The Thinking Frames Approach: A case study of inclusion using student-generated multiple representations

Abstract

Many teachers struggle to provide equitable opportunities for students with special educational needs (SEN) to learn science concepts in the inclusive classroom. This study examines the experience of teaching in an inclusive classroom using a conceptual change approach, the Thinking Frames Approach (TFA), incorporating the use of discrepant events, social construction of scientific conceptions followed by the production of multiple student-generated representations of their understanding. An in-depth case study is presented of the experience of Wayne, a student with complex SEN and the effect on his behaviour and science learning based on video/audio recordings of lessons, teacher journal entries, student artefacts, questionnaire results and interviews. It was found that there were positive effects for Wayne's learning using this approach including improved behaviour, greater feelings of self-efficacy, increased participation in small group and class discussions and improved outcomes on the same assessment tasks as peers. It is suggested that the structured approach of the TFA, the communication of understanding in different modalities, particularly drawing, and the support of peers enabled Wayne to more deeply engage in construction of understanding and may provide teachers with an easy and effective approach to authentic inclusion where real conceptual gains are made by all students.

Keywords

inclusive classroom, student-generated multiple representations, social emotional behavioural difficulties, small group interactions

This study arose from a two-year intervention studying the implementation and efficacy of a conceptual change strategy, the Thinking Frames Approach (TFA), in my grade 8-10 classrooms. Some of those classrooms included a number of students with special educational needs (SEN), including those with social, emotional and behavioural difficulties (SEBD). One of the unexpected results of the implementation of the TFA in my classroom was that I began to observe that students with SEN were able to fully participate in construction of conceptual understanding without any modifications of the approach and with little extra input from Special Education Learning Assistants (SELAs). An in-depth illustrative case study of Wayne's experience, a student with complex SEN who had significant SEBD, is presented in order to gain understanding of the changes in cognitive, emotional and behavioural outcomes that he experienced.

In the Australian educational context students who are classified as having SEN, including SEBD or learning disabilities (LD), can be educated in fully inclusive classrooms, partially included or placed in separate special schools (ACT-Government, 2018; Forlin, Chambers, Loreman, Deppeler, & Sharma, 2013). The Australian Disability Discrimination Act (1992) led to the development of Disability Standards for Education (2005) which 'require education and training service providers to support the rights of students with disability to access the curriculum on the same basis as students without a disability. Students with disability are entitled to rigorous, relevant and engaging learning opportunities drawn from age equivalent Australian Curriculum content on the same basis as students without disability' (ACARA, 2016).

Within schools, evidence must be provided for students to be classified as having one or a combination of disabilities or disorders (ACT student disability criteria, 2016). On the basis of this evidence and in consultation with the caregivers, the special education teacher and the classroom teacher, Independent Learning Plans (ILP) are produced which guide teachers in making adjustments to teaching based on the students' needs (AITSL, 2017). Depending on the funding available, the school may provide SELAs to work in some of the classes of which a student with SEN is a member.

Teachers are encouraged to act as agents of social justice (Pantić & Florian, 2015) to bring about inclusion of students with special needs in the mainstream classroom involving both social inclusion and 'active engagement' with the learning taking place in the classroom (Cooper, 2004, p. 219). This involves all students having opportunity to express insights, purposefully connect understanding and experiences and cognitively engage with peers as they build their social and cognitive capabilities (ACARA, 2016; Bennathan & Boxall, 2003). Too often, however, the physical presence of a student with special needs in a mainstream class is equated with inclusion without ensuring full participation by authentically addressing social, emotional and cognitive aspects of learning (Monsen, Ewing, & Kwoka, 2014; Polat, 2011).

Some of the challenges of inclusion of students with special needs within general classrooms are the attitude of the teachers to inclusion (Monsen et al., 2014), the effective implementations of strategies which will support these students' success in the class (Kurth & Keegan, 2014), and the teachers' beliefs about the students' capacity to succeed (Cook, Cameron, & Tankersley, 2007). In particular, the behavioural challenges displayed by some students with special needs, particularly those with social, emotional and behavioural difficulties (SEBD), has been shown to result in teachers giving these students less praise, constructive critical feedback and higher order questions than other students (Cook et al., 2007). Likewise, these students are more likely to receive negative attention from the teacher related to their behaviour rather than feedback about their learning (Cook et al., 2007) and teachers are much less likely to willingly include students with SEBD in their classrooms (Monsen et al., 2014). Students with SEBD are also more likely to require modified curriculum since they may find relating productively with peers and following classroom prompts challenging and may be at risk of exclusion (Michail, 2011; Rosenberg, Wilson, Maheady, & Sindelar, 2003).

