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

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There is a large science attainment gap between students with and without special educational needs, and many students with developmental disabilities (DD) struggle to access the mainstream science programmes of study. The purpose of the present project was to pilot the use of the Early Science (ES) curriculum over a six week period with nine students with moderate to severe DD in a special education setting in the UK. Staff members indicated positive experiences of using the curriculum, especially the use of the structured teaching methodology as a helpful tool. Evaluation data suggested that all nine pupils improved their science knowledge over the course of the intervention. Some suggestions are made to improve the delivery of the ES curriculum in UK special education settings, and the need for larger scale evaluation research.

***Key words*: science education, Early Science curriculum, developmental disabilities, intellectual disability, autism spectrum disorder.**

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The Department for Education (2014c) 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 disabilities (Department for Education, 2014a). Furthermore, the Special Educational Needs and Disability code of practice advocates for practitioners to select teaching methods based on available evidence (Department for Education, 2015).

In England, 14.4% of school age children have special educational needs (SEN) (Department for Education, 2017a). 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 an Education, Health and Care (EHC) plan or a statement (pupils with additional needs that cannot be met by the school alone). Moderate learning difficulties (i.e. mild to moderate intellectual disability in the international terminology) are most prevalent among students with SEN support and autism spectrum disorder 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 achieving the expected level in Key Stage 1 (4–7 years). In 2014, the gap was 47% (Department for Education, 2017b). O nly 24% of students aged 4–7 years with an EHC plan or a statement achieved the expected level in science (Department for Education, 2014b).

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 developmental disabilities (DD) in particular (i.e. those with intellectual disability and/or autism spectrum disorder) indicates that a behavioural teaching approach may be effective. Spooner *et al*. (2017) in their review of evidence-based practices for teaching students with severe disabilities identified systematic instruction,a teaching approach based on behavioural principles, as an effective approach to teach range of skills, including academics. The majority of published research on teaching students with severe disabilities focuses on literacy and mathematics but there are 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 standards (in the USA) to a population of 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 benefit especially from teaching procedures like errorless learning and time delay. Spooner *et al*. (2011) conducted a systematic review on teaching science (based on standards in the USA) to students with severe DD. Seventeen studies published up to 2009 were identified. All used systematic instruction teaching methodology and Spooner *et al*. (2011) concluded 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 as a result of inquiry-based instruction, 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) 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 (students regulating and directing their own learning) and comprehension based instruction (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) concluded that systematic instruction in particular is a promising method to teach science to students with DD.

The Early Science (ES) curriculum (Jimenez *et al*., 2012) uses systematic instruction approaches and has been used in several studies included in the existing systematic reviews. The ES curriculum covers content that aligns with the science education standards in the USA for elementary age students (5 to 11 years old) 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: guided inquiry, scripts, a Wonder Wally storybook (a set of stories with pictures to accompany each lesson of the unit), science safety (related to practical activities), 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, task analysis (breaking down a complex task into smaller steps) and special accommodations/adjustments for the students. Lessons should be repeated multiple times but not more than five times. Based on students' performance at short quizzes completed at the end of each session, the teacher decides 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*. (2013) taught science skills and knowledge using the ES curriculum to 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 as a result of the curriculum implementation. Students answered more questions correctly during assessments for all four units after the intervention was introduced and maintained their scores for most units over time (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 ASD 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% and the teacher reported preferring 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 ASD 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, researchers recorded data on the duration of the lessons and the number of sessions that the students needed to reach the mastery criterion and concluded that 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), there are no available published comprehensive curricula utilising this methodology to teach science to this population 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

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 spectrum disorder (ASD), intellectual disability (ID) and profound and multiple intellectual disabilities (PMID) among others. Nine students (see Table 1) from one primary class took part in the project. To ensure students' confidentiality, pseudonyms have been used.

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 chart (see later for a full description) and a science safety rule poster. Four staff members took part. The Head

Table 1. Summary of students' characteristics

Student	*Sex*	*Chronological age*	*Primary label*
Tom	Male	8 years 9 months	ASD
Sam	Male	7 years 8 months	Severe ID
Harry	Male	9 years 9 months	Severe ID
Peter	Male	9 years 3 months	PMID
Steve	Male	10 years 0 months	ASD
Daniel	Male	10 years 7 months	Severe ID
Larry	Male	9 years 7 months	Severe ID
Ben	Male	9 years 7 months	Severe ID
Ann	Female	9 years 5 months	Severe ID

of Science in the school (the second author) 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 the 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 (first author) 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 conceptsand the predictions that they made before conducting the enquiry task. The remaining time was spent on students reviewing key concepts targeted during the lesson and completing 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 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. The training lasted around 30 minutes and included the use of scripts, the time delay procedure (prompt/help for the student is delivered following a specific amount of time after the instruction), 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 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, informal interviews were conducted by the evaluator 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 2.

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 is the only known to her evidence-based science curriculum that is suited to meet the needs of her students. 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 were 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 more knowledge-based curriculum as opposed to the school's usual sensory approach.

Table 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

Staff feedback indentified 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 with the science teacher noting 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 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 challenging behaviour, was not able to take part in the project. This placed an additional demand on the sciene 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 enquiry-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 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.

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