasionok
School or Department:	Centre for Educational Development, Appraisal and Research (CEDAR)
Warwick e-mail address:	[redacted]
Contact telephone number:	07801284584

Applicant's Status:

STUDENT:		**STAFF:**	
Undergraduate Student	☐	**Professor**	☐
Taught Postgraduate Student	☐	**Associate Professor**	☐
Postgraduate Research Student	☒	**Assistant Professor**	☐
		Research Fellow	☐
Name of course/qualification: PhD in Education and Psychology		**Teaching Fellow**	☐
		Other	☐
		Please specify:	

1.2 SUPERVISOR (COMPLETE FOR ALL STUDENT PROJECTS)

Supervisor's Title: Professor
Supervisor's Forename: Richard
Supervisor's Surname: Hastings
Supervisor's Post: Professor and Cerebra Chair of Family Research
Supervisor's Faculty/School and Department: Centre for Educational Development, Appraisal and Research (CEDAR)
Supervisor's Warwick e-mail address: [redacted]
Supervisor's contact telephone number:

1.3 OTHER INVESTIGATORS/COLLABORATORS (INTERNAL & EXTERNAL)

Please list all other known collaborators, internal and external to Warwick, including the name of the company/organisation or Investigator's Warwick department/school and their role in the project:

Dr Corinna Grindle – Associate Fellow in CEDAR
Dr Richard Watkins – Associate Fellow in CEDAR

1.4 REFERRALS

Has the Project been referred to HSSREC from another REC or delegated process? No *If yes, please provide the reason:* **Referred by department as not within the remit for delegated approval** ☐ **Other** ☐ Please provide details:

SECTION 2. PROJECT DETAILS	
2.1 Project Title:	Teaching Numeracy Readiness to Children with Developmental Disabilities: A Feasibility Randomised Controlled Trial
2.2 Estimated start date:	December 2019
2.3 Estimated completion date of project:	December 2020
2.4 Does the project involve the NHS or social care:	No
2.5 Type of Project: https://warwick.ac.uk/services/ris/research_integrity/researchethicscommittees/biomed/study_design/ Research ☒ NHS Service evaluation or Development ☐ NHS Clinical Audit ☐ Other- please specify:	
2.6 Research Sponsor: If **not** research in the NHS, please state N/A	N/A
2.7 Funder: If unfunded, please state N/A	This study will be carried out as a part of Magdalena Apanasionok's Doctoral Dissertation. Mrs Apanasionok is a recipient of Warwick Collaborative Postgraduate Research Scholarship funded by the University of Warwick and Calthorpe Academy.
2.8 IDEATE/Funder reference (if applicable) If your study is funded, please provide a reference	
2.9 Links with other HSSREC applications Is the project linked to any other HSSREC application? No If yes, detail: Project title: Chief Investigator: HSSREC Reference (if known): Nature of linkage:	

SECTION 3: BACKGROUND/LAY SUMMARY
Please provide a lay summary of the project: The summary should be brief and easily understood by someone who is not an expert in the area. Definitions and explanation of terms should be provided (avoid technical language). *To include:* • *a description of the proposed study and population to be studied building on review of previous studies/evidence*

- *the scientific benefit of the proposed study*

The purpose of this study is to research the feasibility of implementing a new numeracy readiness curriculum in a special school setting for children diagnosed with developmental disabilities (DD).

Numeracy can be especially difficult to learn for students with DD and often requires a systematic approach. Calthorpe Academy previously collaborated with the research team in evaluating a numeracy curriculum (Teaching Early Numeracy to students with Developmental Disabilities - TEN-DD) for students with autism spectrum disorder with emerging numeracy skills. Now the school would like to implement a new numeracy readiness curriculum – Teaching Early Numeracy to children with Developmental Disabilities - Readiness (TEN-DD R) for students who do not yet have any numeracy skills and who cannot access the school's regular numeracy curriculum.

Curriculum overview
The TEN-DD R is based on previous research on teaching numeracy to children with DD and successful implementation of the TEN-DD curriculum in Calthorpe Academy and other schools. The TEN-DD R curriculum consists of two parts. The first part contains lesson plans that describe how to teach pivotal skills like imitation, matching and general attending that are considered necessary for the student to be able to learn more complex numeracy skills, like counting. The second part contains lesson plans that describe how to teach very early numeracy skills that are immediate prerequisite skills for the numeracy targets described in the first phase of the TEN-DD curriculum. Before accessing the TEN-DD R curriculum students' skills and knowledge are assessed to identify any gaps. The pivotal skills are taught first and only after the student has mastered (i.e., learnt) them all can he/she proceed to the numeracy focused part of the curriculum.

Setting
Calthorpe Academy is a special school in Birmingham which caters for around 380 children aged two to 19 with severe learning disabilities. Students attending the school have diagnoses of Intellectual Disability, Autism Spectrum Disorder, Down syndrome and Profound and multiple learning disabilities among others.

Teaching procedure
The school has decided to introduce the TEN-DD R curriculum in its primary and secondary departments in the school year 2019-2020 and has asked the research team to research the feasibility of implementing the curriculum. Teaching instruction will be delivered in an individual or small group format depending on the class teacher's preference. If the group teaching model is preferred, students will be assigned to groups by their class teacher. One group of two or three students will work with one member of staff (either teacher or teaching assistant). Whether taught individually or in a group, students will have approximately three sessions of TEN-DD R per week within usual slots for numeracy as per school's timetable. Each session will last approximately 20-30 minutes.

Design
This study will utilise a waiting list randomised controlled trial design. Half of the recruited students will be randomly (like tossing a coin) assigned to receive the new curriculum and the other half to carry on with numeracy teaching as usual in the school. After the study has finished, as long as the new curriculum is a positive development, students not assigned to TEN-DD R will begin using the new curriculum.

