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Teaching early numeracy to students with autism using a school staff delivery model

Magdalena M. Apanasionok, Barah Alallawi, Corinna F. Grindle, Richard P. Hastings, Richard C. Watkins, Gemma Nicholls, Leanne Maguire and Darragh Staunton

Mathematics is one of the core school subjects in the UK and an emphasis is placed on developing pupils' mathematical competencies throughout all key stages. Despite that, the attainment of students with disabilities in mathematics remains low. The current study explored ways in which the Teaching Early Numeracy to children with Developmental Disabilities (TEN-DD) programme could be implemented by teaching staff in a special school in the UK to improve the numeracy skills of students with autism. Adaptations to the delivery of the programme were made during the study as a result of continued collaboration with the participating school. The findings suggest that it may be feasible to implement the TEN-DD programme using a school staff delivery model and it may help learners improve their early numeracy skills. Practical aspects of TEN-DD's implementation highlighted the need to incorporate more systematic adaptations for minimally verbal students, as well as for learners who might need additional training with prerequisite skills.

Key words: **numeracy, mathematics, special educational needs, autism, systematic instruction**

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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 (DfE, 2014a, 2014b). Number is one of the core strands in mathematics in the National Curriculum for England (DfE, 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 (DfE, 2014a, 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, DfE (2019b) data show that 14.9% of all students have special educational needs (SEN). Autism is the most prevalent (29%) 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) (DfE, 2019b). The introduction of the Equality Act 2010 (DfE, 2014c) and the Special Education Needs and Disabilities Code of Practice (DfE, 2015) 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 students with disabilities and assess the progress of all learners in the core academic areas, including mathematics. Additionally, schools were required to make decisions about education for students with disabilities based on the best available evidence.

Despite this policy shift, the attainment of students with autism 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 students with autism, especially those who also have an intellectual (learning) disability, are likely to be considerably lower.

Grindle et al. (2020) suggests five possible reasons why students with disabilities (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 students with autism;
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 students with autism 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).

1. 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 students with disabilities (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, typically developing 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 students with autism due to the complexity and length of the instructions and targets. Available evidence suggests that students with autism can benefit more from teacher-led/direct instruction as opposed to child-led/enquiry teaching (Apanasionok et al., 2019; 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 children with autism (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 model. Tzanakaki et al. recruited 24 students with severe intellectual disability 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.

2. 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 teachers' and teaching assistants' suggestions on improvements to the provided training and implementation of the TEN-DD programme.

3. 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).

3.1. 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, second and third 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 the first and second authors). 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 teacher and TA had a weekly in-class session with one of the two researchers/trainers (the first or second author). 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 teaching staff 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 teaching staff were ready to move to a less frequent mentoring schedule, a set of criteria was developed:

1. The trainer is not reminding the teacher/TA what they should be doing more than once during the session.
2. The teacher/TA 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 teacher/TA is updating the targets on the target list and prepares new data sheets as needed.
5. The teacher/TA indicates that they feel ready to receive less support when asked.

Once a teacher/TA 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. At the end of the session, the trainer provided the teacher/TA with feedback on that session based on the completed

record, and discussed what went well and what could be improved. After the teacher/TA and the trainer agreed on an action plan, they both signed the paper record. The bi-weekly visits were carried out by one trainer (the first author) to ensure consistency.

3.2. 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 bi-weekly 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) 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 a teacher or TA 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 (teacher/TA 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 teacher/TA 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 – teaching staff were asked to take data only on the first try of the session for each current target. They scored a trial as correct (by putting a tick on a datasheet) 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 non-verbal response equivalent guidelines in their teaching packs (folders; see 'Materials' section) that provided examples of adaptations that could be made to facilitate responses of minimally verbal students for all six key topics. Further adaptations were made by the teaching staff after consultations with the trainers.