While many teachers are positive, in principal, about inclusion of students with SEN within their classrooms, the difficulties presented to a teacher in managing the learning needs of a widely diverse group of students cannot be overestimated (Avramidis & Norwich, 2002; Brackenreed, 2011; Crombie, 2012; Westwood & Graham, 2003). Without adequate support within the classroom teachers are more likely to develop negative attitudes towards inclusion and this has a significant impact on the existence of a positive and cohesive learning environment (Monsen et al., 2014). The lack of research on effective approaches to teaching science which would support the learning of students with SEN or the limited description of how research into effective interventions may be translated into practice means that teachers are left without guidance or support on how to produce a unit of work which gives opportunities to students with many and varied needs to learn science and become scientifically literate citizens (Hott, Berkeley, Raymond, & Reid, 2018; Palincsar, Magnusson, Collins, & Cutter, 2001).

Students with SEBD may feel powerless to learn and excluded within the classroom, often believing that the teacher is victimising them (Cefai & Cooper, 2010). Of particular concern is the tendency of teachers to underestimate the capacity of students with SEN,

particularly those with SEBD, to achieve compared to their expectations for other students in the classroom (Carlisle & Chang, 1996; Scanlon & Barnes-Holmes, 2013). For instance, students with SEBD frequently present disruptive and off-task behaviour in the classroom which results in a low level of achievement and engagement with tasks which reduces teachers' belief in the possibility for academic success (McKinney, McClure, & Feagans, 1982; Scanlon & Barnes-Holmes, 2013). This may result in teachers providing extensive modifications to the content and assessment tasks based on a student's prior poor achievement, which may be related to their behavioural challenges rather than their cognitive abilities (Cho & Kingston, 2013).

Recommendations from the literature suggest that lessons supporting students with SEN should be made up of evidence-based 'active, teacher-directed' components, giving students clear objectives, breaking down learning into manageable chunks and providing multiple opportunities for practice and timely feedback (Westwood, 2018, p.10). The use of small peer group interactions to support both cognitive and social gains amongst SEN students, however, stands out as being a powerful pedagogical approach which requires less dependence on additional support staff (Nind & Wearmouth, 2006; Thousand & Villa, 1999). For instance, Belland, Glazewski and Ertmer (2009) found that middle school students with SEN who worked with mainstream students in supportive small groups were more motivated to engage effectively and had greater confidence when participating in Project Based Learning.

In the science classroom, there is some concern expressed in the literature that constructivist approaches may not be the most beneficial for learning for many students with SEN due to the need for higher order thinking skills (Apps & Carter, 2006). Inductive and deductive reasoning may pose difficulties for students with SEN, particularly those with LD (Mastropieri, Scruggs, Boon, & Carter, 2001). Similarly, learning of the extensive and unfamiliar vocabulary associated with science topics creates further challenges for these students (Scruggs, Mastropieri, & Boon, 1998). Discovery learning, for instance, where students draw out and synthesise concepts from a number of experiences, was found to be very challenging for students with SEN (Scruggs & Mastropieri, 2007).

Research evidence, however, has shown that constructivist approaches in science learning can be successful for students with SEN, in terms of conceptual gains and improved behaviour, if certain supporting aspects are also provided, such as peer support (Belland et al., 2009; Jimenez, Browder, Spooner, & Dibiase, 2012) and scaffolding of learning through guided instruction (Jimenez, Lo, & Saunders, 2014; Lynch et al., 2007; Therrien, Taylor, Hosp, Kaldenberg, & Gorsh, 2011). Peer support is a frequently studied mechanism for providing guidance (Jimenez et al., 2012; Mastropieri et al., 2006). For instance, support from peers through indirect or higher order questioning (Scruggs & Mastropieri, 2007) or when teachers guided students to co-construct knowledge with peers and made students' alternative conceptions visible in inquiry classrooms (Dalton, Morocco, Tivnan, & Rawson Mead, 1997) resulted in gains in conceptual understanding for students with SEN. However, a cross-case analysis of a number of different inquiry strategies confirmed the difficulty that many students with LD have with adopting science process knowledge (McGrath & Hughes, 2017).

A promising approach to addressing some of the concerns raised has been the development of a student-centred approach to differentiation known as Universal Design for Learning (UDL) (Meyer, Rose, & Gordon, 2014). Rather than producing individualised programs to address students' learning disabilities, this approach focuses on making learning more accessible for all members of the class, including those with SEN (CAST, 2019). The

general guidelines suggested by UDL include using multiple representational modes for presenting concepts and knowledge, giving learners a variety of different methods of presenting their understanding and using a number of different means to engage students' interest and increase motivation (CAST, 2019; Meyer et al., 2014). The studies that have been carried out so far into the effectiveness of the application of UDL principles have shown some improvement in learning outcomes for students with SEN, improved student engagement and self-efficacy and a perceived reduction in workload for teachers (Al-Azawei, Serenelli, & Lundqvist, 2016).