Scientific benefit
The majority of the research literature on teaching numeracy to students with DD focuses on children who already have basic understanding of numbers and some emerging skills. Numeracy readiness for students with DD is a very under researched area. Results obtained from this study will enhance scientific knowledge of numeracy readiness and numeracy education for children with DD in general. This project will contribute to the further development of a numeracy readiness curriculum to teach students with DD.

SECTION 4 RISK AND ETHICAL CONSIDERATIONS CHECKLIST

Complete the checklist ticking '**Yes**' or '**No**' to **all** questions.

Where you have ticked '**Yes**' to a question below, you will need to specifically address the ethical issues raised by that point and detail what safeguards will be put in place to minimise the potential risks/harm in the relevant section of the application form or in the space provided.

		Yes	No
A	Does the study involve **participants who are particularly vulnerable** or **unable to give informed consent** or **in a dependent position** (e.g. children, your own students, over-researched groups, people with learning difficulties, people with mental health problems, young offenders, people in care facilities, prisoners)? *(If yes, please provide details in section 7 – Informed Consent)*	☒	☐
B	Will participants be taking part in the study without their consent or knowledge at the time, or will **deception** of any sort be involved (e.g. covert observation of people in non-public places)? *(If yes, please provide details in section 7 – Informed Consent)*	☐	☒
C	Is there a risk that the **highly sensitive nature** of the subject might lead to **disclosures** from the participant concerning their involvement in illegal activities or other activities that represent a threat to themselves or others (e.g. sexual activity, drug use, or professional misconduct)? If yes, please provide details:	☐	☒
D	Could the study induce **psychological distress or anxiety**, or produce **humiliation**, or **cause harm**, or lead to **negative consequences** beyond the risks encountered in normal life? • *Applicable to studies involving sensitive topics, vulnerable participants as well as studies involving driving experiments, simulators, computational or physiological experiments. For the latter, please detail potential risks associated with any equipment and how these will be monitored and addressed in the space below.* • *Please also consider the risk to individuals if any personally identifiable data collected as part of the study is accidently disclosed. Please see guidance note for more information.* If yes, please provide details:	☐	☒
E	Does the study involve **substantial physical exertion**? If yes, please provide details:	☐	☒
F	Does the study involve the **administration** of any substance? If yes, please provide details:	☐	☒
G	Does the study involve **physically intrusive procedures**, use of **bodily materials** or **human tissue**, or **DNA/RNA analysis**? If yes, please provide details:	☐	☒
H	Is any **reward**, apart from travelling and other expenses, to be given to participants? If yes, please provide details and justification for this, to ensure this is appropriate, and **not** seen as a bribe or to coerce participants into taking part:	☐	☒
I	Could the proposal give rise to researchers having any **conflicts of interest**? ***https://warwick.ac.uk/services/finance/resources/regulations/fp1*** • *Consider relationships/previous personal interactions with participating organisations, participants etc.* If yes, please provide details including how this will be managed:	☐	☒
J	Will any part of the project be undertaken overseas? If yes, please state which Country/Countries, the locations at which the project will be undertaken, e.g. public place, school, company, hospital, University, researcher's office, including the services of an overseas cloud hosting provider for storage or a	☐	☒

	market research company etc. and the local permissions in place for this (where required): Please see University Guidance for data processing overseas: **https://warwick.ac.uk/services/idc/dataprotection/internationaldatatransfers/**		
K	Will the researchers go to any areas where their **safety may be compromised**? If yes, please provide details, including what measures will be put in place to minimise risks and ensure the researcher's safety. A risk assessment should be submitted with the application:	☐	☒
L	Will **pregnant women** be participants in the study? • *Please note, while you may not purposefully be recruiting pregnant women to the study, consider if any special measures would need to be put into place or if it is appropriate for these individuals to take part, e.g. safety risks* If yes, please provide details:	☐	☒
M	Will the study involve children **under 5 years** old? If yes, please provide details:	☐	☒
N	Is the research commissioned by the **military**?* If yes, please provide details:	☐	☒
O	Is the research commissioned under an **EU security call**?* If yes, please provide details:	☐	☒
P	Does the research involve the acquisition of **security clearances?*** If yes, please provide details:	☐	☒
Q	Does the research concern **terrorist or extreme groups**?* If yes, please provide details:	☐	☒
R	Does the study involve any additional ethical considerations or risks to participants or the researcher that are not listed above? If yes, please provide details:	☐	☒

** Please refer to the University webpages on Prevent Duty*

SECTION 5: STUDY DESIGN, METHODOLOGY & ANALYSIS

5.1 Clearly state the research aim(s) of the project:

To include:

- *a clear explanation and justification for the research question(s)/aim(s)*

Calthorpe Academy has decided to introduce the TEN-DD R curriculum in their primary and secondary departments in the school year 2019/2020 and has asked the research team to research its feasibility. Therefore, our research aims are to pilot the use of the TEN-DD R curriculum and research its feasibility. This study will help to inform the future use of the TEN-DD R curriculum at Calthorpe Academy and with other children who might benefit.

This study will explore the following research question:

What is the feasibility of implementing the TEN-DD R curriculum to teach numeracy skills to students with DD?

5.2 What are the objective(s) for the project:

- *Objectives are intermediate steps that will help you to meet your research aim(s)*

The study will be guided by the following objectives:

1. To assess students' numeracy related skills at baseline (before randomisation) and after two terms.
2. To compare (using statistical methods) students' numeracy related scores at baseline and after two terms.
3. To compare (using statistical methods) numeracy related scores of students in experimental and control groups.