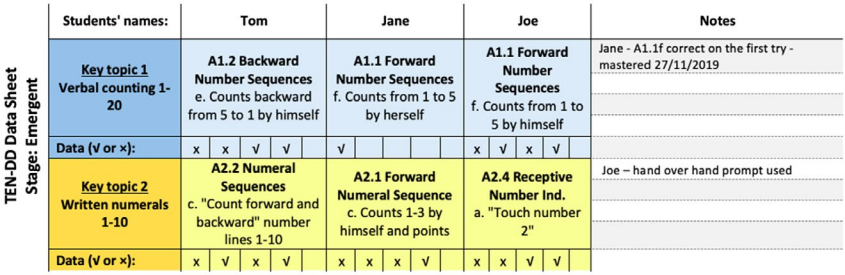
3.3. Materials

All teachers and TAs working on TEN-DD were given a folder with all the necessary information and a resource kit. Folders contained the TEN-DD framework, a suggested session structure, the teaching plans, suggested response equivalents for minimally verbal students, a DTT information sheet, suggested entry (warm-up) activities, a DTT data sheet (to collect individual data for up to three students; see Figure 1), a skills tracker (list of all targets covered in the programme to record introduction and mastery dates), a copy of a bespoke mentoring checklist (a task analysis of all steps that the teaching staff should do during one TEN-DD session), 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 (number lines 1–10; number 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.

3.4. 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

Figure 1: Sample DTT data sheet [Colour figure can be viewed at wileyonlinelibrary.com]



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 √ √	

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.

4. Evaluation study

Approval was sought and obtained from the Humanities and Social Sciences Research Ethics Committee at the University of Warwick.

4.1. 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 teaching staff 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. Ten teaching staff (six females, four males; five teachers, five TAs) agreed to take part in an interview.

4.2. Setting

The study took place in a special school in the UK, catering for around 380 children aged two to 19 years with severe intellectual disabilities. Students attending the school have diagnoses of intellectual disability, autism, or profound and multiple intellectual disabilities, 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.

4.3. 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. 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. 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., forthcoming).

4.4. 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).

5. 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 1 for individual students' outcomes.

Teaching staff had a generally positive training experience (see Table 2). Ratings of the data collection training session were also positive (Table 3).

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.

6. 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.

6.1. 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

Table 1: Summary of students' TEMA-3 scores at pre- and post-test

Student no.	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

Table 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 the TEN-DD programme in a 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-DD programme.	4.09
	I understand the rationale of using the TEN-DD programme.	4.18
	I understand what TEN-DD aims to do.	4.27
	I understand how to use the TEN-DD 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 student.	4.18
	I understand what Discrete Trial Teaching (DTT) is.	4.45
	I will be able to follow the trial structure of Discrete Trial Teaching (DTT).	4.36
	I understand what TEN-DD generalisation sessions aim to do.	4.20
	Training in a small group outside the classroom is useful for learning how to use the TEN-DD programme.	4.18
	Mean	**4.17**

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.

Table 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-DD weekly data sheet was clear and useful.	4.79
Trainers	Trainers presented the data collection procedure in a 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 the 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 are.	4.77
	I will be able to make decisions about students' targets.	4.64
	I understand the process of mentoring visits.	4.71
	Overall mean	**4.69**

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 teaching staff 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 minimally verbal students was challenging at times. We provided a document outlining possible ways of adapting teaching plans to meet

Table 4: Summary of changes to the TEN-DD curriculum suggested by teaching staff

Category	Suggested change	Example comment	No. of staff
1. Training	Break down the initial training session into a few separate sessions	*'… 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 teaching staff familiarise 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	*'… 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 …'*	2
	Move more quickly 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 … so that's something I would change'.*	1

(Continues)

Table 4: (Continued)

Category	Suggested change	Example comment	No. of staff
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 teaching staff members	*'It's not all the target, it's just some of the targets, understanding exactly what is required … maybe some of the interpretation … [pause] so that's little bit more understandable – understandable [yeah]'.*	3
	Make targets more realistic/ as they would be done by the general population	*'… maybe some of the targets are unrealistic to special needs kids because I think as a person with no special needs … 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 are required to complete	*'Again, paperwork isn't – well not all TAs but a lot of TAs don't like paperwork I would say … 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

(Continues)

Table 4: (Continued)

Category	Suggested change	Example comment	No. of staff
	Include prerequisite targets for students that don't 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	*'… The folder again is a big folder with a lot of reading which – and … 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 [name of first author] 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 minimally verbal students	*'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 number 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 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'.*	3

the needs of minimally verbal students, and the trainers helped teachers and TAs 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 autism 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 minimally verbal students, 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.

6.2. 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.

6.3. 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).

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Address for correspondence:
Magdalena M. Apanasionok
Centre for Educational Development, Appraisal and Research (CEDAR)
University of Warwick
Coventry CV4 8UW
UK
Email: M.Apanasionok@warwick.ac.uk

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