In terms of providing students with a variety of different methods of communicating their learning and understanding, as suggested in the UDL, the use of multi-modal *student-generated* representations, particularly drawings, has been recognised as being a powerful tool for students to learn science (Ainsworth, Prain, & Tytler, 2011). However, this methodology has not been studied extensively for students with SEN. Student-generated drawings have been used in other subjects. For instance, a study of middle school students who were struggling readers found that producing drawings of what they read helped these students with comprehension (Hibbing & Rankin-Erickson, 2003). Another study of grade 8 students with LDs showed improved problem solving of word problems in mathematics when students were taught to draw diagrams (van Garderen, 2007).

Many strategies supporting inclusion often assume that the classroom teacher will be working closely with a special education co-teacher or assistant. However, it was found that when the support was withdrawn teachers may not be willing to continue using the strategy (Katz, 2015; Mastropieri & Scruggs, 2001). The complexity of concepts addressed and the pace at which topics are covered in the secondary science classroom present additional challenges to teachers in authentically including students with SEN within their classes (Mastropieri & Scruggs, 2001). What strategies can the teacher use in the science classroom when a special education co-teacher or assistant is not available, as is often the case? This research investigates this question and the effects of using the TFA on students' learning and social inclusion.

Method

Study Design

This study was part of a larger two-year explanatory sequential mixed-methods (Creswell, 2014) research investigating the effects of the TFA, in grades 8-10, as implemented in the teaching of a variety of science topics. As data was analysed it became clear that there were unexpected effects for students with SEN. This is an illustrative case study (Yin, 2009) of a SEN student's and my own experiences learning with the TFA and its support for inclusion. An ethnographic approach is taken based on classroom observations, quantitative data from tests and pre/post teaching questionnaires, student artefacts and the student's own reflections in semi-structured interviews collected over a one year period where several science topics were taught using the TFA.

Setting

The school was a moderate fee, faith-based co-educational private school in Australia. The majority of students had a mid-range socio-economic status for the region, according to government statistics. The grade 8 class included students with a wide range of abilities and was made up of 25 students. The general education students mostly had positive attitudes to inclusion. However, students were wary of interacting with Wayne, due to his volatility and past

experiences where he had been aggressive towards them. The study commenced when ethics approval was granted and informed consent was obtained from all participants.

Participant

In the first year of the study the grade 8 TFA class had three students with SEN present. This study focuses on Wayne (pseudonym) who was a student with significant and complex SEN: ASD, OCD and challenging behaviour and was on a variety of medications. He was also considered to have learning disabilities due to compromised oxygen levels during a difficult birth. Prior to this study, Wayne's behaviour was very impulsive and he could easily spiral out of control when he became frustrated with other students or felt that he could not understand or express himself. If he became disengaged in class, he would either become vacant and unresponsive or become disruptive and aggressive with other students and he frequently needed to be supported to stay on task. Care needed to be taken to ensure that Wayne did not assault other students. His unpredictable behaviour meant that he was sometimes not included in practical tasks to protect himself and other students.

In most classes, his work was modified in order to give him achievable goals. Teachers generally had low expectations of what Wayne was able to achieve. In the previous year, he was given an alternative report in science due to low grades in tests and limited completion of tasks. His National Assessment Plan – Literacy and Numeracy (NAPLAN) standardised test scores were the lowest in the class. Because of Wayne's frequent aggressive behaviour he was often removed from classes and had many absences. He also had few friends because other students were wary of interacting with him.

Wayne rarely contributed to classroom discussions and when asked for his ideas he frequently indicated that he had been thinking of other things. Wayne also resisted completing tasks, particularly if they involved writing. His parents were supportive of him and teachers, but were embarrassed by Wayne's aggressive behaviour with other students. His mother tried to help Wayne to complete school tasks at home. However, he was often frustrated and aggressive and refused to co-operate.

The Thinking Frames Approach

The TFA was developed in the UK by the Cams Hill Science Consortium (CHSC) of teachers and researchers for use with students in primary and lower middle school (Newberry & Gilbert, 2007). The TFA is a systematic approach which makes use of cognitive conflict strategies to make students' alternative conceptions visible and challenge those conceptions. It combines this strategy with social construction of conceptual understanding. Students predict the outcome of carefully designed demonstrations in heterogeneous small groups, then present their explanations to the class. After observing the outcome of the demonstration, they return to their group to revise their explanations. This section of the lesson follows the Predict-Discuss-Explain-Observe-Discuss-Explain strategy (PDEODE) (Demircioglu, 2017) as students work in their small group of peers to build verbal scientific explanations based on their observations. Teacher questioning encourages them to apply the scientific ontological model to the observed phenomenon. Students then work together as they each construct multiple representations of their understanding, by choosing vocabulary which will help answer the question and production of verbal, pictorial and written explanations using a structured worksheet (Newberry, Gilbert, & Consortium, 2011). Students evaluate their written explanations against a 'Levels Mountain'

rubric (Newberry, Gilbert, & Hardcastle, 2005) where level 1 is a simple description, level 3 is simple cause and effect and level 5 is an elaborated causal explanation using scientific vocabulary and adoption of the scientific model. The teacher also provides rapid, constructive feedback. A series of TFA lessons builds understanding of the ontological model underlying the phenomenon.