5.3 Study design and data collection methods:

To include:

- *a clear description of the study design and data collection methods*
- *a suitable design should reflect the aim(s) of the study*
- *This may include ethnography/observations, interviews, focus groups, questionnaires, document analysis etc.*
    - ***Ethnography/Observations**- what/who will be observed, by whom, for how long? What equipment (if any) will be used for recording etc.?*
    - ***Interviews**- who is conducting the interviews, how, where and when- by telephone/in person/skype; will they be recorded- how? How long will they last? How will the interview guide be developed? etc.*
    - ***Focus groups**- who is leading, how will they be organised, when and where will they take place, how will they be recorded? How long will they last? etc..*
    - ***Questionnaires**- who has designed the questionnaire, who will distribute it, how long will it take to complete etc.*
    - ***Document analysis**- what documents will be requested, where from, by whom, what permissions are in place for this etc.*
    - ***Experimental** – what tests/lab work will be undertaken on participants, by whom, is specialist training required before undertaking?*
    - ***Secondary analysis of previously collected data**- analysis of data that has been previously collected by a third party for research or other purposes, that is not publicly available e.g. healthcare, student, financial records. Please state whether the data set is identifiable or anonymised.*

Design

This study will utilise a waiting list randomised controlled trial design. Approximately 30 students will be recruited and then randomly assigned to either a control or an experimental group. Students from the experimental group will be taught numeracy using the TEN-DD R curriculum between January and July 2020, while students from the control group will access the school's regular numeracy curriculum (i.e., "teaching as usual"). In September 2020 students from the control group will start learning numeracy through teachers using the TEN-DD R curriculum - as long as the initial evaluation is positive.

This design will allow for direct comparison of numeracy outcomes of students taught numeracy using the new curriculum (TEN-DD R) and those receiving teaching as usual while also ensuring that at the end of the study all students will be able to access the TEN-DD R curriculum if it is beneficial.

Assessment tools

Students' progress will be evaluated using two assessment tools. First, sub tests from the Assessment of Basic Language and Learning Skills- Revised (ABLLS-R; Partington, 2006) will be used to assess students' pivotal prerequisite skills such as matching, imitation and general attending. ABLLS-R is a tool developed for children with developmental disabilities to assess their language and learning skills. It consists of 25 skill areas but only domains relevant to the TEN-DD R curriculum will be used. Those will be: visual performance, receptive language, motor imitation, vocal imitation (for verbal students only), intraverbals, group instruction, generalised responding, maths skills and fine motor skills. We will also use an additional bespoke assessment to determine students' numeracy skills. This tool is a structured interview for teachers based on numeracy skills covered in the curriculum. It is comprised of 17 questions about participants' skills. Those two assessment tools (ABLLS-R and the TEN-DD R bespoke assessment) have been selected due to the nature of the skills included in the curriculum. The research team could not find any standardised numeracy assessments that would be accessible to students with DD and cover very early numeracy skills. The majority of available standardised numeracy assessments start at the equivalent of age four for a neurotypical child, whereas the TEN-DD R curriculum includes skills that could emerge in neurotypical children as early as age two. Therefore, we have decided to use the two assessment tools described above as they best cover the skills included in the TEN-DD R curriculum, despite not being standardised measures.

Data collection

Baseline data will be collected between December 2019 and January 2020 (before the students are randomly assigned to either the control or experimental group) using the ABLLS-R and the TEN-DD R bespoke assessment. The ABLLS-R assessment will be completed by the participants' usual teachers based on their knowledge of the student's existing skills and through their observations. The TEN-DD R bespoke assessment in a form of a structured interview will be completed by a Masters student or a Research Assistant from the University of Warwick. The interviews will be conducted with a member of staff who knows the student well (e.g., either the child's class teacher or their Teaching Assistant (TA)). Post intervention testing (for both the ABLLS-R and the TEN-DD bespoke assessment) will occur between June and July 2020.

5.4 Data Analysis

To include:

- *Specifically what data sets will be collected (name, date of birth, email address, ethnicity, health status, financial records, IP addresses, etc.)*
- *whether this data will be collected directly from participants (e.g. via questionnaires/interviews) or indirectly, from a third party (previously collected data set) and how i.e. web form, online application, paper form*
- *Detail the analysis methods that will be undertaken e.g. content analysis, framework analysis, interpretative phenomenological analysis etc. and any statistical analyses.*
- *Describe how and by whom any data will be transcribed, coded, de-identified, stored, transferred, accessed, archived*
- *Any software used in the analysis should be specified and detailed how it will be used in the project*

Collected data

The school will provide student's details that are necessary for data analysis and interpretation from their records. This information is the child's age, sex, and learning needs (diagnostic labels such as autism). Students names will be replaced by codes that will only be known to Calthorpe Academy staff. Students' numeracy related scores will be collected directly from teachers using ABLLS-R and the TEN-DD R bespoke assessment. Hard copies of the assessments will be stored in lockable cabinets in Calthorpe Academy. An anonymised database prepared by Calthorpe Academy staff member with students' codes, age, sex, diagnosis and numeracy related scores will be transferred to an encrypted folder on University's shared server using an encrypted USB stick to be analysed.

Data analysis

Data from numeracy assessments will be analysed by comparing pre to post intervention scores of intervention and control groups using a mixed Analysis of Variance model, including if possible, class membership as a random factor (to address clustering of children within school classes).

SECTION 6: RECRUITMENT

6.1 State the total number of planned participants and the sampling strategy; provide justification for this:

To include:

- *The rationale behind the proposed size of the sample*
- *Will the sample size provide enough data to answer the research question?*
- *If sampling will be continued until saturation is reached, then this should be stated and linked to the research question*
- *Sampling strategy- is this random, snowball, purposive, convenience etc.*
- *What is the rationale for this- it should reflect the methodological framework for the study*

The TEN-DD R curriculum will be introduced to all students in the school's primary and secondary department that meet the inclusion/exclusion criteria and that are not accessing other more suitable numeracy curriculums already. This is estimated to be around 30 students. Final decisions about included students will be made by the school's Assistant Head and Maths Lead and will depend on obtaining parental consent.

6.2 Where applicable, state the breakdown of participants by type and number of each type of participant, e.g. children (include age), parents, teachers, health care professionals etc.:

Type of Participant:	Number:
Students (age 5-15 years old)	up to 30

6.3 Please provide clear inclusion criteria:

1. The student does not have the prerequisite skills to access school's other numeracy curriculums.

2. The student has no or very few gaps in the prerequisite pivotal skills part of the curriculum. Children will be included if teachers' advice is that any existing gaps could reasonably be expected to be taught in a six week period to enable the student to access the numeracy part of the curriculum in the time frame of the study.

3. Has no visual or auditory impairments that may impair learning but that cannot be corrected by glasses or hearing aids.

6.4 Please provide clear exclusion criteria:

1. Has multiple gaps in the prerequisite skills part of the curriculum than cannot be addressed in six weeks.

2. Has visual or auditory impairments that may impair learning and cannot be corrected by glasses or hearing aids

6.5 Please detail **how** participants will be recruited to the study:

To include:

- *How participants will be identified/screened and approached; by whom?*
- *Where participants will be recruited from and when?*
- *Detail the source of any personal information that may be used to identify participants. If this information will be accessed by someone outside the team who would have access to this information as part of their day to day role, the reason for this should be explained, and permissions detailed e.g. healthcare, student records etc.*
- *Will any vulnerable groups be recruited?*
- *What materials will be used to recruit participants- please provide copies of posters, leaflets, invitation emails, etc.*
- *Where will the above materials be advertised: list and provide details of locations, websites, social media etc.*
- *Will any recruitment tools be used e.g. SONA- please specify and provide details.*

The school's Assistant Head and Maths Lead will decide on the list of students from the primary and secondary departments who meet the inclusion and exclusion criteria. Parents of the students included on the list will be sent a study information sheet and consent form to read. Magdalena Apanasionok will be available to answer all potential questions. A translator will also be available for parents for whom English is not a first language. Students whose parents sign the consent form will be assessed using the ABLLS-R and TEN-DD R bespoke assessment and randomly assigned to either an experimental or control group.

SECTION 7: INFORMED CONSENT

7.1 Please detail the process for obtaining informed consent.

*Informed consent **must** be obtained prior to the participant undergoing any research activities that are specifically for the purposes of the study. This should involve discussion with potential participants or their legally acceptable representative; the presentation of written materials e.g. participant information leaflet(s) –PIL(s) and consent form, and the opportunity to ask questions.*

To include:

- *How and when informed consent will be obtained- written, verbal etc. provide details and justification. Justification must also be provided if informed consent will **not** be sought or if consent will be assumed (please note this needs to be appropriate to the study type).*
- *Who will be taking consent? What training has been undertaken for this?*
- *When and how potential participants will be issued with the information leaflet, in what format and how long they will be given to consider taking part?*
- *Does the study involve children- if so, will consent be obtained from parents, if not provide clear justification why not.*
- *Are the informed consent materials appropriate for the target audience- consider age / language / literacy levels / cultures etc.*

Parents of students who will be listed by the School's Assistant Head and Maths Lead as meeting the study's inclusion and exclusion criteria will be sent a study information leaflet and consent form to review at home. Parent will have an option to come to the school to talk to the Maths Lead and Magdalena Apanasionok or to talk to them on the phone. A translator from the school will also be available for families for whom English is not a first language. Both the information leaflet and consent form will be written in plain English and will avoid research jargon. If the parents do not return the consent form within one week they will be contacted by 'phone by a member of the school's staff to offer more clarification.

Informed consent for students' participation in the study will be obtained in writing either in person (after talking to Maths Lead and Magdalena Apanasionok) or will be sent to parents and returned to the school.

Due to the nature of needs of the participants, informed consent will be obtained only from the parents. Children are not being tested directly, and so their assent to take part in research testing is not relevant.

7.2 Please detail how participants withdraw from the study if they have requested to do so.

The process by which an individual can withdraw their participation from the study without giving a reason or experiencing any detrimental effects e.g. should they not wish to continue with their participation in an interview or focus group.

To include:

- *Consideration for any data already collected up until this point- whether it is possible for this to be removed. E.g. it may not be possible to identify data once submitted for an anonymous survey. This needs to be clear in the participant information leaflet (PIL).*
- *Researchers should specify up to what point participants can withdraw their data from a study and **how** a participant would request this- this also needs be clear in the participant information leaflet (PIL).*
- *Consideration should be given to when data will be anonymised, analysed, published etc. make sure it is possible/feasible for data to be withdrawn if this is being offered to participants. It may be appropriate to provide a time frame for withdrawal.*

Particpants' parents will be able to withdraw their children at any point during the study without any consequences. They will be provided with information details in the information leaflet if they decide to do so. However, due to the fact that students' data will be anonymised before being passed on to the researchers, parents will not be able to withdraw their children's data from the study after post-test data collection has finished (July 2020). This is mentioned in the information sheet.

SECTION 8: DATA COLLECTION, USE & STORAGE (DPA 2018 & GDPR)

For projects involving processing of personally identifiable data, please map the data flow to indicate the data controller(s) and data processor(s). This can be submitted as a separate document if necessary, please see accompanying guidance note from the Information Data Compliance Team.

8.1 Does the project involve the collection, analysis or storage of **personally identifiable data**? Yes

*'Personal data' is any information relating to an **identified** or identifiable natural person- a 'data subject'.*

*An identifiable natural person is one who can be identified, **directly or indirectly**, in particular by reference to an identifier (such as a name, an identification number, location data, financial data, opinion, an online identifier), or to one or more factors specific to the **physical, physiological, genetic, mental, socio- economic, cultural, race, religion, trade union membership, political beliefs, medical, gender or social identity** of that natural person.*

If yes, please provide details of what will be collected: Researchers will only have access to an anonymised database containing students' codes, age, sex, diagnosis and numeracy related scores. Hard copies of students' assessments will be kept in Calthorpe Academy in a lockable cupboard to which only the school's staff members have access too. Participants' names will be coded by Calthorpe Academy staff and the codes will only be known to them.