Thinking Frames Approach lessons

Some examples of topics and lessons taught using the TFA and the driving questions used are summarised in Table 1. Each lesson was of 50 minutes duration. Students were placed in heterogeneous small groups chosen based on my knowledge of the relationships and prior attainments of students. Particular care was taken in choosing groups to ensure that peers of students with SEN had a positive attitude to inclusion and would be willing to support that student. Students stayed in these same small groups throughout the year.

Table 1 TFA lessons for grade 8

Unit	Lesson Topics	Guiding Questions
Cells and body systems	Surface area to volume ratio	Why do cells need to be so small?
	Cell structure and function	Why do cells have different structures from one another?
	Mitosis	How do our bodies grow and repair?
	Digestive system	Explain how different types of cells and organs enable the digestive system to do its job
	Respiratory system	Explain how different types of cells and organs enable the respiratory system to do its job
Plants	Dispersal of seeds	Explain how plants can travel from one area to another. What is the benefit to them?

Experimenter

As the teacher/researcher, with 10 years' experience, I introduced the TFA to my grade 8 students. While I was committed to inclusion and worked to provide learning opportunities for all students within my class, I often felt that my efforts were inadequate for the task. I frequently relied on the help of SELAs to work with particular SEN students. There was a SELA present for one or two lessons out of four to five lessons per week to work with Wayne and other students with SEN. The SELA frequently gave one on one support, sitting separately with Wayne and guiding him in completing work through verbal questioning, directing his attention to questions and eliciting verbal responses before encouraging him to write answers. When the SELA was absent, I spend some part of each lesson working individually with students with SEN, providing support and direct teaching as required. Like many of my colleagues, I found there was little guidance to teachers about how to successfully include students with SEN in the science classroom from special needs coordinators.

Data and Analysis

Videos and audio recordings of TFA lessons were obtained and Wayne's participation noted. Wayne was interviewed at the end of the teaching period and his responses transcribed. TFA worksheets were collected and written explanations were analysed. Students also completed a five point scale, 56 item questionnaire (Kind, Jones, & Barmby, 2007; Pell & Jarvis, 2001)

probing attitudes towards science and student self-efficacy in writing, understanding and explaining scientific concepts at the beginning and the end of the year. I kept a journal of my reflections and observations teaching with the TFA. Corroboration of my observations of Wayne, his learning, behaviour and participation were obtained from the SELA who was present.

Results

Wayne's experience of learning using the TFA was very different from his previous classroom experience. Rather than Wayne sitting separately from other students as had been his habit, he was encouraged to fully participate in the TFA lessons. He was placed in a small group willing to encourage his participation, although they were wary at first because of his unpredictable behaviour. Initially, when he became inattentive his peers prompted him to return to his task. He also looked at his peers' work and was able to follow along with the TFA process. As he became familiar with the TFA process, he was observed engaging in the PDEODE aspect of the TFA by listening carefully and later expressing his own ideas. As the year progressed, he was observed more frequently putting up his hand and volunteering explanations to the whole class. For instance, one day he put up his hand after other students had put forward their ideas and volunteered an excellent answer to a question about respiration.

> *Teacher's Journal:* This was quite a breakthrough for him as he generally wouldn't feel comfortable answering a question when everyone else had not really known the answer.

Being able to contribute to group and class discussions built relationships within his small group as his responses became more valued. The other students recognised his improvement in conceptual understanding and became more at ease with including him in the group.

Wayne particularly enjoyed the body systems unit, using the TFA, and he found that drawing his ideas helped him to stay focused and motivated. He became so engaged in these tasks that he even completed two extra TFA worksheets at home for other body systems than the ones that had been set in class. His mother commented that he was very focused on working on these tasks at home whereas he generally refused to do homework and could become very aggressive when asked to do so.

Both the SELAs and I noted a marked decrease in aggressive behaviour and no incidents of him hurting other students after beginning with the TFA were reported. The frequency of having to call his attention back to the task in hand also reduced dramatically. He became able to participate fully in science classes, including practical tasks and as a result of his greater engagement, no modification of content or conceptual level was required.

Wayne's responses to the questionnaire given before and after learning with the TFA are shown in Table 2. He displayed improved interest in learning science in school, self-concept and self-efficacy in science, all of which moved from negative (<3) to positive (>3) and his overall attitude toward school improved although it remained somewhat negative. The only questionnaire score that decreased over this period was his belief in his ability to write explanations.

Table 2 Mean results from questionnaires given before and after teaching

Questionnaire topic (no of items)	Mean Likert score	
	February	December
Learning science in school (6)	2.2	3.7

Self-concept in science (7)	2.3	3.4
Attitude to school (8)	1.6	2.6
Self-efficacy in science (6)	2.8	3.3
Writing explanations (3)	3.3	2.7

Wayne completed the two topic tests given to other students without modification during semester 1, one on cells and the second on body systems. He achieved a score of 41% on the cells test and a score of 60% on the body systems test, receiving an overall grade of 60% at the end of Semester 1. In the second semester, he achieved 60% on a states of matter test after learning using the TFA. His end of semester grade was 65%. This was a remarkable improvement on his science grade from the previous year when he had only completed one assessment task at the same level as other students, a test on which he obtained 54% and his overall mark was 9%.