8.2. Does the project involve the collection, analysis or storage of any **personally identifiable special category data** or **criminal offence data**? Yes

Special category data includes personal data which is by its nature, particularly sensitive in relation to fundamental rights and freedoms of individuals such as: racial or ethnic origin, political opinions, religious or philosophical beliefs, trade union membership, genetic data, biometric data (for the purpose of identifying a natural person), data concerning health or data concerning a natural person's sex life or sexual orientation. This type of data merits specific protection as the context of its processing. Failure to handle this data correctly could result in significant risks to the fundamental rights and freedoms of the individuals.

If yes, please provide details of what will be collected and for what purpose: Calthorpe Academy already collects data on students' diagnosis as part of their record system, these data will be shared with the researchers in an anonymised format for the purpose of conducting full analysis of numeracy evaluation data.

What measures are being implemented to reduce or eliminate the risk to these participants' data for the duration of the period that their personal data is collected and stored? Please see accompanying guidance note for more information.

Hard copies of students' assessments will be kept in Calthorpe Academy in a lockable cupboard to which only the school's staff members have access too. All students' names will be coded by Calthorpe Academy and the codes will be only known to them. Researchers will only have access to anonymised data, which will be stored in an encrypted folder on the University's shared server or on an encrypted USB stick.

8.3 Does the project involve the collection or analysis of personal data relating to children under 13 or vulnerable groups? Yes

UK law provides that for data protection purposes an individual aged under 13 years old is considered a child. For the purposes of the GDPR, a child is someone aged under 16 years old, although Member States are able to reduce this age. Please consider Member State law as Parental/Guardian consent will be required for a child participating in the research.

If yes, please provide details of what will be collected:

Data in relation to diagnosis, age, sex and numeracy related assessments scores will be collected by Calthorpe Academy and shared with the researchers in an anonymised form.

For what purpose do you need to process the children's or vulnerable person's data?

These data will be collected by Calthorpe Academy as part of the numeracy curriculum evaluation. Data will then be shared with the researchers and analysed to evaluate the feasibility of the TEN-DD R curriculum.

What measures are being implemented to reduce or eliminate the risk to these participants' data for the duration of the period that their personal data is collected and stored?

Hard copies of students' assessments will be kept in Calthorpe Academy in a lockable cupboard to which only staff members have access to. All students' names will be coded by Calthorpe Academy and the codes will be only known to them. Researchers will only have access to anonymised data, which will be stored in an encrypted folder on the University's shared server or on an encrypted USB stick.

8.4 Who will have access to the study data?

Include individuals internal and external to the University and what level of access they have to the data e.g. anonymised, pseudonymised, identifiable etc.

Please note you will need to hold a University approved data sharing/processing agreement with each third party (external to the University) with whom data is to be shared.

Magdalena Apanasionok, Professor Richard Hastings, Dr Corinna Grindle and Dr Richard Watkins, all from the University of Warwick, will have access to anonymised study data only. No data with students names will be shared with the research team.

8.5 During the project, will data be hosted on any external platforms or use new technology? No

e.g. Apps, online survey tools (qualtrics, Bristol online surveys etc.), recruitment tools (Prolific, SONA etc.), cloud hosting tools.

If yes, please provide details of the system(s) and how they operate:

Have you contacted Information Security (informationsecurity@warwick.ac.uk) regarding whether these technologies will be required to go through the Information Assurance workbook approval process? https://warwick.ac.uk/services/idc/informationsecurity/faqs/purchasingissues/ Select

How and when will the data be deleted and who by?

8.6 Will any research activities be audio or video recorded? No

This needs to be clear in the participant information leaflet and consent form.

If yes, please provide details of what will be recorded, how long it will be kept, how it will be stored securely and how it will be deleted:

8.7 Will data be shared with any organisation external to the University for processing? No

e.g. external transcription services, external statistics support, archiving etc.

If yes, please provide details of the sharing arrangements: clarify whether the data shared will be identifiable, the external organisation to which it will be sent and what contracts/arrangements are in place to safeguard the data and ensure the data processors/controllers will comply with data protection requirements:

8.8 Please detail how, where, in what format and for how long the research data will be stored securely, including on back up storage.

e.g. hard/electronic copies, locked filing cabinets in researcher's office, encrypted files, password protected devices, Warwick servers. Please also consider consent forms here. These should be stored separately to research data.

Hard copies of students' assessments will be kept in Calthorpe Academy in a lockable cupboard to which only staff members have access to. These data will be kept for 3 years as per Calthorpe Academy policy. Researchers will only have access to anonymised data, which will be stored in an encrypted folder on the University's shared server or on an encrypted USB stick. After publication, anonymised research data in electronic format will be kept for 10 years before being destroyed in accordance with University of Warwick Research Data Policy.

Signed consent forms will be stored separately to research data in a lockable cabinet in the Centre for Educational Development, Appraisal and Research (CEDAR) at the University of Warwick and will be kept for 10 years before being destroyed in accordance with University of Warwick Research Data Policy.

8.9 For this project, will data be processed, (to include the collation, collecting, distributing, sharing, accessing, reviewing, amending, deletion) transferred or stored in any Countries outside UK? No

e.g. the use of transcribing service outside the UK , market research company, cloud hosting provider

If yes, please provide details of the country/countries and the collection/transfer/storage arrangements:

8.10 Describe compliance and proportionality measures in place to satisfy the requirements of the Data Protection Act 2018 and the GDPR.

e.g. how will you ensure: fairness and transparency to research participants, data quality, data minimisation (only collect data which is necessary for the purpose(s) of the study), purpose limitation (no further processing of the data for purposes incompatible to those for which it was collected), de-identification of the data as soon as possible, appropriate technical and organisational measures in place to avoid unauthorised access and accidental loss or damage to data etc. Please see accompanying guidance note from the Information Data Compliance Team to help answer this question.