In interviews after learning with the TFA, Wayne expressed that he loved science classes. This had not been the case before learning with the TFA, as evident from his negative responses to the questionnaire given at the beginning of the year (Table 2, Attitude to science in school). When he returned to school after being hospitalised at the end of Semester 1, he began part time at first and he chose to attend science classes in particular. His behaviour in other classes continued to be aggressive and challenging and most teachers continued to modify his tasks.

Wayne's written response to the first TFA question about why different types of cells have different structures, was very simple, without elaboration or examples.

> *Wayne:* Cells are different from one another because they all do different kinds of things to help in the human body or in other kinds of living things.

However, the pictures that he drew were far more elaborated (see Figure 1) showing structure of different types of cells and noting their functions. This was a consistent feature of Wayne's TFA responses. In interviews he noted that being able to draw his ideas allowed him much greater depth of explanation.

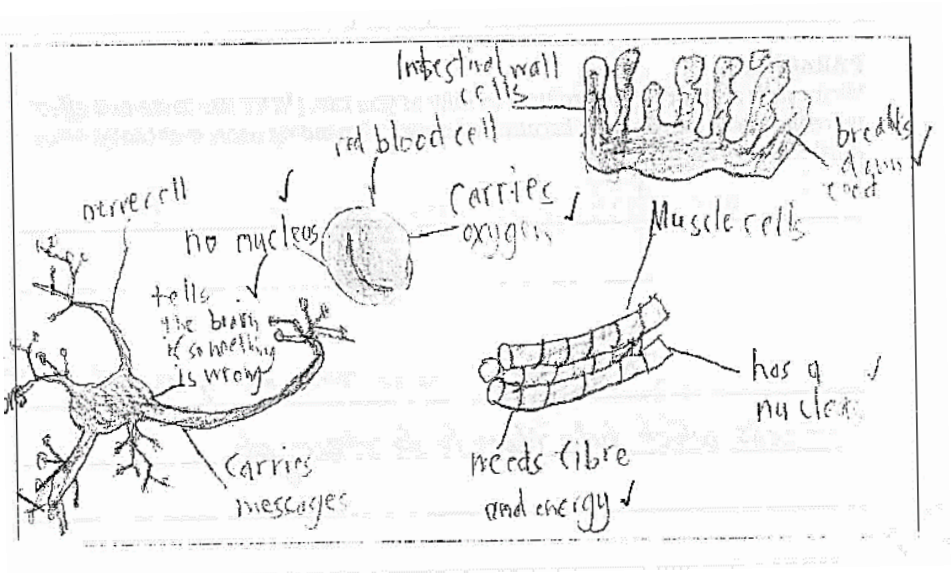

Figure 1 Wayne's diagram on 'why do different kinds of cells have different structures?'

However, Wayne's written explanations did improve in complexity as he became familiar with the TFA and he began to produce causal arguments. For instance, in his answer to how and why plants travel he produced a detailed list of words to use, followed by pictures describing different ways in which seeds are spread (Figure 2). He did not, however, incorporate these descriptions into his written explanation, appearing to see the written explanation as a continuation of his drawings to explain why plants use these strategies to spread their seeds.