Data on students' age, sex and diagnosis is already collected by Calthorpe Academy as part of their students' records. Numeracy related data will be collected by Calthorpe Academy and trained individuals with no risk or disturbance to the students. Researchers will only have access to data necessary to answer our research questions and evaluate the feasibility of the TEN-DD R curriculum. All data shared with the researchers will be anonymised by the school staff and transferred to an encrypted folder on University's shared server using encrypted USB stick only after the intervention will finish. Hard copies of the students' assessments will be kept in Calthorpe Academy in a lockable cupboard to which only school's staff members have access too.

Signed consent forms will be stored separately to research data in a lockable cabinet in the Centre for Educational Development, Appraisal and Research (CEDAR) at the University of Warwick and will be kept for 10 years before being destroyed in accordance with University of Warwick Research Data Policy.

8.11 Is it anticipated that there will be any future use of the data? No

If yes, please provide details (if known at this stage). This should be clear in the Participant Information Leaflet and on the consent form if there is potential for future use of this data:

SECTION 9: DISSEMINATION

Please describe the dissemination arrangements for the study:

To include:

- *What will happen to the results at the end of the study*
- *Will this study have any pathways to impact? ('Pathways to Impact' are activities designed to ensure any potential impact is realised, measured and evidenced.)*
- *How and where will the results be reported/published?*
- *Are there any plans to notify/debrief the participants of the outcome of the study, either by provision of the publication, or via a specifically designed newsletter, presentation etc.?*
- *If it is possible for the participant to specifically request results from the researcher when would this information be provided e.g. after the Final Study Report had been compiled or after the results had been published?*

Findings of this research will be shared directly with the school and the teaching staff to inform their curriculm planning. The study will also be written up for a peer reviewed journal paper.

SECTION 10: FURTHER INFORMATION (OPTIONAL)

Please provide any further details/information relevant to this application that may aid the ethical review process.
To include:

- *For complex studies with multiple work packages, collaborators or steering groups, applicants may wish to submit a protocol or supplementary documents in addition to this application form detailing the roles and responsibilities of each party.*
- *Projects that require further approvals e.g. HRA approval for research in the NHS may also wish to submit a protocol for review.*
- *Peer review*
- *Patient and public involvement*
- *Flow diagram*
- *Data management plan*

References:
Partington, J. W. (2006). The assessment of basic language and learning skills-revised (the ABLLS-R). Pleasant Hill, CA: Behavior Analysts

SECTION 11: SUPPORTING DOCUMENTS

HSSREC will need to review **all** participant facing documents associated with this application.

There may be more than one type of each document for each study, i.e. multiple participant information leaflets if there are different participant groups, or work packages.

Please specify below, which documents have been submitted with this application (where applicable):

☒ Participant information leaflet(s)
☒ Consent form(s)
☐ Poster(s)/advertisement(s)
☐ Invitation email(s)
☐ Questionnaire(s)/Survey question(s)
☒ Interview schedule(s)/topic guide(s)
☐ Data Collection form
☐ Data flow map
☐ Data Management Plan
☐ Risk assessment
☐ Protocol (optional- needs to be consistent with the application)
☒ Other, please specify: Letter from Calthorpe Academy Headteacher

SECTION 12. SIGNATURES AND DECLARATIONS

The information in this form together with any accompanying information is complete and correct to the best of my knowledge and belief and I take full responsibility for it.

I undertake to abide by the University of Warwick's Research Code of Practice in undertaking this study.

I understand that HSSREC grants ethical approval for projects, and that the seeking and obtaining of all other necessary approvals and permissions prior to starting the project is my responsibility.

I confirm I am familiar with and will conduct my project in line with the General Data Protection Regulation (GDPR) and Data Protection Act 2018 (DPA 2018), reporting any data breaches to the University's Information and Data Director: DPO@warwick.ac.uk.

I understand that I must not begin research and related projects with human participants, their data or tissue until I have received full approval from the relevant Research Ethics Committee of the University of Warwick.

I understand that any changes that I would like to make to this study after receiving approval from HSSREC, require further review. As such they must be submitted to hssrec@warwick.ac.uk before such changes are implemented.

Signature of Applicant: Magdalena Apanasionok **Date:** 11/11/2019

Signature of Supervisor (If applicable): Richard Hastings **Date:** 11/11/2019

Signature of Head of Department: Geoff Lindsay **Date:** 11/11/2019

Note. Your electronic submission should contain signatures (electronic signatures will be accepted) of all relevant parties. Applications without the necessary signatures will be returned

Please send an electronic copy of the application to hssrec@warwick.ac.uk

If you have not already done so, you are strongly recommended to undertake the Research Integrity Online Training Course. All details relating to this course can be found here.

Version 3 17/12/2019

WARWICK
THE UNIVERSITY OF WARWICK

Participant Information Leaflet for primary caregivers (consenting on behalf of themselves and their children)

Study Title:	Teaching Numeracy Readiness to Children with Developmental Disabilities: A Feasibility Randomised Controlled Trial
Investigator(s):	Magdalena Apanasionok, PhD student, Centre for Educational Development, Appraisal and Research, University of Warwick. Professor Richard Hastings, Professor and Cerebra Chair of Family Research, Centre for Educational Development, Appraisal and Research, University of Warwick. Dr Corinna Grindle, Associate Fellow, Centre for Educational Development, Appraisal and Research, University of Warwick. Dr Richard Watkins, Associate Fellow, Centre for Educational Development, Appraisal and Research, University of Warwick.

Introduction

Your child is invited to take part in a research study. Before you decide, you need to understand why the research is being done and what it would involve for your child. Please take the time to read the following information carefully. Talk to others about the study if you wish.

Please ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish your child to take part.

Who is organising and funding the study?

This study will be carried out as a part of Magdalena Apanasionok's Doctoral Dissertation at University of Warwick. Mrs Apanasionok is a recipient of Warwick Collaborative Postgraduate Research Scholarship funded in collaboration by the University of Warwick and Calthorpe Academy.

What is the study about?