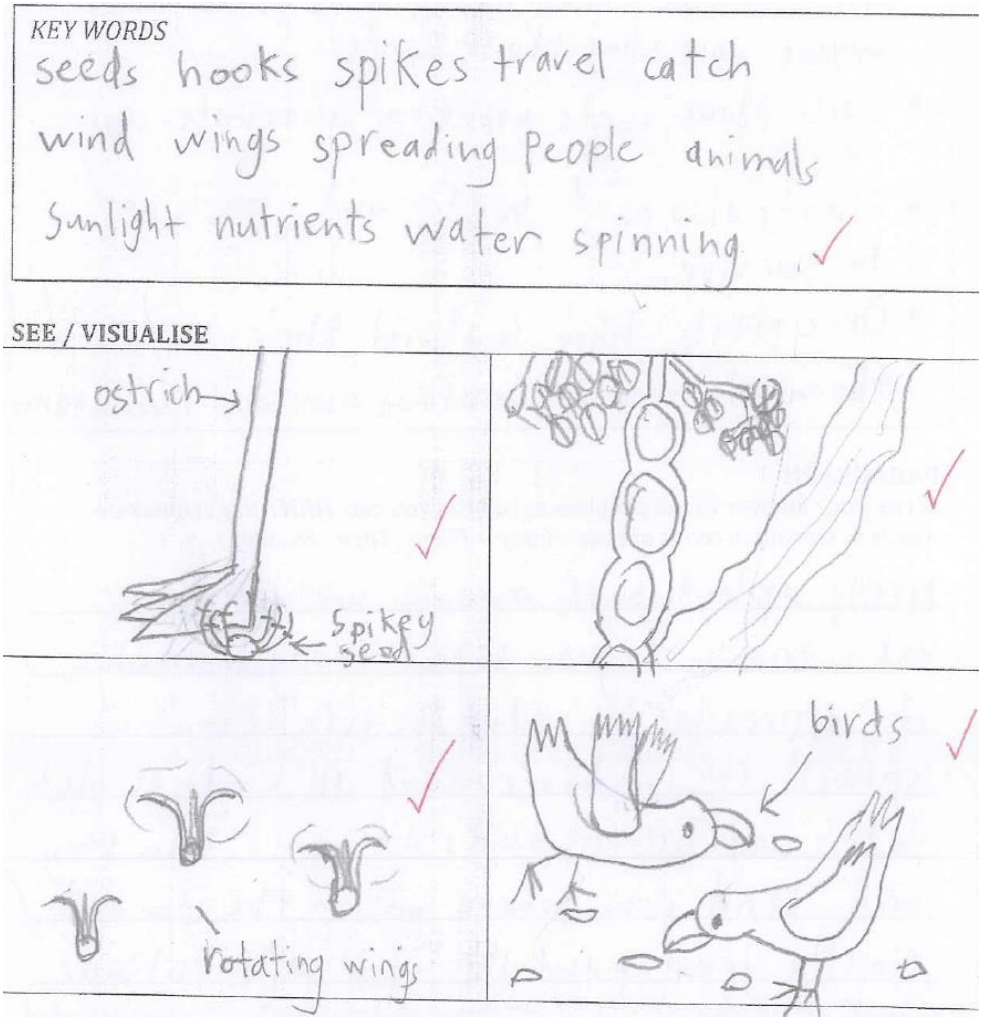

Figure 2 Wayne's keywords and diagrams explaining how and why plants move

> *Wayne:* Firstly, a plant needs enough sunlight, water and nutrients to grown big and strong then when it approaches the end of its life it will spread its seeds everywhere and all kinds of plants do this in different kinds of ways. Then they will land somewhere out in the open and finally grow up and this cycle will continue.

In this case he elaborated his explanation giving several reasons why there are advantages to plants spreading their seeds.

In interviews, Wayne expressed several times how much he enjoyed science and that he had found the TFA helpful in building his understanding and writing of explanations. He felt supported in his learning and found the progression from keywords to dot points and a paragraph helpful in organising his writing. Although he is critical of his own drawings, the time and care that he took in producing these, and the details that he included in them indicate that he was using the drawings to organise his ideas and produce written explanations.

> *Wayne:* [The TFA] taught me how to think by being able to draw and write my explanations. It's a bit tricky at first but I get to learn it over a few days and weeks. I can understand if I keep trying. [I'm better at understanding] because I paid more attention. I think the Thinking Frames are good and the experiments are my favourites. I like drawing pictures but I'm not very good at it. I've got more help in science this year than I did last year and I've learned a lot more. Writing is not my strength. When we write down the keywords and then we put them together and we can extend that to write a paragraph. I am more confident. Because throughout the year, I have learned a lot and it has been lots of fun. I think I feel more confident about writing explanations. Because of the prac[tical]s and thinking frames. I do like science in school. It is my favourite subject.

Discussion

The TFA provides a guided constructivist conceptual change approach which incorporates the power of student-generated multiple representations to build conceptual understanding. Various aspects of the TFA result in students of all abilities, including those with SEN, engaging in restructuring of their conceptual understanding. As students engage in these activities more authentic social inclusion of these students also occurs (McLure, 2018).

When including students with SEN in the classroom, a focus should be on building opportunities for authentic interactions with peers in order to develop stronger relationships and appreciation for each other's abilities (Cooper, 2004). Upon reflection on my own practice before introduction of the TFA, I recognise that, rather than focusing on developing authentic social relationships between the students with SEN in my classroom and the other students, I had focussed on supporting them in purely cognitive aspects of learning. Like many teachers, the complexities of negotiating the learning needs of students with a wide variety of abilities and emotional/behavioural demands with little classroom support had led to feelings of disempowerment in being able to support all students (Avramidis & Norwich, 2002; Brackenreed, 2011).

In the case of Wayne, who had complex learning needs, including SEBD, this had led to adoption of teaching strategies that were based on 'damage control' - preventing him from adversely affecting other students - rather than implementing strategies that would develop his conceptual understanding and build more positive relationships with peers. I also recognised that my interactions with Wayne were mainly ones that commented on behaviour – calling him to pay attention in class, moving him when he began to disturb other students or asking the SELA to work separately with him (see Cook et al., 2007).