Calthorpe Academy is developing a new numeracy curriculum – Teaching Early Numeracy to Children with Developmental Disabilities: Readiness (TEN-DD R) for eligible students in primary and secondary departments. This curriculum consists of two parts. The first part focuses on skills that are necessary for your child to have to access more numeracy-based tasks. Those skills include imitation, matching and general attending. The second part of the curriculum consists of early numeracy skills such as counting and recognising patterns and numbers.

As the first step in starting to test the new numeracy curriculum, Calthorpe Academy has requested researchers from the University of Warwick to support the school with introducing the TEN-DD R curriculum and in evaluating how well children learn with the new curriculum.

Your child is invited to take part in this research project.

What would taking part involve?

This study will involve your child's teacher completing two numeracy and developmental assessments based on their knowledge of your child and observations of your child in class. This will take between 30 and 60 minutes. No assessments will be carried out directly with your child.

Assessments that will be used are 1) the Assessment of Basic Language and Learning Skills- Revised (ABLLS-R) - a tool developed for children with learning disabilities to assess their language and learning skills. This assessment will be completed by your child's teacher based on their knowledge and observations of your child; and 2) TEN-DD R bespoke assessment - a structured interview about your child's numeracy skills conducted with your child's teacher by trained professionals (masters students and/or research assistants). No assessments will be carried out directly with your child.

First, your child's teacher will complete above assessments between December 2019 and January 2020. After that, your child will be randomly assigned (like tossing a coin) to one of two groups - one will access the numeracy curriculum immediately while the other will access it in the next school year. Children not assigned to the new curriculum this year will carry on learning from school's existing numeracy programmes in the meantime. We need to work with some children on the new curriculum and some not so that we can look at whether the new curriculum helps children to learn more. In June and July 2020, your child's teacher will again complete the numeracy and developmental assessments based on observation and the knowledge he/she has about your child. Teachers of all children in both groups (with the new curriculum and without) will complete these assessments.

The TEN-DD R curriculum will be introduced as part of Calthorpe Academy's maths teaching and as such it will be taught during maths lesson's as per the school's timetable. Therefore, there will be no change to your child's routine if they will be assigned to the group accessing the new curriculum this year.

Calthorpe Academy will share information about your child's age and their learning needs with the research team in an anonymised format. This means that your child's name will be replaced with a code by the school and will not be known to the research team.

Do I have to take part?

No. Participation in this study is completely voluntary and if you choose not to take part in the study your child will carry on with the school's regular numeracy curriculum this year. You can also choose to withdraw your child's participation from the research at any time during the study, without giving a reason by contacting one of the research team. Please note that it will not be possible to withdraw your child's data after the data have been anonymised. This is estimated to be in July 2020. Further details about withdrawing from the research study are provided later on in this document.

What are the possible benefits of taking part in this study?

The goal of this study is to see if the TEN-DD R curriculum helps students learn numeracy skills. If it does, your child might improve his/her numeracy skills. The results will also inform school's curriculum planning in the future.

What are the possible disadvantages, side effects or risks, of taking part in this study?

There are no known risks of taking part in this study.

Expenses and payments

Your child will not receive any reimbursement for taking part in this study.

Will my taking part be kept confidential?

Hard copies of the assessments will be stored in a lockable cupboard in Calthorpe Academy. At the end of the school year, Calthorpe Academy will share your child's age, learning needs (e.g., whether they have autism, severe learning difficulties) and assessment scores with the research team. However, all data will be anonymised prior to that, and your child's name will be replaced with a code by the school before being shared with the research team. Anonymised data will then be stored securely in an encrypted folder on University of Warwick server. Data will not be shared with anyone outside of Calthorpe Academy or University of Warwick.

What will happen to the data collected about my child?

As a publicly-funded organisation, the University of Warwick have to ensure that it is in the public interest when we use personally-identifiable information from people who have agreed to take part in research. This means that when you agree for your child to take part in a research study, such as this, we will use your child's data in the ways needed to conduct and analyse the research study.

We will be using information about your child to undertake this study and will act, alongside Calthorpe Academy, as the data controllers for this study. We are committed to protecting the rights of individuals in line with data protection legislation. The University of Warwick will keep anonymised information about your child for 10 years after the study has finished.

Research data will be **anonymised** as quickly as possible after data collection and it will not be possible to withdraw your child's data after this point. This is estimated to be completed in July 2020.

Data Sharing

Your rights to access, change or move your child's information are limited, as we need to manage your child's information in specific ways for the research to be reliable and accurate. The University of Warwick has in place policies and procedures to keep your child's data safe.

The data may also be used for future research, including impact activities following review and approval by an independent Research Ethics Committee and subject to your consent at the outset of this research project.

For further information, please refer to the University of Warwick Research Privacy Notice which is available here: https://warwick.ac.uk/services/idc/dataprotection/privacynotices/researchprivacynotice or by contacting the Information and Data Compliance Team at GDPR@warwick.ac.uk.

What will happen if I don't want to carry on being part of the study?

Participation in this research study is completely voluntary, and if you choose for your child to not take part your child will continue with the school's regular numeracy curriculum. You can also choose to withdraw your child's participation at any time during the study, without giving a reason by contacting Magdalena Apanasionok ([redacted].

Please note that it will not be possible to withdraw your child's data after the data have been anonymised. This is estimated to be in July 2020.

Version 3 17/12/2019

What will happen to the results of the study?

The results of this study will inform future curriculum planning in Calthorpe Academy. The study will also be written up for a peer reviewed educational research journal.

Who has reviewed the study?

This study has been reviewed and given favourable opinion by the University of Warwick's Humanities and Social Science Research Ethics Committee (HSSREC).

Who should I contact if I want further information?

If you have further questions about this study, please contact Magdalena Apanasionok (Centre for Educational Development, Appraisal and Research (CEDAR), University of Warwick, Coventry, CV4 8UW, United Kingdom; email: M.Apanasionok@warwick.ac.uk).

You can also contact study's supervisor – Professor Richard Hastings (Centre for Educational Development, Appraisal and Research (CEDAR), University of Warwick, Coventry, CV4 8UW, United Kingdom; email: R.Hastings@warwick.ac.uk).