For students with ASD, negotiating the social context can be challenging (MacKay, Knott, & Dunlop, 2007), however, consistent with other studies of the benefits of small groups for students with SEN (Belland et al., 2009; Nind & Wearmouth, 2006; Thousand & Villa, 1999), careful choice of the small group environment, as part of the TFA, gave greater opportunities for Wayne to contribute to small group discussions, argue for his own explanations

and hear others' explanations. Since he interacted with the same small group for most TFA lessons, group members became familiar with the each other's strengths and challenges. Wayne was able to watch peers in his small group as they produced drawings and writing and could follow along with this process. His peers also acted as tutors within the small group.

Since the TFA process addresses alternative conceptions that many students hold, not just those with SEN, this sets a level playing field for all students, since all members of the group need to work towards building consensus understanding of the phenomenon based on the scientific model. In this way Wayne was not singled out as the only one who needed to receive an explanation from others in order to understand. Input from all members is valued and the PDEODE process gave the opportunity for Wayne, whose ideas previously had not often been taken into account, to contribute to the construction of understanding. The opportunities that he had to explain his ideas to peers during the PDEODE process, raised his status within the group since he put forward reasonable arguments.

Rather that feeling it necessary to separate Wayne from peers due to his aggressive behaviour, the support of peers took the place of my own or the SELA's interactions with him, helping him to stay on task as he watched and copied what they were doing. This also built social cohesion, and both the SELAs and I noted that the aggressive behaviours that he had previously exhibited, and which had been a cause for peers to withdraw from him, reduced considerably in frequency.

The predictable structure of TFA lessons built Wayne's engagement with the process, particularly as a student with ASD, for whom routines can have a calming effect (Carnahan, Hume, Clarke, & Borders, 2009). The TFA structure is consistent with Westwood's (2018) suggestions that students with SEN require a step-wise, structured approach to learning which gives students clear objectives, breaks down learning into manageable chunks and provides multiple opportunities for practice and timely feedback. The TFA process uses a simple worksheet where students record the thinking question to be answered, a list of words that they decide upon that could be useful for answering that question based upon a process of negotiation with other students in the class, sections for producing conceptual drawings to give a pictorial explanation for the phenomenon and for ordering ideas in dot-point form, followed by a section for recording a complete written explanation answering the question. A variety of prompts are given to remind students to think about what is happening and why it is happening. The students also use the Levels Mountain rubric as a prompt to remind them that the goal of their multi-modal explanations is to provide a causal explanation based on the scientific model, incorporating scientific vocabulary. The teacher gives written feedback on the product by providing explanations of how to elaborate and improve their explanation, suggestions of scientific vocabulary and an estimate of the level that they have attained on the Level Mountain. Wayne noted that this structure helped to build confidence in knowing what to do next and how to go about writing the final explanation. His evident decrease in anxiety appears to be one consequence of providing this structured format.

While the production of student-generated pictorial representations have been shown to support students with SEN in mathematics (van Garderen, 2007) and reading comprehension (Hibbing & Rankin-Erickson, 2003), despite the evidence for the powerful benefits for students learning science (Ainsworth et al., 2011), there appears to be little investigation of the benefits for students with SEN in the science classroom. Wayne's experience illustrates the way in which the four stages of the TFA process, choosing key words, production of a verbal explanation,

pictorial explanations, followed by a written explanation was an iterative process which acted as a step-wise scaffold for him to clarify his understanding. The productive constraints of each mode of representation resulted in a deeper understanding of the concepts being examined (Tytler, Prain, Hubber, & Waldrip, 2013). Wayne noted that he looked back at his drawings and used those drawings to structure his written explanation. He said that it 'taught me how to think by being able to draw and write my explanations'.

As suggested by research into the use of UDL, giving students opportunities to express their understanding using different modalities, opens up opportunities for students to explore communication in different formats that may present lower barriers for their learning compared to the more traditionally accepted written mode of communication (Meyer et al., 2014). For Wayne, it appears that production of explanations through drawing appeared to help him to overcome the resistance that he had previously displayed towards writing explanations. It seems that, as he produced explanations in a series of modalities, verbal, keywords and drawing, Wayne more willingly engaged in writing and these written explanations increased in elaboration and causality over the period of the study. From his questionnaire responses about his writing abilities (Table 2), however, it appears that he did not recognise this improvement, possibly because he continued to find producing written explanations much more challenging than pictorial explanations, even though he was critical of his drawings. His interview responses did indicate that he had a greater understanding of what needed to be included in written explanations, particularly due to knowing how to use the keywords that he had chosen. Wayne was observed enthusiastically embracing drawing of his conceptual understanding and this benefitted others within his group who had less confidence in drawing their ideas. They were able to watch what he drew and use some of his ideas in their own drawings. Since the TFA gave him an opportunity to use a variety of different modes to explain his understanding, Wayne, who enjoyed drawing out his ideas, was given the chance to produce explanations in a modality that his peers did not necessarily find easy to use, and thereby his status was further raised within the group.

One of the outstanding effects of using the TFA was Wayne's increased feelings of self-efficacy in his ability to pay attention, understand and express his understanding. As he noted, 'I can understand if I keep trying, because I paid more attention'. He also said that he felt much more confident writing explanations, an area where he had struggled previously. The improved topic test results he obtained and the fact that he was able to complete the same tests as other students built this feeling of self-efficacy further and led to him feeling higher self-concept as a student of science. This in turn seems to have led to positive emotions about science, it was 'fun' and his 'favourite subject'. Thus he was motivated to complete other assessment tasks in science as well. His feelings of greater self-efficacy seem to have reduced the frustration levels that he had been feeling in science prior to this study and this led to a significant reduction in negative behaviours within science classes.

Wayne's experience illustrates the ways in which the abilities of students with SEBD, in particular, can be underestimated (Carlisle & Chang, 1996; Cho & Kingston, 2013). Like many students with SEBD, the types of modifications and adjustments that Wayne's teachers, including myself, made to the content and scope of the curriculum, prior to using the TFA, was based on the low achievement that he had attained in class, often due to his behaviour and non-compliance in completing tasks (Cho & Kingston, 2013). It was assumed that he was not able to complete the same tasks as the other students. This resulted in Wayne not being given the

opportunity to learn content at a similar level to other students in the class. The temptation can be to give these students 'busy work' rather than to genuinely engage them in learning (Clark & Artiles, 2000). This case study is a clear illustration of the way in which many teachers think about inclusion, as being physically present in the classroom, rather than authentically engaging the student with SEN in social learning experiences (Cooper, 2004; Polat, 2011). The difficulties that he experienced in communicating his understanding to teachers in the usual science lessons which involved text book work or completion of experimental reports, led to frustration and frequent outbursts of uncontrolled behaviour which were disruptive to the class. However, with the introduction of the TFA into the classroom, I began to recognise that the opportunity he had to express his understanding in multiple modes, particularly a pictorial format, reduced this frustration and provided a way forward for him to develop conceptual understanding.

My experience teaching an inclusive class using the TFA has led me to recognise the benefits to all students, including those with SEN, and the possibilities that it opens up for these students to work together with peers to co-construct conceptual understanding and bring about a much more authentic level of inclusion, both in the social and cognitive domains. As a consequence of this improvement in students with SEN, my attitude and expectations of what they may be capable of achieving within the classroom have changed considerably. As a teacher I had previously neglected the use of peer tutoring and found group work generally unproductive. As I began observing the positive interactions between peers in the small groups and the way in which students such as Wayne became active members of the group, putting forward his ideas and even presenting the group's explanations to the whole class, both his peers and I began to see him as valuable contributor within the classroom. It became evident from Wayne's worksheets and the answers that he volunteered within the PDEODE process, that he was much more capable than most teachers, including myself, had realised. I therefore insisted that he be given the opportunity to complete the same assessment tasks as other students, without modification despite his Individual Learner Plan suggesting that assessment tasks should be modified due to his previous low achievements. The results that he attained on these assessment tasks were very encouraging for both his parents and Wayne, himself. He began to take pride in his own work, displaying a desire to master concepts where he had previously shown little interest in learning.

In my experience, the TFA provides a structure which allows the teacher to include students of many differing abilities, including those with SEN, challenge alternative conceptions and support construction of understanding with little support from SELAs. This was also the observation of the SELAs themselves. This addresses a significant problem within the inclusive classroom, where limited funding often results in the teacher being provided with little or no support for those students with SEN that are in their class. This also corroborates findings of other student-centred approaches such as UDL (Al-Azawei et al., 2016).

Conclusion

The greatest limitation of this research is its small scale, being a single case study. However, presentation of an in-depth view of one student's learning may give a fine-grained understanding of the interaction between aspects of the learning approach and that student's unique learner characteristics. Further studies of the TFA and the applicability of these findings to other teachers and students with a wider variety of SEN would provide valuable insight into the generalisability of this strategy. The powerful effects of encouraging students with SEN to

produce explanations through generation of multiple representations should also be further examined.

Wayne's story illustrates the strength of the TFA as a means of providing genuine learning opportunities for a student with complex learning needs. The opportunities extended through the TFA process to strengthen social relationships between Wayne and his peers were evident. The TFA also allowed Wayne to have multiple opportunities within the one lesson to construct his understanding, making use of the unique affordances provided through verbally defending, drawing and writing explanations. Recognition of Wayne's capacity to complete the same tasks as other students, due to his increased engagement and greater conceptual understanding led to greater equity in learning opportunities and assessment. Many teachers find addressing the challenge of providing authentic opportunities for equitable inclusion of all students difficult in a crowded classroom where there are many competing calls on their attention (Brackenreed, 2011). However, Wayne's case suggests that the TFA provides a reproducible framework for supporting students' in social construction of their understanding of concepts at a much higher level than was previously expected and building their self-concept and motivation as students of science.

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