Who should I contact if I wish to make a complaint?

Any complaint about the way you or your child have been dealt with during the study or any possible harm you or your child might have suffered will be addressed. Please address your complaint to the person below, who is a senior University of Warwick official entirely independent of this study:

Mrs Jane Prewett - Head of Research Governance
Research & Impact Services
University House
University of Warwick
Coventry
CV4 8UW
Email: researchgovernance@warwick.ac.uk
Tel: 024 76 522746

If you wish to raise a complaint on how we have handled your child's personal data, you can contact our Data Protection Officer, Anjeli Bajaj, Information and Data Director who will investigate the matter: DPO@warwick.ac.uk.

If you are not satisfied with our response or believe we are processing your child's personal data in a way that is not lawful you can complain to the Information Commissioner's Office (ICO).

Thank you for taking the time to read this Participant Information Leaflet

CONSENT FORM

Child Identification Number for this study:

Title of Project: Teaching Numeracy Readiness to Children with Developmental Disabilities: A Feasibility Randomised Controlled Trial

Name of Researcher(s):

Magdalena Apanasionok, PhD student, Centre for Educational Development, Appraisal and Research, University of Warwick.
Professor Richard Hastings, Professor and Cerebra Chair of Family Research, Centre for Educational Development, Appraisal and Research, University of Warwick.
Dr Corinna Grindle, Associate Fellow, Centre for Educational Development, Appraisal and Research, University of Warwick.
Dr Richard Watkins, Associate Fellow, Centre for Educational Development, Appraisal and Research, University of Warwick

Please initial all boxes

1. I confirm that I have read and understand the information sheet (*version 3, 17.12.2019*) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my child's participation is voluntary and that I am free to withdraw my consent for this at any time during the study without giving any reason, without my child's education rights being affected. I also understand that it will not be possible to withdraw my child's data after the data have been anonymised. This is estimated to be in July 2020. ☐
3. I understand that data collected during the study, may be looked at by individuals from The University of Warwick, from regulatory authorities, where it is relevant to my child taking part in this study. I give permission for these individuals to have access to my child's anonymised data. ☐
4. I am happy for my child's data to be used in future research. ☐
5. I agree for my child to take part in the above study. ☐

________________	________________	________________
Name of Child's Parent/Carer	Date	Signature
________________	________________	________________
Name of Person taking consent	Date	Signature

To whom it may concern,

I am writing to confirm that Calthorpe Academy is introducing a new numeracy readiness curriculum (TEN-DD R) for pupils in primary and secondary departments in 2019/20. We have invited Magdalena Apanasionok (who is funded through a joint PhD studentship between the University of Warwick and Calthorpe Academy) to support us with researching the feasibility of implementing this new curriculum over the course of the academy school year, as part of her PhD studies with the University of Warwick. The new curriculum will be implemented in the primary and secondary departments in Calthorpe Academy as a part of an initiative to develop a stronger numeracy curriculum and inform educational practice across the whole school. We have made arrangements to gather numeracy skills data from approximately 30 children, using the Assessment of Basic Language and Learning Skills revised (ABLLS-R) and a TEN-DD R bespoke assessment. Calthorpe Academy staff, along with Mrs Apanasionok and trained professionals (masters students and/or research assistants), will gather the ABLLS-R and TEN-DD R assessment data in December 2019 and January 2020 and then again in June and July 2020. We are happy to support the use of a randomized design to support initial research on feasibility of implementing the new numeracy curriculum.

Calthorpe Academy is happy for data collected from the two assessment tools (ABLLS-R and TEN-DD R assessment) by the school to be accessed and analysed by Magdalena Apanasionok as part of her research project at University of Warwick.

All data will be anonymised for use in this research so that no pupil can be identified.

Yours sincerely,

[redacted]

Head Teacher

WARWICK
THE UNIVERSITY OF WARWICK

Humanities and Social Sciences Research Ethics Committee
Kirby Corner Road
Coventry
CV4 8UW

Monday, 23 December 2019

Mrs Magdalena Apanasionok
CEDAR
University of Warwick
Coventry
CV4 7AL

Dear Mrs Apanasionok,

Ethical Application Reference: HSSREC 33/19-20
Title: Teaching Numeracy Readiness to Children with Developmental Disabilities: A Feasibility Randomised Controlled Trial

Thank you for submitting your revisions to the Humanities and Social Sciences Research Ethics Committee (HSSREC) for consideration. We are pleased to advise you that, under the authority delegated to us by the University of Warwick Research Governance and Ethics Committee, **full approval for your project is hereby granted.**

Before conducting your research it is strongly recommended that you complete the on-line Research Integrity training:
www.warwick.ac.uk/ritraining. Support is available from the HSSREC Secretary.

In undertaking your study, you are required to comply with the University of Warwick's Research Code of Practice:
https://warwick.ac.uk/services/ris/research_integrity/code_of_practice_and_policies/research_code_of_practice/

You are also required to familiarise yourself with the University of Warwick's Code of Practice for the Investigation of Research Misconduct:
https://warwick.ac.uk/services/ris/research_integrity/research_misconduct/codeofpractice_researchmisconduct/

You must ensure that you are compliant with all necessary data protection regulations:
https://warwick.ac.uk/services/idc

Please ensure that evidence of all necessary local permissions is provided to HSSREC prior to commencing your study.

WARWICK
THE UNIVERSITY OF WARWICK

Please also be aware that HSSREC grants **ethical approval** for studies. The seeking and obtaining of all other necessary approvals is the responsibility of the investigator.

Any substantial changes to any aspect of the project will require further review by the Committee and the PI is required to notify the Committee as early as possible should they wish to make any such changes. The HSSREC Secretary should be notified of any minor amendments to the study.

May I take this opportunity to wish you the very best of luck with this study.

Yours sincerely

[redacted]

Dr Fiona MacCallum
Chair, Humanities and Social Sciences Research Ethics Committee